Self-Prioritization
in Motor Responses

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A thesis submitted for the degree of

Doctor of Philosophy in Experimental Psychology

at the University of Oxford, Hilary Term 2022

Abstract

In psychology, *self-representation* is widely held to guide our cognition and action. Self-relevant stimuli typically enhance our attention, perception, memory, and decision-making. A shape-label matching paradigm provides a standard method for investigating the self-advantage. However, the evidence suggests that self-prioritization (self-bias) in the matching task may be distinct from higher-level self-referential processing. To better understand the operation of this subcomponent of self, this thesis took a broad approach and asked: what are contextual constraints on the emergence and extent of self-bias in manual motor responses? Self-bias was examined with unisensory and multisensory stimuli and manipulations of stimulus factors and task-design, for the first time in a multisensory detection motor paradigm, in the initiation and execution of arm-movements, and in the relationship between self-bias and subjective perceptions of empathy and perceived closeness to others.

This thesis demonstrates that: (1) stimulus and label modality and task-design can modulate self-bias; (2) self-associations did not produce similar motor speed gains in simple detection motor responses, suggesting that self-bias in motor responses to unisensory and multisensory stimuli depends on explicit self–other evaluations; (3) self-bias can influence non-ballistic visual-feedback-driven arm-movements, ballistic arm-movements without visual feedback, and arm-movements directed ‘toward’ and ‘away’ from the stimuli; in other words, self-bias modulates ballistic arm-movements using proprioceptive, kinaesthetic, and tactile information (and potentially visual imagery), but not relevant exogenous visual input; (4) self-bias can influence both the initiation and execution of arm-movements; highlighting a modulation at multiple stages; (5) empathy and perceived closeness can predict self-bias and friend-bias, suggesting that the biases in manual motor responses are influenced by consciously-accessible representations of the interrelations between others and the self.

The wider implications of these findings are discussed in relation to neurodevelopmental disorders and relevance for future translational research. Taken together, these findings present a novel overview of self-bias in manual motor responses.

Approximate word count: **74,000 words**

Declaration

I hereby declare that this thesis has not been submitted previously as an exercise for a degree at this or any other university, and that it is entirely my own work. The contents of this thesis are based on accepted versions of the articles listed in the *Publications* section, for which I give full acknowledgement.

Clea Desebrock

Dedication

In memory of my beloved father and Professor Glyn Humphreys. Dedicated to my family.

Acknowledgements

I am immensely grateful to Professor Charles Spence for taking me on as his student after the tragic passing of my first supervisor, Professor Glyn Humphreys. Thank you for so expertly mentoring my autonomy and independence as a researcher, and supporting my direction. Your encouragement in the publication process, along with consistently being available to provide feedback on my manuscripts within hours, has been invaluable. I cannot thank you enough and have been very lucky to work with you. My sincerest thanks also go to Dr Ayla Barutchu for taking on the role of my co-supervisor, for your expertise in EEG, coding, and statistical matters, and again for your encouragement and providing feedback so promptly. I have learnt so much from working with you both, and very much look forward to benefitting from your expertise on my upcoming manuscripts.

I also wish to remember the important contribution of Professor Glyn W. Humphreys (1954–2016) who made possible the self-representation and action project at the Cognitive Neuropsychology Centre (CNC), from which I latterly formed my DPhil proposal. I will never forget his mentorship and the opportunity he gave me.

My thanks also to the Eurofins Foundation, the Sir Richard Stapley Educational Trust, the Psychology Postgraduate Affairs Group, the British Neuropsychological Society, the British Psychological Society, the Experimental Psychology Society, and Wolfson College, University of Oxford for their generous support during my doctoral studies.

I am also extremely grateful to the colleagues and friends that I have met since joining Oxford; first at the CNC lab, and then at the Crossmodal lab. You have made my transition from music into psychological research a truly inspiring and life-affirming experience. There are too many wonderful people to name, so just thinking of specific projects: Toro Graven for teaching me so much about haptic touch while working on her projects, and the fun we had

filming for JOVE. Zuo Zhang who so generously gave me my first lessons in programming, which have been invaluable to me. Amar Sarkar for working together to make the impossible possible while running the tDCS projects. Nora Turoman for such fun times while conferencing internationally together. Tara Venkatesan for the restorative teas and cakes. Jane Ralph and Gabi Waldhof for their camaraderie during those long nights and weekends in the lab, Florence, Rachel, Diana, and all the amazing people in B100 and B101, and Laura Monroy for introducing me first of all. And not forgetting the Crossmodal crew Alejandro Salgado-Montejo, Yi-Chuan Chen, Janice Wang, Jae Lee, Noemi Dreksler, Charles Michel, Daniel Ospina, Greg Simmonds, Maria, and Irune, who made me feel so welcome when I joined.

Thank you too to the staff and students at Bath University for welcoming me as a Postgraduate Visiting Scholar.

My deepest appreciation also goes to the late Morag MacLean (1955–2020) who was a wonderful mentor. I will never forget your belief in me, and also other former tutors who made all the difference in my path through education, Kevin Stannard, the late Barry Seaman (1946–2020), and Mark Constable.

And last, but very much not least, my family and friends who have supported me throughout the immensely trying times of this period. A number of life-changing and devastating events in quick succession have presented immense challenges during this process. Thank you so much AW, FT, JR, BD, SH, GW, EM, LB. Words cannot express how grateful I am to you, and my beloved family, F&G, the little ones, and especially to my mother for her truly incredible support. I could not have done this without her.

Publications

The research presented in Chapters 1, 2, 3, 5, and 6 of this thesis are based on previously published journal articles, details for which are given below. Acknowledgment of each of these articles is also given within the respective chapters of this thesis. I confirm that I wrote and produced the material reproduced.

Chapter 1: Background and conceptual framework is partly-based on content in the following article: Desebrock, C. (2019). The power of our names, faces, and the Self-Reference Effect: is there more than meets the eye? *The Quarterly*, *111*, 17–21.

Chapter 2: **Self-bias with unisensory and multisensory stimuli in manual motor responses (Study C2)** is based on research presented in the following article: Desebrock, C., Spence, C., & Barutchu, A. (2022). Self-prioritization with unisensory and multisensory stimuli in a matching task. *Attention, Perception & Psychophysics*.

Chapter 3: Self-bias beyond response selection (Study C3) is based on research presented in the following article: Desebrock, C., Sui, J., & Spence, C. (2018). Self-reference in action: Arm-movement responses are enhanced in perceptual matching. *Acta Psychologica, 190*, 258–266.

Chapter 5: Self-bias in arm-movements highlights modulation at multiple stages (Study C5) is based on research presented in the following article: Desebrock, C., & Spence, C. (2021). The Self-Prioritization Effect: Self-referential processing in movement highlights modulation at multiple stages. *Attention, Perception, & Psychophysics*, *83*(6), 2656–2674.

Chapter 6: The influence of empathy and perceived closeness on self- and friend-bias in arm-movements (Study C6) is based on research presented in the following article: Desebrock, C., Barutchu, A., & Spence, C. (2022). The influence of empathy and perceived closeness on self- and friend-prioritization in arm-movements. *Journal of Experimental Psychology: Human Perception & Performance.*

Contents

Chapter 1—Background and conceptual framework

1.1. The construct of self

The construct of self has a long history in psychological science, and continues to stimulate research across diverse fields (Calkins, 1915; Guenther & Alicke, 2013; James, 1890/2007; Koffka, 1935; Sui & Humphreys, 2017a; Talland, 1964), although precisely how to characterise the self and its ontological status remains contentious (Gallagher, 2013; Hood, 2012; Klein & Nelson, 2014; Northoff, 2016). Nonetheless, central to the study of psychology and our sense of how we function in the world is the notion that at a fundamental level our 'self' distinguishes us from our environment and from other people (Blanke & Metzinger, 2009; Boyer et al., 2005; Gallagher, 2000; Neisser, 1988).

In psychology, *self-representation* is widely held to guide our cognition and action (Golubickis et al., 2018; James, 1890/2007; Neisser, 1988; Turk et al., 2008), and is commonly conceptualised as operating at multiple levels of information processing. During development, a pre-reflective core self-representation is thought to emerge through sensorimotor exploration of the physical and social environment, which gives rise to a sense of agency and ownership over the body and its movements (Cunningham et al., 2008; Fotopoulou & Tsakiris, 2017; Hommel, 2019; Noel, Blanke, et al., 2017). Concomitantly, representations of self–other relations emerge which guide automatic responding in interpersonal contexts (Luyten et al., 2021; Zahavi, 2014). Higher-level semantic or conceptual representations of the self are thought to develop later on these foundations through semantic and autobiographical memory processes which give rise to an explicit knowledge-base and story-like understanding of one's self in time and space (Blanke & Metzinger, 2009; Cermolacce et al., 2007; Hommel, 2019; Noel, Blanke, et al., 2017).

Although numerous taxonomies of the self have been proposed since the inception of psychology as a science (originating with James' 'subjective I' versus 'objective Me' conceptualisation; James, 1890/2007), it is now widely agreed that the self is a multidimensional and multifaceted dynamic construct (Gallagher & Daly, 2018; Golubickis et al., 2020; Hutchison et al., 2021; Klein & Nelson, 2014; McConnell, 2011). Borrowing from philosophical approaches, for example, Gallagher (2000) distinguishes between two conceptions of self—the *minimal* and *narrative* self. Minimal self typically pertains to a person's phenomenal experience as a conscious embodied subject, emerging on a moment-by-moment basis from multisensory input, and lacking temporal extension. The narrative self pertains to higher-level representations of self, one's personal identity, comprising personality traits, beliefs, attitudes, preferences, and is extended in time, drawing on autobiographical memories and explicit reflections about ourselves (Gallagher, 2000; Hommel, 2019; Noel, Blanke, et al., 2017; Noel, Cascio, et al., 2017; Schäfer & Frings, 2019b).

As with all conceptualisations of the self, the distinction between the minimal and narrative self is not without its shortcomings (Bortolan, 2020; Hommel, 2019). However, this basic and widely accepted distinction serves as a useful dichotomy when contextualising the present thesis within the broader psychological literature, and on which the next section expands.

1.2. Empirical treatment of the self

In cognitive psychology, the construct of self is investigated indirectly, using proxy measures of self-representation; for example, by asking people about themselves or their experience, or examining functional and neural changes associated with processes related to the self. The various research threads may be regarded in terms of their relative alignment with Gallagher's (2000) minimal and narrative selves (Hommel, 2019, 2021; Schäfer & Frings, 2019b). For example, aligned with the notion of the minimal self are studies investigating the sense of self in body ownership and agency in experimental tasks. Participants may be asked to explicitly reflect on their bodily experience and, for example, to indicate a perceived limb position or whether they attribute a limb or its movements to the self or another person (Blanke & Metzinger, 2009; Botvinick & Cohen, 1998; Longo & Haggard, 2009; Qu et al., 2021; Tsakiris, 2017; Tsakiris et al., 2006, 2007; Tsakiris & Haggard, 2005). Aligned with the second notion—of the narrative self—are those studies in which participants are asked to introspect on their mental or psychological self; for example, by evaluating their beliefs, attitudes, intentions, and self–other relations in self-report measures (e.g. Davis, 1980; Keaton, 2017; Rosenberg, 1965, 1989; Singelis, 1994; Snyder, 1974).

A third research strand examines biases in our responses to self-associated phenomena (e.g., own name, own face, personality traits, or stimuli that are newly and arbitrarily associated with the self). Most commonly, the speed and accuracy of responses to self- and non-self-associated stimuli are compared in manual motor responses (e.g. Keyes & Brady, 2010; Sui et al., 2012; Tacikowski & Nowicka, 2010), oculomotor responses (e.g. Dalmaso et al., 2019), and in tasks using verbal report (e.g. Moray, 1959; Rogers et al., 1977). Across tasks, a performance advantage for self typically emerges. Neural activity underpinning the self-advantage is also examined (e.g. Nowicka et al., 2018; Sui, Rotshtein, et al., 2013; Tacikowski & Nowicka, 2010). It is thought that the underlying self-representation(s) can be indirectly accessed through the systematic measurement of these behavioural and neural modulations (Humphreys, 2015; Humphreys & Sui, 2016).[1]

Aligned with the third approach, this thesis examines self-bias (comparing responses to self- versus other-person-associated stimuli) in manual motor responses. Specifically, self-

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[1] This third strand of research may also be further sub-divided into two broad categories according to the memory or attentional systems activated by the task (Hutchison et al., 2021; Turk et al., 2008), or by whether responses to representations of the physical self (one’s own voice or face) or psychological self (one’s own name, personality traits) are examined (e.g. C. Hu et al., 2016; L. Liu et al., 2019).

bias is investigated in simple keypress motor responses using unisensory and multisensory stimuli (Chapter 2), in arm-movement responses (Chapters 3–6), and in the relationship between self-bias in arm-movements and higher-level constructs of self as reflected in self-report measures (Chapter 6). As such, this research is situated at the intersection between investigations of the multisensory agentic or bodily self and the conceptual psychological (or narrative) self.

In investigating self-bias in manual motor responses, the present thesis aims to increase our understanding of the impact that self-relevance has on our cognition and action, and also the role that self and self–other representations play in shaping our behaviour. In the latter part of this introductory chapter, the specific aims and research goals of the present thesis in respect of these investigations will be discussed in more detail. Having briefly contextualised this thesis in terms of some of the broader literature on the self, this chapter will now review in more detail the evidence related to the research strand above that specifically investigates self-biases in our responses to self- and non-self-associated stimuli.

Specifically, the following section (*1.3*) reviews traditional research on the empirical self which has used self-referential stimuli such as the participant's own-name, own-face, or personality traits, and presents some of the key evidence that has demonstrated a robust and consistent performance advantage for self. Section *1.4* reviews criticism of those studies in respect of their use of highly-familiar stimuli, and the development of a novel matching paradigm (Sui et al., 2012) to address this limitation—and which forms the central methodology of this thesis. Rationale for the adoption of this paradigm in a recent sub-strand of research on the empirical self is then outlined, and current gaps in this literature identified. In the light of this discussion, this chapter then returns to elaborate on the particular focus and aims of this thesis, and details the specifics of the methodological approach taken (Sections *1.12–1.14*).

1.3. The impact of self-relevance in human information processing

In the service of optimal socio-cognitive functioning, those stimuli relevant to the goals of an individual must typically be prioritized in human information processing in order to facilitate appropriate action. Indeed, self-relevance has been extensively demonstrated to modulate our performance across a diverse range of experimental tasks (Desebrock et al., 2018; Desebrock, Barutchu, et al., 2022; Desebrock, Spence, et al., 2022; Desebrock & Spence, 2021; Golubickis et al., 2017; Golubickis & Macrae, 2021; Janczyk et al., 2019; Lee et al., 2021; Moray, 1959; Moseley et al., 2021; Mu & Han, 2010; Navon & Makovski, 2021; Nijhof et al., 2020; Orellana-Corrales et al., 2021; B. Payne et al., 2020; Rogers et al., 1977; Stolte et al., 2021; Sui et al., 2012; Sui, Rotshtein, et al., 2013; Svensson et al., 2021; Tacikowski & Nowicka, 2010; Turk et al., 2008; Turk, van Bussel, Waiter, et al., 2011). Although certain self-related processes have been attributed to animals as well as humans (Butler & Suddendorf, 2014; Gallup Jr. & Anderson, 2020; Northoff & Panksepp, 2008), and mammals have been argued to have a rudimentary form of self (Northoff & Panksepp, 2008), self-referential processing is generally considered to be a human phenomenon (Gallup Jr. & Anderson, 2020). Visual self-recognition, for example, has only been clearly evidenced in some great apes and humans (Gallup, 1970; Gallup Jr. & Anderson, 2020). This chapter focuses on the literature investigating self-referential processing in human information processing.

1.3.1. Self-relevance and attention

Traditionally, studies investigating the effects of self-relevance have used the participant's own-name, own-face, or autobiographical information (such as personality traits) as stimuli. In one of the earliest studies of the effects of one's *own-name*, Moray (1959) used a dichotic listening task in which participants were asked to repeat aloud a continuous verbal message presented to one ear, while in the other ear a short list of simple words was presented. When asked to recognise or recall the items on the short list (i.e., presented to the unattended ear), the participants were not able to remember a single item. However, when the participant's own name was included in the list, by contrast, this item could be recalled. While the unattended message was apparently otherwise rejected by the participant's conscious perception, own-name stimuli appeared to have attention-grabbing effects.

The dichotic listening task has since been criticized for not ensuring that the unattended ear was unattended (Lachter et al., 2004), and the universality of the effect has been questioned—the auditory self-bias is typically exhibited by only ≈33% of participants (A. R. A. Conway et al., 2001; Wood & Cowan, 1995). In the light of subsequent studies (e.g. Alexopoulos et al., 2012; Bargh, 1982), however, it has been suggested that own-name stimuli can automatically cue attention. For example, using a visual search task, Alexopoulos et al. (2012) cued target locations using self- and other-person names. The authors documented that responses were faster and more accurate proceeding the self-name cue, even when the cues were subliminal. Furthermore, when the cue and target were placed on opposite sides of the screen, and the participants were explicitly instructed to ignore the cue, responses proceeding the own-name cue were less accurate—it was thought to be more difficult for participants to override the attention-capturing effects of one's own name.

Studies using images of faces as stimuli have similarly demonstrated that responses to self-faces are faster and more accurate, including when the stimuli are rendered subliminal (Keenan et al., 1999; Keyes & Brady, 2010; M. Liu et al., 2016; Sui et al., 2006; Tao et al., 2012; Tong & Nakayama, 1999). As with one's own name, when used as distractors, self-face stimuli are harder to ignore than familiar or unfamiliar face-stimuli of other people (Brédart et al., 2006). Self-ownership can also modulate attentional processes (Turk, van

Bussel, Brebner, et al., 2011). In a study measuring event-related potentials (ERPs), for example, self-ownership was reported to modulate the P3 component, indexing frontal attentional processes, and also the lateral occipital P1 component, indexing visuospatial attention at the perceptual level (Turk, van Bussel, Brebner, et al., 2011). It has been widely-contended on the basis of such evidence as outlined here that self-relevant stimuli can automatically capture attention (although cf. Devue et al., 2009; Devue & Brédart, 2008; Wuillemin & Richardson, 1982).

1.3.2. Self-relevance, perceptual decision-making, and memory

Evidence also suggests that self-relevance can enhance the perceptual processes that underpin decision-making (Humphreys & Sui, 2016; M. Liu et al., 2016). A number of behavioural studies have documented that self-relevant stimuli modulate perceptual processes (Golubickis et al., 2017, 2020; C.-P. Hu et al., 2020; Svensson et al., 2021). For example, a stimulus bias (i.e., the rate of information uptake) has been documented to underpin enhanced responses to stimuli associated with the self (namely, the ‘current self’; Golubickis et al., 2017). In a study measuring ERPs and using a cueing task, a superior spatial cueing effect was found for self-over-other-faces which was underpinned by an enhanced N1 component (indexing attentional processes) and a reduced P3 component (often associated with certainty in decision-making). The extent of the self-bias in the N1 and P3 components was also negatively-correlated such that a greater self-bias in attentional processing was associated with reduced self-bias in decisional processes. The authors suggested that enhanced attention to the self-associated stimuli reduced uncertainty in decision-making, facilitating the behavioural responses (M. Liu et al., 2016).

Memory processes, in particular, recognition and recall, can also be modulated by self-relevance (M. A. Conway & Pleydell-Pearce, 2000; Cunningham et al., 2008, 2013; Heatherton et al., 2004; Symons & Johnson, 1997). In a seminal study by Rogers, Kuiper, and Kirker (1977), the authors instructed their participants to complete a ratings task. The participants encoded a list of adjectives either self-referentially (by evaluating whether the trait described them), semantically (by comparing the meaning of words), phonemically (by deciding whether words rhymed), or structurally (by evaluating the size of the text), and were then asked to recall as many of the adjectives as they could. Those lists of adjectives that had been encoded using ‘self-reference’ were far better recalled than in any other condition. The Self-Reference Effect (SRE) in memory has been consistently found in subsequent studies (e.g., Cunningham et al., 2013; for a review, see Symons & Johnson, 1997), including when participants incidentally rather than explicitly encode the self-relevance of the stimuli (Hutchison et al., 2021; Turk et al., 2008).

A memory advantage for self in both the evaluative and incidental encoding of self-referential information has also been documented in children of around four years of age and upwards (Cunningham et al., 2014; Hutchison et al., 2021; Maire et al., 2020; Pullyblank et al., 1985; Sui & Zhu, 2005). For example, in one study using a between-groups design, children aged 6–11 years carried out either an evaluative SRE (eSRE) task or an incidental SRE (iSRE). In the eSRE task, the children were asked whether or not they liked a series of objects presented with a photograph of their face or another person’s face. In the iSRE version of the task, the children simply indicated the location of the object. In the subsequent memory phase, the children recalled whether each item on a list of objects had been presented with their face, or the other person’s face, or whether the object was new. Consistent with previous research, the authors documented both an eSRE and an iSRE across all ages in their sample. They also documented that while the eSRE and iSRE were equivalent up until age 8 years of age, the eSRE became larger than the iSRE in children aged 8–11 years, and larger still in their adult sample. These findings were consistent with the theory that the iSRE (thought to be underpinned by automatic attentional processes) develops early in development and remains unchanged throughout childhood, while the eSRE (thought to relate to self-knowledge and autobiographical memory) becomes larger but unchanged in magnitude throughout middle childhood, and then continually increases from age 10 years into adulthood (Hutchison et al., 2021).

1.3.3. Self-relevance and cultural differences

Culture can also impact on the operation of self-relevance in our information processing (Markus & Kitayama, 1991; Triandis, 1989, 2019). Construals of others and the self, and their interdependence, in terms of the connectedness between individuals, can differ quite markedly across cultures. For example, participants from independent cultures (usually found in the West and associated with the notion of individualism), typically manifest a robust self-bias in responses to self and familiar-other-associated stimuli. By contrast, participants from interdependent cultures (which are usually non-Western and associated with the notion of collectivism), for example, have been documented to manifest a mother-over-self advantage (Sparks, Cunningham, et al., 2016). However, this is not always the case (Golubickis et al., 2019; Zhang et al., 2020). In a study using an object categorization task, participants reported whether exemplar items belonged to a category previously allocated as belonging to the self or to their mother (i.e. pens or pencils). The authors documented that both Western and Asian participants responded more quickly to the self-owned items (Golubickis et al., 2019).

In other studies, it has also been demonstrated that the self-advantage can be modulated by priming interdependent and independent self-construals (e.g. Jiang & Sui, 2022). Representations of the self are thought to be able to flexibly extend to include others or not, and to differing degrees; not only in correspondence with fixed traits, but also across contexts within the individual (Hong et al., 2001; Jiang & Sui, 2022; Y. Ma & Han, 2009; Singelis, 1994).

1.4. Novel self-associations and the matching paradigm

The literature reviewed thus far demonstrates that self-referential stimuli can modulate our attention, perception, memory, and decision-making processes. However, it is not clear from this evidence whether the mechanisms underpinning the self-advantage are self-specific, and, by extension, what implications the self-advantage has for our cognition. Researchers have been divided over whether the self has ‘special’ status in cognition (Beggan, 1992; Boyer et al., 2005; Gillihan & Farah, 2005; Heatherton et al., 2004; Sui & Humphreys, 2017a; Sun et al., 2016; Symons & Johnson, 1997). Gillihan and Farah (2005) have argued that it has often erroneously (or, at best, prematurely) been inferred that the effects of self-relevance are distinct from those of other factors. The attention-grabbing effects and processing advantage for own-name and own-face stimuli, for example, may be due to the high familiarity and overlearning, or to the emotional or reward value, of these self-relevant stimuli (Brédart et al., 2006; Northoff & Hayes, 2011; Tong & Nakayama, 1999). Other researchers have contended that non-self-specific factors such as the high-familiarity of own-name and -face stimuli are unlikely to underpin the self-advantage (Keenan et al., 1999; Yang et al., 2013). Disentangling the effects of non-self-specific factors, however, is generally problematic when there are long-standing associations between the stimuli and the self.

In order to address criticism that the effects of self-relevance may be driven by stimulus familiarity or overlearning, Sui et al. (2012) developed a novel perceptual-matching paradigm using ‘neutral’ stimuli. Instead of the traditional stimuli of the participant’s own-name, own-face, or attributes, the authors’ used stimuli that were newly and arbitrarily associated with the self. In the prototypical task, participants are instructed to associate neutral geometric shapes (e.g., a circle, a square, and a hexagon) with person-identity labels (e.g., self, stranger, friend). In the main task, the participants then judge whether or not sequentially-presented shape-label pairs ‘match’ the designated associations or not (i.e., if they ‘mismatch’). Responses in the self-associated shape-label matching condition are consistently found to be faster and more accurately-selected. In other words, like the traditional self-referential stimuli, these novel self-associations can also enhance task performance. The self-advantage in these motor responses has been termed the Self-Prioritization Effect (SPE), or simply, self-bias[2]. See Figure 1 for a schematic representation of the matching task (Sui et al., 2012).

Control experiments and subsequent studies using different referents for the personal labels have further indicated that effects are independent of word concreteness, word frequency, and word length (Schäfer, Wentura, et al., 2020; Sui et al., 2012), and self-bias has been consistently demonstrated across numerous studies (e.g. Enock et al., 2018; Humphreys & Sui, 2016; Schäfer, Wesslein, et al., 2016; Stolte et al., 2017; Sui, Rotshtein, et al., 2013; Sui et al., 2014). Evidence suggests that the self-advantage is stable and trait-like (Stolte et al., 2017; Sui & Humphreys, 2015b), and furthermore, self-bias has recently been documented in children (Maire et al., 2020). In one study using an adaptation of the matching task, children aged 6–10 years associated pictures of items representing imaginary holiday locations (e.g. a teepee or igloo) with the identities self, friend, and stranger, and then carried out the matching task. The authors reported a robust self-advantage in both RT and accuracy in the children’s responses (Maire et al., 2020).

Adaptations of the standard procedure have also been used to shed further light on the mechanisms underlying the self-advantage (Golubickis & Macrae, 2021; C.-P. Hu et al., 2020; Schäfer, Wesslein, et al., 2016; Stolte et al., 2017; Sui, Yankouskaya, et al., 2015; Sui & Humphreys, 2015c; Yankouskaya et al., 2017; Yankouskaya & Sui, 2021). The next

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[2] Note, this thesis reserves the terms *self-prioritization*, the *SPE*, and *self-bias* to refer specifically to the self-advantage in task performance as elicited by the novel self-associations formed in the learning phase of the matching task (see Sections *1.9–1.11* for rationale). By contrast, some researchers apply the terms self-prioritization, SPE, and self-bias more liberally and include, for example, effects of self-relevance in ownership and face-perception paradigms among others (e.g. Bola et al., 2021; Lee et al., 2021).

section (*1.5.1*), briefly reviews some examples of these adaptations in studies that have examined whether domain-general factors such as stimulus reward value or emotional valence underpin self-prioritization in the matching task (Stolte et al., 2017; Sui & Humphreys, 2015b, 2015c). Section *1.5.2* then reviews research examining the neural circuitry recruited by the task (Sui, Rotshtein, et al., 2013; Yankouskaya et al., 2017).

1.4.1. Self-bias, emotional valence, and reward value

The matching task (Sui et al., 2012) has been used to pit the effects of self-relevance directly

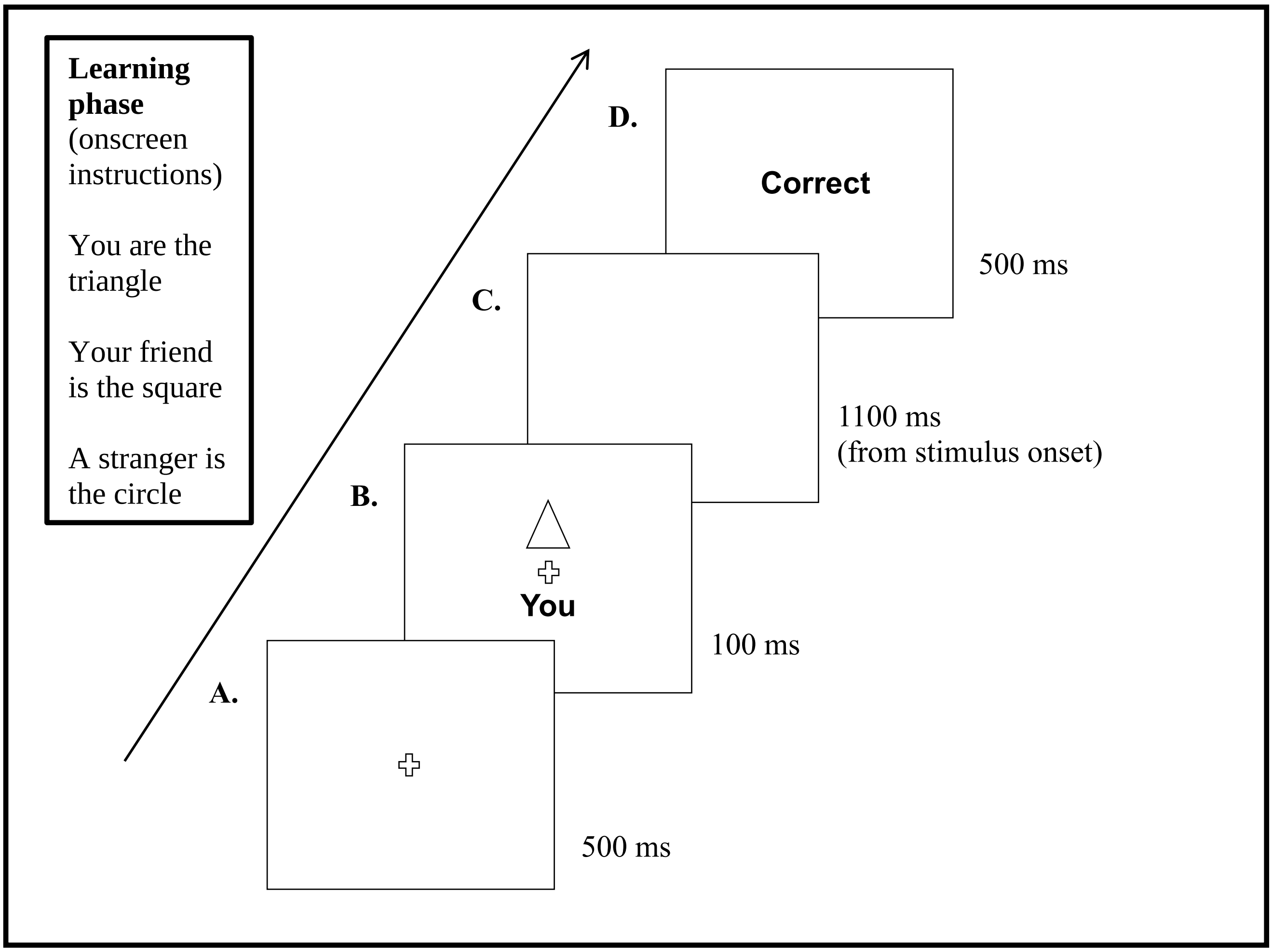

Figure 1. Schematic overview of an experimental trial sequence for the matching task developed by Sui et al. (2012). (Displayed elements not to scale). A. Fixation cross. B. Onset of visual shape and label stimulus pair. C. Blank screen. D. Written feedback displayed on screen—“Correct” / “Incorrect” / “Too slow”.

against those of factors such as reward and emotional valence. For example, in a study by Stolte et al. (2017), the participants completed both the standard matching task, and a modification in which the geometric shape stimuli were swapped for emotional faces (happy, sad, neutral). The authors documented a similar pattern of findings for both types of stimuli, with a processing advantage for the self-associated stimuli and the positive emotional (happy) stimuli. However, no correlation between self-bias and positive emotion-bias was found, suggesting that the two biases are subserved by distinct mechanisms. Similarly, dissociations between the effects of self-prioritization and negative valence have been documented in early versus later-stage stimulus processing (Schäfer, Wentura, et al., 2020), and in terms of neuroanatomical recruitment (Yankouskaya & Sui, 2021). Such findings indicate that self-bias and emotion-bias reflect differential underlying processes (although cf. Yankouskaya & Sui, 2021).

As with emotional valence, studies have also documented that stimuli with high and low reward value produce a similar pattern of results to self- and other-related stimuli in the matching task. For example, when the geometric shape stimuli were swapped for monetary values (e.g. £9, £6, £1), a performance enhancement in responses to the high-reward-value over mid- and low-reward-value stimuli was observed (such that £9 > £6 > £1). Self-bias and high-reward-bias also interacted in the same way with a stimulus contrast manipulation (Sui et al., 2012). Further studies, however, have revealed that differential mechanisms underpin the two types of bias. For example, redundancy gain effects were demonstrated to differ across newly self-associated and high-reward stimuli: reward was documented to modulate only conceptual processes, while self-associations modulated perceptual processes as well (Sui & Humphreys, 2015c). In another study, no relationship was found between self-bias and high-reward-bias (Sui & Humphreys, 2015b). Furthermore, evidence suggests that there are distinct neural representations for self and reward in the context of the matching task

(Yankouskaya et al., 2017). While behavioural effects of self-prioritization in the matching task may often be analogous to reward, evidence suggests that mechanisms underpinning the two biases are distinct (Stolte et al., 2021; Sui & Humphreys, 2015b; Yankouskaya et al., 2017). Such findings add to a body of work (using other tasks and types of self-referential stimuli) that suggest that the effects of self-relevance are somewhat independent of stimulus reward value, emotional valence, and semantic elaboration (e.g. Kelley et al., 2002; Sui & Humphreys, 2013; Zhou et al., 2017; although cf. Yankouskaya & Sui, 2021).

1.4.2. Neural circuitry underpinning self-bias

As noted earlier, there has been some contention in the literature regarding whether self-related processing has special status or is an emergent property of more general-purpose cognitive processing (Gillihan & Farah, 2005; Klein et al., 2002; Sui & Humphreys, 2017a). As outlined, self-bias has been (at least partly) behaviourally-dissociated from the effects of other factors such as stimulus reward value and emotional valence. Research has also documented that the neural circuitry underpinning responses to self-associated stimuli in the matching task is distinct from the circuitry supporting other-person-related responses and the effects of stimulus reward value (Sui, Rotshtein, et al., 2013; Yankouskaya et al., 2017).

In a study using functional magnetic resonance imaging (fMRI) and dynamic causal modelling (Sui, Rotshtein, et al., 2013), the authors documented that the self-advantage was supported by a functional coupling of the ventral medial prefrontal cortex (vmPFC)—an area (mPFC) associated with self-representation (Huang et al., 2022; Kelley et al., 2002; Liang et al., 2021; Macrae et al., 2004; Moran et al., 2006)—and the left posterior superior temporal sulcus (lpSTS; the ventral attentional network linked to social attention; Sui, Rotshtein, et al., 2013). The strength of the functional connectivity between the two regions predicted the behavioural advantage for self in response times. In contrast, other-person-related responses were associated with the recruitment of the frontoparietal attentional control network:

specifically, the dorsolateral prefrontal cortex (dlPFC), middle superior frontal gyrus, inferior parietal cortex, and right cuneus (Sui, Rotshtein, et al., 2013; Yankouskaya et al., 2017). In another study, while behavioural self-bias in the matching task was linked to functional connectivity between the posterior vmPFC and frontal pole, reward-bias was linked to functional connectivity between the posterior vmPFC and middle frontal gyrus. Such evidence provides further support for the contention that self-bias may be underpinned by distinct neural processes (although cf. Lockwood et al., 2018).

1.5. Current status of research on self-prioritization

The matching procedure now provides the standard method for those wanting to investigate the effects of self-relevance without the confounds inherent in previous studies using own-name, own-face, or autobiographical information as stimuli (Constable et al., 2021; Golubickis et al., 2017; Golubickis & Macrae, 2021; Moseley et al., 2021; Schäfer & Frings, 2019a; Stolte et al., 2021; Woźniak et al., 2022; Y. Zheng et al., 2022). Among other lines of enquiry, recent research efforts examining the effects of self-relevance using the matching task have begun to focus on exploring the stages of information processing that are influenced by self-bias (Desebrock et al., 2018; Desebrock & Spence, 2021; Janczyk et al., 2019; Schäfer, Frings, et al., 2016; Scheller & Sui, 2022a; Sui & Humphreys, 2015a; Y. Zheng et al., 2022), examining self-bias in sensory modalities other than vision (Desebrock, Spence, et al., 2022; B. Payne et al., 2020; Schäfer, Wesslein, et al., 2016, 2020; Scheller & Sui, 2022a; Stolte et al., 2021), identifying boundary conditions or contextual constraints on the emergence of the self-advantage (Desebrock et al., 2018; Desebrock, Spence, et al., 2022; Desebrock & Spence, 2021; Golubickis et al., 2017; Golubickis & Macrae, 2021; C.-P. Hu et al., 2020), and exploring the relationship between self-bias and other measures of self-related processing (Desebrock, Barutchu, et al., 2022; Moseley et al., 2021; Nijhof et al., 2020; Schäfer & Frings, 2019b; Williams et al., 2018).

At the inception of this thesis, these lines of enquiry had yet to be established. Over the course of preparing this monograph, I have conducted and published studies that have made novel contributions to and helped progress this literature. Other related studies have also begun to emerge. Each chapter of this thesis is based on a corresponding journal article, and, accordingly, this monograph starts at the foothills of these endeavours. In the following sections (*1.6.1–1.11*), the research preceding the published work in this thesis is reviewed, and emergent gaps in the literature are highlighted. Sections *1.12–1.13* then present the rationale for the focus and aims of this thesis.

1.5.1. Self-bias in visual attention and perception

In line with the view that cognition can penetrate perception (e.g. Newen & Vetter, 2017; cf. Firestone & Scholl, 2016; Pylyshyn, 1999), and studies using the traditional (self-face, self-name) self-referential stimuli, researchers in earlier studies held that self-bias in the matching task emerged in perceptual processing (Humphreys & Sui, 2016; Sui et al., 2012; cf. Scheller & Sui, 2022a; see also Chapter 4). Effects have been likened to those of highly-perceptually salient stimuli (Humphreys & Sui, 2015, 2016; Scheller & Sui, 2022a; Sui et al., 2012; Sui, Liu, et al., 2013). Responses to self-associated stimuli are faster and more accurate, and the bias is argued to be somewhat automatic (Humphreys & Sui, 2016). Self-associated responses were also reported to be less affected by reduced stimulus contrast than friend-associated responses, which was interpreted to reflect an interaction between self-prioritization and perceptual processes (Sui et al., 2012, Experiment 4A). Furthermore, in a level-priming paradigm, both perceptual saliency and novel self-associations were shown to modulate response selection in hierarchical stimuli (Liu & Sui, 2016), and to modulate attentional suppression mechanisms that recruited the intraparietal sulcus (IPS; Sui, Liu, et al., 2013).

It has been argued that self-bias is not simply a general saliency-driven effect, however. For example, the effects of the semantic distinctiveness of stimuli can be dissociated from the SPE (Schäfer et al., 2017), and when stimuli are both socially- and highly-perceptually-salient, response accuracy is increased relative to the effects of simply perceptually-salient stimuli (Liu & Sui, 2016). Furthermore, perceptual and ‘social salience’ also activate distinct neural areas (Sui, Liu, et al., 2013). Effects of perceptual saliency are thought to originate from early visual areas. In contrast, those of ‘social saliency’ are thought to be generated in the vmPFC (Liu & Sui, 2016).

Based on convergent behavioural, neuroimaging, and neuropsychological evidence, Humphreys and Sui (2016) put forward the Self-Attention Network model (SAN) as a framework for understanding the effects of self-relevance in visual attention and perception. In the SAN model, increased projections from the vmPFC are thought to upregulate the pSTS such that it is primed to respond more strongly to self-associated stimuli, and enhances bottom-up driven (orienting) processing of these stimuli. As such, self-associated stimuli are afforded increased gain in attentional salience (Humphreys & Sui, 2015, 2016; Sui, Liu, et al., 2013). Top-down (fronto-parietal) attentional control (associated with the intra parietal sulcus; IPS) can enhance self-related responses by engaging with prior expectancies for self-associated stimuli, but also inhibit bottom-up-driven self-related responding for other-person-related responses (Humphreys & Sui, 2016). In contrast, other-person-related responses in the matching task activated the dorsal frontoparietal attentional control network.

Numerous studies are consistent with the SAN model. Other researchers have documented that a stimulus bias (i.e., the rate of information uptake) underpins self-prioritization in the matching task (Golubickis et al., 2017, 2020; C.-P. Hu et al., 2020; Svensson et al., 2021). Effects of newly-self-associated stimuli in other tasks compare to those of highly perceptually-salient stimuli (Humphreys & Sui, 2016; Sui, Liu, et al., 2013; although cf. Wade & Vickery, 2018), and studies using newly-acquired ownership paradigms have also found that self-relevance modulates perceptual processes (e.g., Truong et al., 2017).

Furthermore, recent findings are consistent with a causal role for the vmPFC (Yankouskaya et al., 2017) and the LpSTS (Liang et al., 2021) in the emergence of the SPE. In a study using transcranial magnetic stimulation (TMS) while participants carried out the matching task (Liang et al., 2021), it was reported that selective inhibition of the LpSTS resulted in diminished performance for self-associated stimuli, consistent with the SAN (although cf. inconsistent findings regarding a causal role for the dlPFC in responses to other-person associated stimuli; Liang et al., 2021).

The SAN model encompasses perceptuo-cognitive operations in the matching task, but seeks to explain the self-advantage in attention and perception across tasks. However, in other studies using identification tasks or object categorization tasks within self-ownership paradigms, perceptual processes were not always modulated (e.g., Falbén, Golubickis, Wischerath, et al., 2020). Using a hierarchical drift diffusion model approach to statistically separate the different components of perceptual decision-making processes (Ratcliff, 1978; Voss et al., 2013; Wiecki et al., 2013), these studies have variously documented that the self-advantage can reflect a stimulus bias (i.e., a perceptual effect modulating the rate of information uptake; Falbén, Golubickis, Tamulaitis, et al., 2020; Golubickis et al., 2018, 2021), or alternatively a response bias (a propensity to respond ‘mine’ or ‘me’; Macrae et al., 2017), as well as a modulation of non-decisional processes (i.e., encoding or response execution; Macrae et al., 2017). Other findings have also emerged in the literature however that are inconsistent with aspects of the SAN model (cf. Janczyk et al., 2019; Liang et al., 2021; Martínez-Pérez et al., 2020; Schäfer & Frings, 2019a; Vallesi, 2016). For example, as noted above, in a study using TMS to selectively target the lpSTS and dlPFC, while inhibitory stimulation on the lpSTS reduced the self-advantage, the authors failed to find a causal role for the dlPFC in other-person-associated responses (Liang et al., 2021).

1.5.2. Self-bias in later-stage decision-making and memory processes

Some studies have challenged the contention that an advantage in early perceptual processing underpins self-bias in the matching task (Janczyk et al., 2019; Reuther & Chakravarthi, 2017; Y. Zheng et al., 2022). For example, in a study aimed at pinpointing the processing locus of the SPE, Janczyk et al. (2019) documented that self-prioritization only influenced central-stage processes. Central-stage processes include encoding into short-term memory (Jolicoeur & Dell'Acqua, 1998), selection into and switching between items in working memory; Janczyk, 2017), and response selection (Janczyk & Kunde, 2020; A. T. Welford, 1952). In studies using other task paradigms, it has similarly been suggested that self-referential and other-referential processing may only be distinguished in later-stage, higher-order, cognitive processes (Miyakoshi et al., 2007; Schäfer, Frings, et al., 2016; Siebold et al., 2015; Stein et al., 2016).

In one view of cognitive operations in the matching task, the greater strength of self-associations relative to other-person associations in working memory has been postulated to underpin the SPE (Falbén, Golubickis, Tamulaitis, et al., 2020; Golubickis & Macrae, 2021; Orellana-Corrales et al., 2021; Reuther & Chakravarthi, 2017; Yin et al., 2019). Indeed, the newly-formed self-associations in the matching task seem to differ in strength from other-person-associations. One study (Wang et al., 2016) documented that while self-associations in matching trials elicited a performance advantage (in the authors' first experiment), when the shape-identity allocations were switched in a second experiment (e.g. the self-associated shape became the stranger-associated shape and vice versa), performance on mismatch trials was reduced for shapes previously associated with the self. Furthermore, the extent of the self-advantage in match trials correlated with the difficulty with switching shapes in mismatching trials, suggesting that the strength of the original self-associations was interfering with task performance.

In studies using ownership paradigms, on the other hand, it has been well-documented that classifying objects as either ‘mine’ or another person’s modulates memory (Cunningham et al., 2008; Golubickis et al., 2018, 2019; Turk, van Bussel, Waiter, et al., 2011). For example, in one study, the participants were asked to sort picture cards of objects by colour into one of two baskets owned respectively by the participant and an experimenter. In a subsequent surprise recognition test, a self-advantage emerged for the newly self-owned objects (Cunningham et al., 2008). These findings revealed that ‘novel ownership’ or ‘mere ownership’ (Beggan, 1992; Belk, 1988; Cunningham et al., 2008) could modulate recognition memory. Self-referential processing has also been documented to facilitate the binding of memories to their source (i.e., to the context in which the stimulus was encountered, such as recalling that the stimulus was encoded in relation to the self; Cunningham et al., 2011; Rogers et al., 1977; Sui & Humphreys, 2013). The wealth of research on self-reference and self-ownership effects in memory suggests that the association between the self and a stimulus is more strongly anchored relative to the association between another person and a stimulus (Cunningham et al., 2008; Reuther & Chakravarthi, 2017). It may be that instead of modulating perceptual operations, self-bias only arises later in memory-related processes (Janczyk et al., 2019; Y. Zheng et al., 2022).

1.5.3. Multiple stages of influence

As noted, in some studies the self-advantage has been documented to emerge only in later-stages of information processing, i.e., during higher-level processes (Janczyk et al., 2019; Miyakoshi et al., 2007; Schäfer, Wentura, et al., 2020; Siebold et al., 2015; Stein et al., 2016; Y. Zheng et al., 2022; Zhu et al., 2016). Other researchers have proposed that self-relevance can modulate multiple levels and stages of information processing (Desebrock & Spence, 2021; Humphreys & Sui, 2016; M. Liu et al., 2016; Scheller & Sui, 2022a; Sui & Humphreys, 2015a). Sui and Humphreys (2015a) link the self-advantage arising across different types of task by proposing that self-relevant stimuli activate a self-representation located in the mPFC which then functionally couples with distinct domain-specific regions associated with different components of the self. As noted, the vmPFC has been documented to couple with the pSTS in response to self-associated stimuli in perceptual matching (Sui, Rotshtein, et al., 2013). In another study using a spatial working memory task, the vmPFC was demonstrated to functionally-couple to an area linked to a classic working memory region (i.e. the frontoparietal cortex; Yin et al., 2019).

As such, a multiple-stage modulation can take the form of modulating different levels or stages *across* tasks. For example, in one task self-associations may modulate perceptual-level processes, and in another, the self-advantage may arise in decisional and memorial processes. Self-relevance is also thought to influence multiple stages of processing *within* a task—the allocation of attention, memory (the retrieval of a self-representation), and decision-making processes (Humphreys & Sui, 2016; M. Liu et al., 2016; Sui & Humphreys, 2015a). On this view, the self acts as an ‘integrative hub’, and self-association as a ‘glue’—one that binds sensory input to the self and modulates multiple processing stages (M. Liu et al., 2016; Sui & Humphreys, 2015a, 2017a). Self-bias has been suggested to reflect such a multiple-stage modulation (Scheller & Sui, 2022a; Sui & Humphreys, 2015a).

Convergent evidence from studies using self-relevant stimuli in other paradigms and measuring ERPs also highlight modulations at multiple stages within a task (A. Chen et al., 2008; Fan et al., 2011; M. Liu et al., 2016; Muñoz et al., 2020; Sui et al., 2009; Tacikowski & Ehrsson, 2016). Little research has directly examined self-bias in the matching task across multiple stages of processing (Desebrock & Spence, 2021; Golubickis et al., 2017; Scheller & Sui, 2022a; Y. Zheng et al., 2022), however, and research generally has tended to document that the self-advantage arises at later stages (Janczyk et al., 2019; Schäfer, Wentura, et al., 2020; Woźniak et al., 2018; Zheng et al., 2022; cf. Golubickis et al., 2017).

1.6. Neurophysiological correlates of the self-advantage

So far, this introductory chapter has mainly focused on behavioural findings in the literature. However, as noted in Section *1.2 Empirical treatment of the self*, the research thread that investigates self-bias also examines the neural activity underlying the performance advantage for self. Alongside behavioural and fMRI studies (e.g. Sui, Rotshtein, et al., 2013), which have dominated in the literature (Knyazev, 2013), the effects of self-relevance have also been examined in studies using an electrophysiological approach. In particular, a number of these studies have measured ERPs to determine the time-course of effects. The high temporal resolution of ERP can reveal the order and timing of processing stages, and therefore shed further light on the processing stages influenced by self-relevance.

ERP studies typically document that self-referential stimuli modulate the P3 component, but have also documented modulations of components such as the N2 (Fan et al., 2011, 2013; Gray et al., 2004; Knyazev, 2013; Muñoz et al., 2020; Niu et al., 2020; Sui et al., 2009; Tacikowski & Nowicka, 2010; Truong et al., 2013; Zhan et al., 2017; Żochowska et al., 2021), and early-onset components, such as one or both of P1 and N1 (Fan et al., 2011; Turk, van Bussel, Brebner, et al., 2011; Zhan et al., 2017; Zhou et al., 2017), among others. For example, self-faces and self-owned object stimuli have been shown to modulate both the N2 and P3 components (Muñoz et al., 2020; Sui et al., 2009). Responses to one's own-national-flag have also been documented to modulate the N1, N2, and P3 components (Fan et al., 2011). Only a handful of studies to date have examined ERPs associated with self-prioritization in the matching task (Woźniak et al., 2018; Y. Zheng et al., 2022)[3]. Using unfamiliar face-stimuli and labels presented sequentially (1500 ms apart), one study (Woźniak et al., 2018) documented that responses to the self-associated stimuli were

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[3] A conference abstract has been published for a study measuring ERPs while participants carried out an adaptation of the matching task using different size stimuli. The authors found that self-bias modulated the C1 component generated in the primary visual cortex (Sui, Sun, et al., 2015)

associated with a smaller anterior N2, a larger central-parietal P3, and a prolonged increase in amplitude of a late frontal positivity (450–750 ms), suggesting a multiple-stage, but not necessarily early-stage, influence. Another very recently published study is consistent with these findings. Using a matching task with the standard geometric shapes and the labels 'self', 'mother', 'stranger', and 'Chinese', the authors reported that responses to the self-associated stimuli were associated with a reduced N2 and greater P3 and late positive complex (LPC; 500–800 ms) amplitudes. The study concluded that self-bias modulated later-onset but not early-onset components (Y. Zheng et al., 2022).

The research reviewed thus far then suggests that self-relevance can modulate both early perceptual processes and higher-order stages of cognitive processing in some paradigms, but whether such an influence generalises to the matching task is not clear. Further research is needed to better understand the time-course of self-bias.

1.7. The effects of self-relevance beyond response selection

Complementing the research examining self-bias across stages of processing, from early perception to late-stage processing, a growing area of research motivates the hypothesis that self-relevance can modulate action or response execution as well (Constable et al., 2011, 2014; Desebrock et al., 2018; Desebrock & Spence, 2021; Frings & Wentura, 2014; Macrae et al., 2017; Robinson et al., 2014; Sparks, Moodie, et al., 2016). For example, in an fMRI study examining the self-memory advantage using a temporary ownership paradigm (Turk, van Bussel, Waiter, et al., 2011), participants sorted picture items via keypresses into virtual baskets allocated to the self or another person. Only self-owned items were found to evoke activity in action-related perceptual areas; namely, regions associated with motor affordances in the anterior inferior parietal cortex. The authors suggested that self-ownership may activate object motor affordances, whereas other-owned objects may not, perhaps due to socially-mediated associations (such as that other people's property should not be touched). The effects of these motor-related neural activations for self-owned items were not examined in overt movements, though.

In a study designed to assess the influence of self-relevance on access to visual awareness, the authors used a hierarchical-diffusion-model analysis to decompose task performance in an identification task. Self-prioritization was found to influence both decisional as well as non-decisional processes in the keypress motor responses (Macrae et al., 2017). Non-decisional processes can include stimulus encoding or response execution processes or both, so these findings left open the possibility that response execution can be modulated by self-associations. Studies using ownership paradigms, on the other hand, have demonstrated that self-relevance can influence the unfolding kinematics of action (Constable et al., 2014; Holubar & Rice, 2006; Sparks, Moodie, et al., 2016). In one study (Constable et al., 2014), the participants were instructed to lift their own versus an experimenter’s mug. Arm-movement trajectories toward the own-mug were straighter, and toward the experimenter’s mug, more curved. The authors suggested that distinct mechanisms are associated with socially-related visuomotor processing.

Prior to this thesis (Desebrock, Barutchu, et al., 2022; Desebrock et al., 2018; Desebrock & Spence, 2021), no studies had examined the effects of self-relevance beyond response selection[4] in the matching task. Using an action-related adaptation of the matching task, however, Frings and Wentura (2014) demonstrated a ‘motor SPE’. The authors instructed their participants to associate an arm movement (moving a cursor with a mouse up, down, left, or right on a screen) with the self and other-person labels. A directional cursor

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[4] In line with research that indicates that decision-to-motor processing itself is not serial (Cisek, 2007; Kaufman et al., 2015), response selection in this thesis is understood to refer to the final selection of the motor response when a commitment to a response is made. Notably, preparatory ‘motor’ activity can reflect vacillation, or hesitation, during the decisional process (Kaufman et al., 2015). The moment when neural activity begins to activate the motor cortices is not necessarily the moment a decision is finalized (Schurger et al., 2012). In other words, responses can be selected, unselected, and re-selected and held for a period of time before a commitment to a response is made. However, ‘change of mind’ processes have been documented as specific to free choice trials, and not observed in forced-choice trials (Kaufman et al., 2015).

indicated to participants which of the arm movements to execute. On reaching the side of the screen, the participants had to judge whether the label that appeared matched the allocated arm-movement or not by pressing one of two mouse buttons. Judgements were faster and more accurate in self-associated trials. Given that participants' arm-movements terminated before a judgment response was made, the authors thus demonstrated a *motor-related SPE*—a prioritization effect in matching a self-associated label and action representation (i.e., self-associated movements encoded at a 'conceptual level'; Frings & Wentura, 2014; p. 1740; perhaps at the level of internal verbal description or as motor imagery). The authors did not, however, examine whether the novel self-associations could modulate the overt arm-movement response itself. It was therefore not known whether the effects of self-relevance in the matching task could modulate motor responses beyond their selection.

The question of whether or not novel self-associations in the matching task can modulate processes beyond response selection is related to the broader question of what the boundary conditions are for the emergence of the self-advantage, or what contextual constraints modulate the *extent* of the self-advantage. In the following section, I review research that has shed light on the contextual constraints of self-prioritization.

1.8. Contextual constraints on the extent of self-prioritization

The literature reviewed thus far in this introductory chapter demonstrates that a processing advantage for self-associated stimuli arises consistently across diverse tasks, including the matching task (Sui et al., 2012). *How* the self-advantage arises (i.e. what processing stages are influenced), however, has been shown to differ across tasks and types of self-relevant stimuli, even in closely-related task contexts. For example, as noted earlier, studies using identification tasks and object categorization tasks in ownership paradigms have revealed that perceptual-level processes are modulated by self-relevance in some contexts, but not others (Falbén, Golubickis, Tamulaitis, et al., 2020; Golubickis et al., 2018, 2021; Macrae et al., 2017). Elements of task design within the matching task itself can also moderate the extent of the self-advantage. For example, when the self-associated and friend-associated shapes are blocked rather than intermixed in the task, the extent of self-bias is reduced (Golubickis & Macrae, 2021).

1.8.1. Unisensory and multisensory stimuli

One question as yet relatively unexplored is whether the sensory modality of the objects and labels—a stimulus parameter—can also modulate self-prioritization in the matching task. A notable aspect of the research reviewed so far in this introductory chapter is the almost exclusive focus on visuomotor processing (i.e., information processing in keypress motor responses to visual stimuli). Indeed, reflecting traditions in perception and memory research more generally (Hutmacher, 2019), research on self-bias has tended to focus on the visual modality (Humphreys & Sui, 2016; Sui et al., 2012). A handful of studies, however, have examined the SPE using auditory stimulus objects and visual labels. A robust SPE was reported across these studies, which used a range of categorical (instrumental) sounds (Schäfer, Wesslein, et al., 2016), pure tones (high, medium, low; Stolte et al., 2021), and unfamiliar synthetically-generated voices (B. Payne et al., 2020). One study also compared the extent of self-bias in responses to visual, auditory, and tactile stimuli, and reported that it did not differ. These authors suggested that self-bias is therefore likely to reflect a modality-general mechanism. In contrast, however, Stolte et al. (2021) documented a smaller SPE in responses to their auditory as compared with visual stimuli (depending on the frequency of tone allocated to the identities), suggesting that under some conditions, vision may dominate for self-associations (Stolte et al., 2021).

A methodological feature common to all of the studies above was that they used visual text labels. As such, the object-label stimuli in these studies were either visual or audiovisual. No studies prior to the study presented in Chapter 2 of this thesis (Desebrock, Spence, et al., 2022) had examined self-bias with auditory labels paired with auditory or visual objects (cf. Scheller & Sui, 2022b). Differential mechanisms (with which self-bias could interact) have been shown to underlie the processing of visual and auditory linguistic and object stimuli carrying seemingly equivalent information (Arana et al., 2020; Chen & Spence, 2018). Furthermore, certain sensory object-label self-associations may be more easily formed, or accessed than others, or visual dominance may modulate self-bias (see Chapter 2). Although an auditory self-bias has been demonstrated in other paradigms (L. Liu et al., 2019), the universality of Moray's auditory self-bias, for example, has been questioned (the bias is exhibited by only ≈33% of the participants; A. R. A. Conway et al., 2001; Wood & Cowan, 1995). It was not known to what extent self-bias would arise with auditory stimuli (both object and label), and if self-bias could be moderated by the combination of object/label modality (auditory, visual, or audiovisual). More research is needed to better understand self-bias in the matching task outside of visuomotor responses.

1.8.2. Boundary conditions of self-prioritization

As well as how and to what extent the self-advantage emerges, the task context can also constrain *whether* a self-advantage emerges. Although it has been postulated that self-associated stimuli activate a self-representation in the mPFC which then modulates subsequent processing (e.g. Sui & Humphreys, 2015a), such an activation may not be automatic (cf. Humphreys & Sui, 2016). A growing number of studies have suggested that the emergence of the self-advantage depends on making explicit semantic or self–other judgements in the task at hand (Caughey et al., 2021; Constable, Welsh, et al., 2019; Dalmaso et al., 2019; Desebrock, Spence, et al., 2022; Macrae et al., 2017; Siebold et al., 2015; Stein et al., 2016), or at least on perceiving that the self–other associations are relevant to the task (Woźniak & Knoblich, 2021). For example, in one study using a shape-classification task, shapes associated with the self were only classified more rapidly than other-person associated shapes when the participants made judgements about who the shapes belonged to, but not when judging what the shape was, or where on the screen the shapes were located (Caughey et al., 2021). Conversely, the self-ownership effect also arises when stimuli are semantically evaluated (i.e. in ‘what’ judgements; Falbén et al., 2019). The influence of self-relevance on cognition appears to be flexible and task-specific (Caughey et al., 2021; Falbén et al., 2019; Hutchison et al., 2021; Schäfer & Frings, 2019b; Turk et al., 2008).

Studies also suggest that self-bias may depend not just on conditions for activation of a self-representation, but also on the *particular* self-representation activated by the task. For example, an active representation of the ‘good self’ or ‘current self’ may be requisite for the emergence of the SPE (Golubickis et al., 2017; C.-P. Hu et al., 2020). How self-bias in the standard matching task relates to the effects of self-relevance more widely, and whether the self-advantage is activated by a generic self-representation, have been points of contention in the literature, which are reviewed in the next sections (*1.10–1.11*).

1.9. Self-relevance and the operation of multiple components of self

As noted, some researchers have proposed that the self-advantage across tasks is underpinned by the activation of a core self-representation housed in the vmPFC (Humphreys & Sui, 2016; Scheller & Sui, 2022b; Sui & Humphreys, 2015a). Consistent with this notion, for example, studies examining behavioural and neural responses to different types of self-relevant stimuli (e.g. own-name, self-face, own-voice) have revealed similar patterns of findings (Feng et al., 2018; C. Hu et al., 2016; Kaplan et al., 2008; Tacikowski & Nowicka, 2010; although cf. L. Liu et al., 2019). Furthermore, functional connectivity between the vmPFC and LpSTS has been documented to underpin self-bias in the matching task, while in another study, functional connectivity between the vmPFC and a classic working memory region in the frontoparietal cortex was documented to underpin the self-advantage in a working memory task (Yin et al., 2021).

On the other hand, part-representations of the self (such as being a vegetarian or an athlete) can also elicit an SPE, and the self-advantage is moderated by the relative importance of the activated self-representation (Golubickis et al., 2020). Furthermore, only one of multiple self-concepts is represented as the self at any one time (De Freitas et al., 2019). Consistent with these findings, neural patterns in cortical midline structures have been found to differentiate between dimensions of self that are related to personality traits, physical attributes, and social roles, as well as simply self from other (Feng et al., 2018). Rather than a generic core self-representation, then, stimuli may associate to task-specific subcomponents of self (Golubickis et al., 2020).

Some researchers have postulated that the self-advantage across tasks may arise as a function of the self-related system—memorial or attentional—being activated by the task. In other words, some tasks draw on the self-knowledge-based system (the elaboration and organization of self-relevant information through autobiographical memory), and others tap into the system underpinning automatic attentional responses to self-relevant cues, and these two systems may reflect the operation of independent components of self (Hutchison et al., 2021; Turk et al., 2008; Woźniak & Knoblich, 2021).

If self-bias reflects the operation of a core self-representation, also activated by other tasks in which a self-advantage arises, self-bias might be expected to correlate with the self-advantage across tasks, within individuals. In a study using own-name stimuli, the relationship between self-bias in the matching task and in an attentional blink task was examined directly. However, the extent of the self-advantage was found to be unrelated across the tasks. The authors suggested that the effects of one's own name in attentional processes (blink task) and perceptual processes (matching task) are independent (Nijhof et al., 2020). In another study examining self-bias across cognitive domains, no relationship was documented between self-bias in the matching task and the self-advantage in an SRE task (Amodeo et al., 2021). Furthermore, in a study which examined the effects of self-associated stimuli under conditions of attentional competition, an advantage in attention holding was documented for familiar self-associated objects and labels, but not for newly self-associated stimuli (Orellana-Corrales et al., 2021). The authors suggested that pre-existing self-associations and novel self-associations (as formed in the matching task) do not modulate attention in the same way (although cf. Scheller & Sui, 2022b).

Research suggests that effects of novel self-associations formed in the matching task may be underpinned by partly different processes from those of both self-referential stimuli (e.g. self-faces) and arbitrary self-ownership (Constable, Welsh, et al., 2019; Orellana-Corrales et al., 2021; Woźniak & Knoblich, 2021). Self-prioritization in the matching task then may be (somewhat) distinct from the self-advantage arising in other task paradigms.

1.10. Self-prioritization as a subcomponent of self

In another line of enquiry, a handful of studies have examined the relationship between self-bias and higher-level constructs of self using subjective (self-report) measures of the self. For example, in one study (Schäfer & Frings, 2019b), no relationship was documented between the SPE and explicit self-esteem (thought to relate to the *narrative* self; Gallagher, 2000; Schäfer & Frings, 2019b). In contrast, in higher-level self-referential tasks (for example, where the participants had to evaluate personality traits in relation to themselves and other people), a relationship with self-esteem has been documented (Nowicka et al., 2018). Furthermore, while autistic people have been documented to show a reduced or absent SRE (Dawson & McKissick, 1984; Henderson et al., 2009; Lombardo et al., 2007; Toichi et al., 2002; although cf. Amodeo et al., 2021; Lind et al., 2020), an intact SPE has been demonstrated in this population (Moseley et al., 2021; Williams et al., 2018). Indeed, the social deficits in autism are not thought to relate to a lack of basic differentiation between the self and others (Dawson & McKissick, 1984). On the basis of such findings, it has been postulated that self-bias in the matching task may reflect implicit self-related processing which is (somewhat) independent of explicit higher-level self-referential or self-reflective processing (Northoff, 2016; Schäfer & Frings, 2019b; Schäfer, Wesslein, et al., 2020).

The start of this introductory chapter outlined a widely-accepted distinction between the minimal self and narrative self (Gallagher, 2000). Some researchers have postulated that in relating to the function of making a basic distinction between self and other, self-bias in the matching task may constitute a measure of the minimal self (Schäfer & Frings, 2019b). In other studies, however, associations have been found between self-bias and explicit subjective perceptions of the perceived closeness between the self and others (Sui & Humphreys, 2015b, 2017; Yankouskaya et al., 2020). Theories diverge regarding the extent to which such sub-components of the self are interconnected or whether they function independently (Gallagher, 2013; Nijhof et al., 2020; Sui & Humphreys, 2015a), and empirical study of their relationship and dynamic interplay is in its infancy (Amodeo et al., 2021; Banakou et al., 2013; Desebrock, Barutchu, et al., 2022; Maister et al., 2015; Maister & Farmer, 2016; Nijhof et al., 2020; Nowicka et al., 2018; Schäfer & Frings, 2019b; Tao et al., 2012). At present, it is unclear whether and how self-bias may be related to higher-level conceptual constructs of the self, or may instead draw upon distinct lower-level representations.

1.11. Overall aims

As discussed, the empirical evidence is consistent with the notion that there may be multiple and distinct subcomponents of self that differentially influence our behaviour (Amodeo et al., 2021; De Freitas et al., 2019; Golubickis et al., 2020; Nijhof et al., 2020). Indeed, growing evidence suggests that self-bias in the matching task may reflect the operation of a subcomponent of self (Constable, Welsh, et al., 2019; Schäfer & Frings, 2019b). The aim of this thesis is to further examine *self-bias* in manual motor responses in order to map out and better understand the operation of this (putative) subcomponent of self.

As noted at the start of this introductory chapter, the research thread in which this thesis is situated has used a combination of manual motor, oculomotor, and verbal report measures to assess the self-advantage. This thesis focuses specifically on manual motor responses and the effects thereon of the novel self-associations formed in the learning phase of the matching task. As reviewed earlier in this chapter, self-bias in humans has been documented early in development (Maire et al., 2020) and may be modulated throughout the lifespan (Sui & Humphreys, 2017c). Given the nascent status of investigations of self-bias in motor responses, however, the present thesis focuses on samples of young adult participants from the general population.

Commonly, manual motor responses in tasks such as the matching task are used as a proxy measure of cognitive (or premotor[5]) processes, largely based on tradition and the implicit assumption that the motor-stage is influenced by target not stimulus features (see Chapters 3–5). This thesis is aligned with research that considers that the motor stage can also (theoretically) be influenced by self-relevance (Barton et al., 2020; Desebrock et al., 2018; Desebrock & Spence, 2021; Golubickis et al., 2017; Janczyk et al., 2019; Macrae et al., 2017).[6] Accordingly, each chapter examines the self-advantage in a different type of motor response using novel adaptations of Sui et al.'s (2012) matching task, and addresses the overarching question: What are contextual constraints on the emergence and extent of the self-advantage in motor responses?

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[5] *Premotor processes* in this thesis refer to those processes occurring before commitment to the response is made. Premotor processes can include activation of the motor cortex, for example, during ongoing response selection processes prior to the commitment to a decision (Churchland et al., 2012; Kaufman et al., 2015).

[6] In studies using Hierarchical Drift Diffusion model analysis, for example, non-decisional processes are measured which include response execution and encoding processes (Golubickis et al., 2017; Macrae et al., 2017; Voss et al., 2013).

In the latter part of this introductory chapter, extant gaps in the literature were highlighted pertaining to contexts of emergence or moderation of self-bias (extant prior to publication of the studies presented in this thesis). In sum, it was highlighted how: (1) little is known about the operation of self-bias outside of visuomotor responses; (2) whether the effects of self-relevance in the matching task can modulate motor responses beyond their selection, and in multiple stages of information processing; and (3) whether self-bias is related to higher-level conceptual constructs of the self, or may instead draw upon distinct lower-level representations. This thesis addresses these lines of enquiry across four experimental chapters.

1.12. Outline of the thesis

Chapter 2 presents the first experimental study of this thesis (Study C2). In line with traditional research on self-prioritization (Sui et al., 2012), manual keypress motor responses are examined holistically; that is, measures are taken of total response time (i.e. the time taken to process the stimulus information and make a task-designated motor response that is 'correct'). The effects of novel self-associations formed in the learning phase of the matching task are examined both in the standard forced-choice matching task motor responses, and, for the first time, in a multisensory simple detection motor paradigm. Unisensory and multisensory stimuli are used along with manipulations of task design and stimulus parameters to expand on previous research in examining boundary conditions and contextual constraints on the extent of the self-advantage. This chapter asks: does a self-advantage arise in motor responses to unisensory auditory and multisensory stimuli and manifest in the same way as has been demonstrated with visual stimuli? Does task-design (namely, whether the stimuli are blocked or intermixed by sensory modality) moderate the self-advantage with unisensory and multisensory stimuli? Can the novel unisensory and multisensory self-associations influence motor responses when the associations are not (perceived as) relevant to the task at hand?

In Chapter 3 (Study C3), the manual keypress responses are swapped for arm-movement responses in a novel movement adaptation of Sui et al.’s (2012) matching task (Desebrock et al., 2018). Total response time is divided into the initiation and execution of the arm-responses to further investigate contextual constraints and boundary conditions of self-prioritization in cognition and action. Here the focus is on visuomotor processes, and this chapter asks: can self-bias in the matching task influence arm-movement responses as well as keypress motor responses? Does a self-advantage emerge in the execution as well as initiation of arm-movement responses? In other words, can self-bias modulate arm-movements beyond their selection?

Chapter 4 (Study C4) presents a single-study theoretical review of one other study that has investigated self-prioritization at the motor-stage (Janczyk et al., 2019). In contrast to the findings of Chapter 3, these authors documented that the motor-stage of keypress motor responses did not contribute to the self-advantage in total responses times. Taken together, with Study C3, these findings may be interpreted to suggest that the self-advantage in overt movement may depend on response features that characterise arm-movement responses but not keypress responses, and thus account for the absence of self-bias in the motor-stage of discrete keypress motor responses. This chapter reviews the methodology of this study in the context of a theoretical framework for movement preparation and onset and takes a closer look at the evidence to support this conclusion.

Chapter 5 (Study C5) investigates whether features of the arm-movement response reported in Chapter 3 that do not characterise keypresses could account for the self-advantage in movement execution. Specifically, the motor response is manipulated in terms of approach motivation and affective-compatibility mechanisms, the use of visual feedback, and the ballistic nature of the response. This chapter asks: Is the self-advantage in the execution of arm-movement responses specific to the type of motor response used in Chapter 3? Does the self-advantage in the execution of arm-movement responses depend on a stimuli-directed or self-directed motor response, or on non-ballistic, visual feedback-guided responses? Can self-relevance in the matching task influence both the initiation and execution of arm-movement responses and thus speak to whether self-bias has a multiple-stage influence?

Chapter 6 (Study C6) examines the representations underlying the operation of self-bias in ballistic arm-movement responses, alongside friend-bias (the difference in performance for friend- and stranger-associated stimuli). An emerging theoretical view is that biases in the matching task are not influenced by consciously-accessible constructs related to the self, such as explicit self-esteem (Schäfer & Frings, 2019b). An alternative view is that self-bias *is* influenced by explicit self-representations and self-reflective processing. To decide between these two accounts, Chapter 6 examined for the first time the relationship between Self-bias and Friend-stranger bias and subjective measures of empathy and personal distance (the perceived closeness between others and the self). This chapter asks: is the movement self-advantage robust to non-dichotomous social identities; namely to the addition of Friend-associated stimuli alongside Self- and Stranger-associated stimuli; does friend-bias as well as self-bias arise in ballistic arm-movement responses? Is there a relationship between self-bias and friend-bias in ballistic arm-movement responses and higher-level constructs of the interrelations between others and the self?

Chapter 7 (Thesis Discussion) presents an overview of the thesis background, aims, and methodology, a summary of the experimental results, and a discussion of the wider implications of the findings. Limitations of the research presented in this thesis are also discussed, along with directions for future research.

1.13. Significance of this thesis

In examining the influence of self-bias outside of visuomotor processing, beyond response selection, and in arm-movement motor responses, this thesis makes multiple novel contributions to and progresses the literature on the moderating factors and contextual constraints of the self-advantage (Desebrock, 2019; Desebrock, Barutchu, et al., 2022; Desebrock et al., 2016, 2018; Desebrock, Spence, et al., 2022; Desebrock & Spence, 2021). The findings of this thesis thus contribute to the rapidly growing body of research investigating self-bias in the matching task (Golubickis et al., 2017; Golubickis & Macrae, 2021; C.-P. Hu et al., 2020; Janczyk et al., 2019; Lee et al., 2021; Moseley et al., 2021; Navon & Makovski, 2021; Nijhof et al., 2020; Orellana-Corrales et al., 2021; Stolte et al., 2021; Sui et al., 2012; Svensson et al., 2021).

The findings of this thesis also complement research on the effects of self-relevance more widely across levels, stages, and domains of processing (Frings & Wentura, 2014; Golubickis & Macrae, 2021; Janczyk et al., 2019; Macrae et al., 2017; Schäfer, Wesslein, et al., 2016; Sui & Humphreys, 2015a, 2017a), on closely-related socio-cognitive constructs such as ownership (Barton et al., 2020; Constable et al., 2014), in-group identification (Enock et al., 2018; Moradi et al., 2015), and motivational (reward or affective-evaluation) factors, for example in goal-directed action (Constable et al., 2014; Kozlik et al., 2015; Manohar et al., 2015; Mir et al., 2011; Moradi et al., 2018). The findings are also more broadly relevant to the fields of visuomotor research and sensorimotor control (Gallivan et al., 2018; F. Schmidt et al., 2011; T. Schmidt et al., 2006; see Chapters 3–5).

Investigating self-bias in motor responses in particular increases understanding of the operation of sub-components of the self in action, and is likely to have important future translational value for progressing understanding of self-representation(s) in action across different populations. Disorders of the self (such as schizophrenia) and neurodevelopmental conditions (such as autism) also present with motor deficits (Dawson & McKissick, 1984;

Ming et al., 2007; Morrens et al., 2014; Mostofsky & Ewen, 2011). Sensory and motor deficits are thought to influence development of the self (Delafield-Butt & Trevarthen, 2018; Trevarthen & Delafield-Butt, 2013). In turn, motor responding may be automatically reflective of the underlying representations of the self and others (See Chapters 6 and 8). Overall the findings of this thesis progress our understanding of the impact that self-relevance has on cognition and action, the particular operation of self-bias as a subcomponent of self in motor responding, and the influence that underlying representations of the self and others have on shaping our behaviour.

1.14. Methodological approach

The matching task developed by Sui et al. (2012) serves as the central methodology for this thesis. Adaptations of the matching procedure are used throughout this thesis in order to examine the effects of novel self-associations on motor responses. Measures of reaction-time (RT), accuracy (percent correct), and D-prime scores (*d'*) indexing perceptual sensitivity (Sui et al., 2012) are used to examine self-bias in the matching and detection task keypress responses in Chapter 2, along with Cumulative Distribution Frequency plots (CDFs; Ratcliff, 1979) to further assess differences throughout the RT distributions in the detection task.

In Chapters 3–6, novel movement adaptations of the matching task are used which integrate a well-established movement-time paradigm (Barton et al., 2020; Houlihan et al., 1994; Jensen & Munro, 1979; Praamstra et al., 2014) with associated response-time and accuracy measures (see below). Thus, this thesis takes a behavioural approach using methods associated with cognitive psychology and psychophysics (Chapters 2–6). In Chapter 6, self-report trait measures are used in conjunction with the psychophysical measures to explore the relationship between self-bias and higher-level constructs of self–other relations reflected in empathic traits (borrowing from social psychology) and perceptions of closeness between others and the self.

1.14.1 d' scores

Alongside measures of accuracy, across all studies in this thesis, a signal detection approach was used to calculate an index of perceptual sensitivity (D-prime; *d′*; Green & Swets, 1966). *d'* is calculated using the accuracy data, and is given by the formula:

$$d' = z(hit\ rate) - z(false\ alarm\ rate)$$

Matching trials in the matching task require a 'yes' response, and mismatching trials a 'no' response. Hits were coded as *yes* responses to match trials, and false alarms were coded as *yes* responses to mismatch trials with the same shape. Mismatch conditions were defined as shape-based (i.e., a self-mismatch trial consisted of the self-associated shape and the stranger-associated label, a stranger-mismatch trial consisted of the stranger-associated shape and the self-associated label). If a participant has a bias to respond yes to self-associated shapes irrespective of the label, accuracy will be falsely inflated for self-associated matching-trial responses, and accuracy for self-associated mismatch trials would be low. *d′* provides a measure of the participant's ability to discriminate matching and mismatching stimuli, and thus a measure of sensitivity. As such, *d′* scores complement and validate the basic accuracy scores. Combining *d'* scores with RT measures also provides an indication of whether a speed-accuracy trade-off underlies a particular performance advantage (Ratcliff, 1985)

1.14.2. Movement measures

This thesis uses a novel movement adaptation of the matching task (see Chapters 3–6; Desebrock et al., 2018; Desebrock, Barutchu et al., 2022; Desebrock & Spence, 2021) which integrates a well-established 'movement time' procedure (Barton et al., 2020; Houlihan et al., 1994; Jensen & Munro, 1979; Praamstra et al., 2014; Robinson et al., 2014) in which total response time is divided into movement initiation time (IT) and movement execution time (MT). IT is measured from stimulus onset to the release of a home button, and MT is measured from the release of the home-button to the depression of the target key. IT is used for the assessment of correctly-initiated movements, and MT for correctly-initiated and correctly-completed arm-movement responses. Also assessed are movement initiation accuracy (the percentage of correctly-initiated movements), and movement execution correct-completion (the percentage of correctly-completed movement executions, following correct movement initiation).

1.14.3. Self-report trait measures

In Chapter 6, individual differences in empathic traits and perceived closeness between others and the self are measured to assess the relationship between self-bias in the matching task and higher-level constructs of self–other relations. Empathy is assessed using the *Interpersonal Reactivity Index* (IRI; Davis, 1980; Keaton, 2017). The perceived closeness between the self and others is assessed using the Personal Distance Scale (PDS; Sui & Humphreys, 2015b), which provides an explicit self-report measure of the perceived closeness between self–friend, self–stranger, and friend–stranger (Enock et al., 2018; Moseley et al., 2021; Sui & Humphreys, 2017c; Yankouskaya et al., 2020).

Chapter Two—Self-bias with unisensory and multisensory stimuli in manual motor responses (Study C2)

2.1. Chapter overview

As outlined in Chapter 1, the empirical evidence is consistent with the notion that there may be multiple and distinct subcomponents of self that differentially influence our behaviour. These subcomponents appear to be flexibly engaged depending on the task at hand (Hutchison et al., 2021; Nijhof et al., 2020; Orellana-Corrales et al., 2021; Schäfer & Frings, 2019b; Turk et al., 2008; Woźniak et al., 2022). Self-bias in Sui et al.'s (2012) matching task has been suggested to reflect the function of making a basic distinction between self and other, and as such may constitute a measure of the minimal self (e.g. Schäfer & Frings, 2019b). If motor responses in the matching task reflect the function of making a basic distinction between others and the self, then one would expect self-bias to operate not only across sensory modalities (Schäfer, Wesslein, et al., 2016), but also in multisensory processes. To date, the majority of the research has investigated the SPE in visuomotor responses. By contrast, only recently has research begun to explore self-bias using auditory objects and in multisensory processes (B. Payne et al., 2020; Schäfer, Wesslein, et al., 2016; Scheller & Sui, 2022a; Stolte et al., 2021). Optimal functioning relies on processing multisensory input from different sensory modalities into coherent and accurate representations of environmental entities (e.g. Spence, 2018), and evidently such processing is fundamental to distinguishing the self from non-self (e.g., Tsakiris & Haggard, 2005). A stable self-representation at the level of the minimal self would necessarily require optimal processing of incoming multisensory input. Little is known, however, about the operation of self-bias in unisensory auditory or multisensory processes.

In accordance with the overarching aim of this thesis, this first experimental chapter (Desebrock, Spence, et al., 2022) sought to increase understanding of the operation of this (putative) subcomponent of ‘self’ by examining the influence of the novel unisensory and multisensory self-associations in both matching and simple detection motor responses. Specifically, auditory labels were introduced to the matching task, and, for the first time, responses to unisensory auditory, unisensory visual, and multisensory object-label stimuli were compared across block-type (i.e. trials blocked by sensory modality type, and intermixed trials of unisensory and multisensory stimuli). Auditory stimuli were either presented at 50 dB (Group 1), or 70 dB (Group 2). To assess whether the learnt associations and biases generalised, the participants in Group 2 also completed a multisensory detection task, making simple speeded motor responses to the shape and sound stimuli as well as to their multisensory combinations.

In the matching task, self-bias was diminished in intermixed trials, and in responses to the unisensory auditory stimuli as compared with the multisensory (visual shape+auditory label) stimuli. In contrast, self-bias did not differ in responses to the unisensory visual and multisensory (auditory object+visual label) stimuli. There was also a significant interaction between association (self- vs. stranger-associated responses) and audiovisual stimulus type (A+VL vs. V+AL) for multisensory gains and costs in terms of RT. Multisensory costs were descriptively greater for self- than stranger-associated A+VL stimuli, while for the V+AL stimuli, there were costs for stranger, and multisensory gains were observed in responses to the self-associated stimuli. RTs to self- vs stranger-associated stimuli were differentially influenced by the type of multisensory stimulus (auditory object+visual label or visual shape+auditory label). Self-bias was thus modulated both by block-type and the combination of object and label stimulus modalities. There was no significant advantage for self in the detection task. Taken together, these findings suggest that self-bias with unisensory and multisensory stimuli is modulated by both stimulus and task-related parameters within the matching task. The advantage for self does not transfer to a significant motor speed gain when the self-associations are not task-relevant. Implications for understanding self-bias in these manual motor responses are discussed in Section *2.5 Discussion* (see also Chapter 7).

2.2. Introduction

Self-representation is widely held to guide our cognition and action, and self-relevance has repeatedly been shown to influence stimulus processing (Cunningham & Turk, 2017; Golubickis et al., 2018; Sui & Humphreys, 2017a). Using stimuli such as our own face or name, our attributes (e.g., personality traits), our possessions, and also those stimuli that are newly and arbitrarily associated with the self, studies have investigated self-relevance across a diverse range of tasks. Self-related stimuli have been documented to modulate attention (Alexopoulos et al., 2012; Brédart et al., 2006; Humphreys & Sui, 2016; Moray, 1959), perceptual decision-making (Constable, Welsh, et al., 2019; Golubickis et al., 2017; Humphreys & Sui, 2016), and memory (Rogers et al., 1977; Symons & Johnson, 1997; Yin et al., 2019), and overt arm-movements (Constable et al., 2014; Desebrock, Barutchu, et al., 2022; Desebrock et al., 2018; Desebrock & Spence, 2021).

As outlined in Chapter 1, a paradigm for investigating the effects of self-relevance without the confounds of stimulus familiarity (inherent in own-name or own-face stimuli, for example) was established with the introduction of Sui et al.’s (2012) matching procedure. In an initial learning phase, participants are instructed to associate geometric shapes with visually-presented labels referring to people (e.g., self-circle, friend-triangle, stranger-square). Arbitrary associations between the identities and the stimuli are thus formed rapidly. In the main task, participants then indicate whether shape-label stimulus pairs match or mismatch the newly-learned associations, typically by means of keypress responses. RTs to the self-associated shape-label stimulus pairs are consistently found to be shorter, and more accurately selected. This phenomenon is known as the SPE or self-bias. Self-bias can thus be measured without the need to use stimulus objects that are highly familiar. Self-bias appears to be dissociable (at least in part) from the effects of stimulus familiarity, emotional valence, and reward (Schäfer, Wentura, et al., 2020; Stolte et al., 2017, 2021; Sui et al., 2012; Woźniak & Knoblich, 2019; Yankouskaya et al., 2017). Distinct neural circuitry has also been documented to underpin the self-advantage (Sui, Rotshtein, et al., 2013; Yankouskaya et al., 2017). To better understand the operation of this (putative) subcomponent of self (e.g. Schäfer & Frings, 2019b), this chapter investigated the influence of both stimulus- and task-related factors on the extent of the self-advantage, and its emergence across tasks, in keypress motor responses.

2.2.1. The effect of sensory modality on self-bias

In previous studies investigating self-bias, the object and label stimuli used in the matching task have typically been visual (e.g. Golubickis et al., 2017; Sui et al., 2012; Woźniak et al., 2018), and self-bias has been interpreted as arising from the binding of the visual self-associated stimulus to the self-concept (Schäfer, Wentura, et al., 2020; Sui & Humphreys, 2015a). However, it has previously been assumed (Humphreys & Sui, 2016) and later evidenced, in studies using auditory and tactile stimulus objects, that self-bias in the matching task is not a phenomenon that is specific to the visual modality (B. Payne et al., 2020; Schäfer et al., 2015; Schäfer, Wesslein, et al., 2016; Stolte et al., 2021). Furthermore, it has been suggested that the self-representation underpinning self-bias may be modality-general (or ‘abstract’; Woźniak et al., 2018). Indeed, Schäfer, Wesslein, et al. (2016) documented that the magnitude of self-bias did not appear to differ in responses to visual as compared with auditory and tactile object stimuli (with objects presented 500 ms before the visual label stimuli). Self-bias thus appeared to be underpinned by neural processes that are common to responses across all sensory stimuli. The authors concluded that self-bias reflected in the matching task responses was therefore likely to be a modality-general mechanism.

By contrast, Stolte et al. (2021) used simultaneous presentations of auditory objects and visual labels (as such creating opportunity for multisensory integration) and documented that the self-advantage was smaller than to the standard visual shape and visual label stimulus pairs. The authors suggested that under some conditions vision may dominate for self-associations (Stolte et al., 2021). As Hutmacher (2019) points out, visual dominance is socially and culturally reinforced. In certain contexts, we have become accustomed to rely more on visual than auditory (or other sensory) information, and may actively attend to visual over auditory stimuli (Posner et al., 1976; Sinnett et al., 2007). For example, the alerting properties of auditory stimuli are thought to produce an override response in participants such that they actively focus their attention toward the weaker visual stimuli as a consequence. Fewer cognitive resources thus remain to attend to, and process, auditory stimuli. Task-induced visual dominance may reduce the extent of self-bias with auditory stimuli.

2.2.2. Task-design, stimulus parameters, and self-bias

Perhaps not unexpectedly, certain stimulus parameters and elements of the task design have differed across the previous studies that have compared self-bias in responses to both visual and auditory stimuli (Schäfer, Wesslein, et al., 2016; Stolte et al., 2021). For example, Schäfer et al. presented their auditory stimuli at 50 dB, and used a blocked-trial design (with responses to the auditory and visual stimuli being assessed in separate experiments). These authors documented that the magnitude of self-bias did not differ in responses to visual as compared with auditory stimuli. By contrast, Stolte et al. presented their auditory stimuli at 75 dB, and used an intermixed presentation with all stimulus modality types randomly intermixed within a block of experimental trials. These latter authors documented that the self-advantage in responses to paired auditory object and visual label stimuli was smaller than to the standard visual shape and visual label stimulus pairs. Such differences in the stimulus parameters and task design across studies may differentially influence self-bias across visual and auditory stimuli.

2.2.2.1 Blocked vs. intermixed trials

Task design (i.e. whether trials are intermixed or blocked by the identity of the target shape) has previously been demonstrated to influence self-prioritization (Golubickis & Macrae, 2021). In a recent study using visual stimuli in the matching task, the authors documented that the self-advantage was greater in intermixed trials (using self- and friend-associated shapes) than in blocked trials (i.e. using self- or friend-associated shapes; Golubickis & Macrae, 2021). Blocking or intermixing trials by stimulus modality may also modulate self-bias. In intermixed as compared with blocked trials, responding to the randomised unisensory and multisensory trials requires modality-switching. Modality-switching typically results in slower and less accurate responses (Spence et al., 2001), reflecting 'switching costs' (Barutchu & Spence, 2021; Otto & Mamassian, 2012). Sensory switch costs often result in slower responses to unisensory stimuli since attention must be shifted between the senses (Kreutzfeldt et al., 2015; Lukas et al., 2010; Spence et al., 2001). In contrast, responses to multisensory stimuli do not necessarily require any modality-switching since processing just one of the two sensory stimuli is sufficient to produce a valid motor response in those detection paradigms with redundant signals. Switching can thus inflate multisensory gains in detection paradigms (Barutchu & Spence, 2021; Otto & Mamassian, 2017; Shaw et al., 2020). In a matching task, on the other hand, both signals need to be processed in order to make a decision and thereafter a valid motor response; therefore, a switch to a multisensory signal in a matching task may be expected to lead to a multisensory cost. Indeed, multisensory costs were observed in Stolte et al.'s (2021) study, along with a reduced self-advantage in responses to those audiovisual stimuli. Switching could thus (partly) underpin the reduction in self-bias with audiovisual stimuli in their study, which was further investigated in the present chapter.

Increased demands on working memory in intermixed trials, as compared with blocked trials, may also favour those responses involving the stronger of the object-label associations (Golubickis & Macrae, 2021). If certain visual self-associations are stronger than auditory self-associations, those visual self-associations may be prioritized in working memory. Certain self-related categories appear to be prioritized more than others when placed into competition (Enock et al., 2020; J. C. Turner et al., 1987); for example, in intermixed trials (Enock et al., 2020). Automatic self-prioritization has also been demonstrated in endogenous attentional processes in working memory tasks (Yin et al., 2019). Self-prioritization with auditory stimuli may thus be diminished when auditory or audiovisual self-associations compete with (putatively stronger) visual self-associations in intermixed trials.

Alternatively, visual dominance arising in intermixed trials as a result of attentional effects could reduce self-bias with auditory stimuli. As noted, for example, participants may actively focus their attention toward visual stimuli in an override response produced by the alerting properties of auditory stimuli (Posner et al., 1976). Stolte et al. (2021) examined self-bias in the matching task using only visual and audiovisual stimulus objects, so it is not known whether the self-advantage would be similarly moderated with unisensory auditory stimuli (i.e. auditory-only object and label stimuli).

2.2.2.2 Auditory stimulus intensity

Self-bias in the matching task has been shown to be affected by low-level sensory features of visual stimuli (i.e., stimulus contrast): namely, self-bias increased when stimulus contrast was reduced (Sui et al., 2012—Experiment 4). Sui et al. (2012) suggested that this modulation reflected a perceptual-level influence of self-bias. As noted, in contrast to Stolte et al. (2021), Schäfer, Wesslein, et al., (2016) presented their auditory stimuli at 50 dB rather than 75 dB. Here it is worth bearing in mind that sound intensity has been shown to modulate both modality-specific (perceptual) processes and the motor output (Miller et al., 1999; St. Germain et al., 2020), and also multisensory processes (Barutchu et al., 2010; W. J. Ma et al., 2009; Spence & Driver, 1999). If self-bias were to interact with stimulus intensity *per se*, self-relevance in the matching task might be expected to bolster auditory perceptual processes as has been proposed for visual perceptual processes. Conversely, reduced auditory stimulus intensity may well be detrimental to stranger-associated, but not self-associated, responding. The self-advantage with the lower intensity auditory stimuli then may emerge with a magnitude comparable to that observed with visual stimuli. Thus, the extent of the self-advantage may be greater with auditory stimulation at lower (e.g. 50 dB) as compared with higher (e.g. 75 dB) intensities, and so account for the reduced SPE with audiovisual stimuli reported in Stolte at al.'s study.

2.2.2.3 Modalities of the stimulus objects and labels

Typically, previous studies examining self-bias with auditory and visual stimulus objects have used visual labels (B. Payne et al., 2020; Schäfer et al., 2015; Schäfer, Wesslein, et al., 2016; Stolte et al., 2021). To date, no studies have examined self-bias with unisensory auditory stimuli (simultaneously-presented auditory object and auditory label). That said, self-bias arising with unisensory auditory stimuli (e.g., the participant's own name) has been demonstrated in other paradigms, for example, in dichotic listening tasks (e.g., Moray, 1959). Notably, however, the auditory self-bias that was first shown in Moray's early research was exhibited by only ≈33% of the participants (A. R. A. Conway et al., 2001; Wood & Cowan, 1995). As evidenced in marked cross-cultural and historical variation, there is no universal hierarchy of the senses (Hutmacher, 2019). However, reinforcement of visual dominance through social and cultural practices and technologies (Hutmacher, 2019) may impact on self-bias in visual and auditory processing in experimental tasks.

Furthermore, differential mechanisms (with which self-bias could potentially interact) have been shown to underlie the processing of visual and auditory linguistic and object stimuli carrying seemingly equivalent information (Arana et al., 2020; Y.-C. Chen & Spence, 2018). The sensory modality of the label (auditory or visual) may therefore not be interchangeable, and self-bias may be moderated by the combination of stimulus object and label modality type. It could be that visual object-label self-associations are more easily formed, or accessed, than unisensory auditory or multisensory object-label self-associations. Alternatively, however, *unisensory* (rather than just visual) self-associations may be more easily formed or accessed than multisensory self-associations.

Attention has also been shown to modulate self-bias (Humphreys & Sui, 2016), and attentional effects arising in responses to auditory and audiovisual stimuli may also interact with the self-advantage. For example, while attentional-capture is likely to increase with higher-intensity sounds, when those sounds are presented simultaneously with visual stimuli (i.e., as a multisensory warning signal), such effects may be attenuated (Spence & Driver, 1999). In other words, self-bias may be moderated across unisensory auditory and audiovisual stimuli.

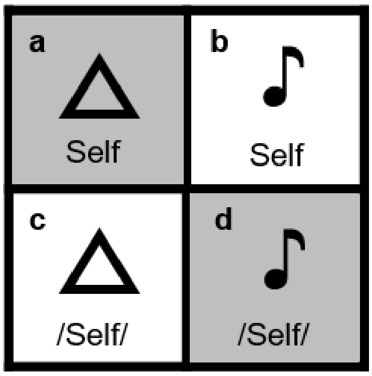

Figure 2.1. Unisensory stimuli and multisensory stimuli used in the matching task in Study C2. Example using the self-associated label. Simultaneously-presented: **a.** Unisensory visual stimulus type: Visual object + Visual Label = V+VL. **b.** Multisensory stimulus type: Auditory Object + Visual Label = A+VL. **c.** Multisensory stimulus type: Visual object + Auditory label = V+AL. **d.** Unisensory auditory stimulus type: Auditory object + Auditory label = A+AL. ♪ = categorical sound. ▲ = geometric shape (triangle presented as example). The Self label is depicted. /Self/ denotes the spoken self-associated label.

2.2.3. The present study

The present chapter explored whether stimulus-related and task-design parameters would moderate self-bias in an adaptation of the matching task using keypress motor responses to unisensory and multisensory stimuli. The present chapter also examined (for the first time) whether the self-advantage would transfer to a multisensory simple detection motor response paradigm whereby, in contrast to the matching task, the associations of the stimuli with the self were irrelevant to the task at hand (cf. Orellana-Corrales et al., 2021; Stein et al., 2016; Wade & Vickery, 2018; Woźniak & Knoblich, 2021).

In order to compare self-bias in the matching task across unisensory auditory stimuli, as well as unisensory visual and multisensory stimuli, auditory labels were introduced (see Figure 2.1). The use of auditory labels also ensured the equal probability of occurrence of the visual and auditory stimuli across all trials. (NB in versions of the matching task using visual and auditory object stimuli, with only visual label stimuli, a visual stimulus but not an auditory stimulus would be presented in every trial.)

In order to compare self-bias across auditory stimulus intensities, two independent groups of participants were recruited to take part in the present study. The participants in Group 1 completed an audiovisual adaptation of Sui et al.'s (2012) matching task, responding to unisensory auditory, unisensory visual, and multisensory object-label pairs, in both blocked and intermixed trials, and with the auditory stimuli presented at 50 dB (following Schäfer, Wesslein, et al. (2016) . For the participants in Group 2, the procedure was identical except that the auditory stimuli in the matching task were presented at 70 dB (consistent with Stolte et al., 2021). The participants in this latter group then subsequently also completed a simple detection task in which they made motor responses to the shape and sound stimuli and their multisensory combinations. Previous studies have examined whether the self-associations formed in the matching task can transfer to other task paradigms (Chiarella et al., 2020; Dalmaso et al., 2019; C.-P. Hu et al., 2020; Moradi et al., 2018; S. Payne et al., 2017; Stein et al., 2016; Woźniak & Knoblich, 2019; Yin et al., 2019). However, the present chapter (Desebrock, Spence, et al., 2022) was the first to examine whether the self-advantage can transfer across tasks to a simple multisensory detection motor response paradigm.

It was expected that the self-advantage in the matching task would be moderated by the block type (blocked or intermixed trials), and reduced with audiovisual as compared with visual stimuli (e.g., Stolte et al., 2021), although the latter may depend on task context (block type and auditory stimulus intensity; cf. Schäfer, Wesslein, et al., 2016). It was further hypothesized that while a modulation of self-bias across stimulus modality types might be expected (i.e., if self-bias interacts with modality-specific processes or differential stimulus effectiveness), a consistently reduced self-advantage with auditory stimuli would lend support to Stolte et al.'s findings. An equivalent self-advantage across stimulus modality types, on the other hand, would lend support to the contention that self-bias is underpinned by a modulation of modality-general processes (in line with Schäfer, Wesslein, et al., 2016). In addition, if a self-advantage arose in the detection task, this would further suggest that the unisensory and multisensory self-associations established in the matching task can be automatically activated in fast motor responses to the unisensory and multisensory stimuli.

2.3. Methods

2.3.1. Participants

2.3.2. Matching tasks

The self-advantage was examined using a 3-way 2x4x2 mixed design: 2 between groups (Group 1 in which the auditory stimuli were presented at 50 dB, and Group 2 in which the auditory stimuli were presented at 70 dB), and, within each group, the effects of the four sensory modality stimulus types (unisensory visual, unisensory auditory, multisensory with visual labels, multisensory with auditory labels), x 2 block types (trials blocked by sensory modality type, intermixed trials of the unisensory and multisensory stimuli) were examined. Multisensory gains in the matching task were examined using a 2 (Auditory stimulus intensity between-groups Groups 1 and 2: 50 dB, 70 dB) x 2 (within-groups Block type: blocked, intermixed) x 2 (within-groups AV Stimulus type: A+VL, V+AL) x 2 (within-groups Association: self, stranger) mixed factorial structure.

In the standard matching task using visual stimuli, the effect size for the self-advantage was $\eta^2 > .25$ (Sui et al., 2012), and in an adaptation of the task using auditory objects and visual labels in a blocked-trial design (Schäfer, Wesslein, et al., 2016), the effect size reported was $\eta^2 = 0.12$ (paired-samples t-tests). (NB all effect sizes were converted to a common metric, η^2, following Correll et al. (2020).) Stolte et al. (2021) reported an effect size of $\eta^2 = .15$ for the interaction between association and stimulus type using an intermixed-trial design (Stolte et al., 2021—Table 1). For an effect size of $\eta^2 = .12$, a probability of $1-\beta=0.80$, and an α-value of 0.05, a minimum sample size of 28 participants was required for a 2 x 4 x 2 between-within-within ANOVA and 60 for a 2 x 2 x 2 x 2 between-within-within-within ANOVA (MorePower 6.0.4 program; Campbell & Thompson, 2012).

Sixty right-handed participants (14 male, ages 18-23 years, mean age 18.92 ± 1.00) with self-reported normal or corrected-to-normal visual acuity and hearing took part in the study. In Group 1, there were thirty-one right-handed participants (7 male, ages 18-23 years, mean age 19.03 ± 1.02); in Group 2, there were twenty-nine right-handed participants (7 male, ages 18-22 years, mean age 18.79 ± 0.98).

The participants were recruited via the Oxford University Research Participation Scheme and received course credit for their time and effort. A written consent form approved by the University of Oxford Central University Research Ethics Committee (MS-IDREC-R61057/RE002) was completed by all participants.

2.3.3. Detection task

No previous studies have looked at self-bias in a multisensory simple detection task, and so the effect size was unknown. As noted, the effect size of the SPE in studies using visual or auditory stimuli or both ranged between $\eta^2 = .12$ to $\eta^2 > .25$ (Schäfer, Wesslein, et al., 2016; Stolte et al., 2021; Sui et al., 2012). For a moderate effect size of $\eta^2 = .20$, a probability of $1-\beta=0.80$, and an α-value of 0.05, a minimum sample size of 16 participants was required (MorePower 6.0.4 program; Campbell & Thompson, 2012). In Group 2, twenty-nine right-handed participants (7 male, aged 18-22 years, mean age 18.79 ± 0.98) with normal or corrected-to-normal visual acuity and hearing completed the matching task. Twenty-six participants (7 male, ages 18-22 years, mean age 18.73 ± 1.00) of the twenty-nine who completed the matching task completed the detection task (three participants who completed the matching task did not complete the detection task).

2.3.4. Stimuli and apparatus

2.3.4.1. Matching tasks

All computer tasks were conducted on a PC with a 23-in. LCD monitor (1920 x 1080 pixels at 60 Hz refresh rate) using E-Prime software (version 2.0). A QWERTY-keyboard recorded keypress responses. Following previous studies (Sui et al., 2012), participants made matching and mismatching responses using the index and middle finger of their right hand on two adjacent keyboard keys. Visual object stimuli consisted of two geometric shapes (V) from the following set (pentagon, hexagon, or octagon, each subtending 3.2 × 3.2 deg. of visual angle), and two written-text self- and stranger-related labels (VL) (*your*, *their*, referring to the self-related shape, the stranger-related shape), subtending a visual angle of 2.1 × 0.7 deg.

The words ‘Your’ and ‘Their’ were chosen as labels due to their similar word length and equivalent number of syllables (with short durations), and low ratings for ‘word concreteness’ (Brysbaert et al., 2014). Word concreteness gives rise to SPE-like prioritization effects, although effects of self-relevance go beyond those of word concreteness (Wade & Vickery, 2017). Previous studies have used a range of different labels to denote the self and a stranger in Sui et al.’s (2012) matching task (e.g., you, self, I, stranger, other; Frings & Wentura, 2014; Golubickis et al., 2017; Hu et al., 2020; Sui et al., 2012). The well-established database of concreteness ratings for 40,000 English lemmas (Brysbaert et al., 2014) provides the following ratings for: ‘You’ (*M* = 4.11, *SD* = 1.22), ‘Self’ (*M* = 3.13, *SD* = 1.71), ‘I’ (*M* = 3.93, *SD* = 1.44), ‘Stranger’ (*M* = 3.76, *SD* = 1.39), ‘Other’ (*M* = 2.04, *SD* = 1.22). Notably, ‘Your’ (*M* = 2.37, *SD* = 1.45) attracted a low rating for concreteness which, furthermore, was lower than the concreteness rating for ‘Their’ (*M* = 3.34, *SD* = 1.49).

The two shapes allocated to each participant and the labels that they were paired with were counterbalanced across participants. The same shape and label pairs were maintained for the blocked and intermixed presentations. The shapes and labels were presented against a black background in the centre of the PC-screen. The shape was positioned above (and the label below) a fixation cross (0.6 × 0.6 deg. of visual angle).

Auditory object stimuli (A) consisted of two neutral instrumental sound samples (150 ms duration) from the following set (violin, synth vocal, and clarinet). The neutral instrumental sound samples were selected from two validated, publically-available sound sets: the Musical Emotional Bursts (MEB; Paquette et al., 2013) and the Montreal Affective Voices (MAV; Belin et al., 2008). The MEB is a set of musical affect bursts expressing basic emotional states (specifically, happiness, sadness, and fear) and ‘neutral’ expressions. Two neutral sounds from the MEB and one neutral sound sample from the MAV on the same musical note were selected for use in the present study: “V3_NEUTRAL_MEB” (violin), “45_NEUTRAL_MAV” (vocal), and “C1_NEUTRAL_MEB” (clarinet). All sound samples were trimmed to a duration of 150 ms. The auditory labels (AL) were two recorded samples (bursts) of fast natural speech utterances of the words “your” and “their” spoken by a female actor. Schäfer, Wesslein, et al. (2016) used auditory stimuli of low intensity (50 dB) just above ambient sound levels in their sound and visual label version of the matching task. The auditory stimuli were presented via two freestanding loudspeakers, one placed on either side of the PC-screen at a distance of 50 cm from the participant. The sound pressure level (SPL) of the ambient background noise was set at 45 dB. The auditory stimuli were presented at 50 dB SPL (following Schäfer, Wesslein, et al., 2016) to one group of participants (Group 1; N=31) and at 70 dB (consistent with Stolte et al., 2021) for a second group (Group 2; N=29). Signal-to-noise (SNR) ratios were thus 5 dB and 25 dB for the two groups, respectively. Auditory and visual object-label stimuli were combined to produce four stimulus types: visual only (object and label both visual = V+VL), auditory only (sound and label both auditory = A+AL), auditory with visual label (A+VL), and visual object with auditory label (V+AL). All of the stimuli were presented simultaneously for 150 ms.

2.3.4.2. Detection task

A Cedrus RB-530 response-box recorded button-presses in the simple detection task. (A response box was used for this task due to the robust nature, size, and spacing of the response-box buttons which could accommodate the fast motor responses required by the detection task—the response box was only used for the simple detection task). The stimuli consisted of the two self-and stranger-associated geometric shapes and instrumental sounds that the participant had been assigned in the preceding matching tasks. (NB: The visual and auditory labels used in the matching task were not used as stimuli in the detection task.)

2.3.5. Procedure

2.3.5.1. Matching tasks

Participants carried out an extended multisensory version of Sui et al.'s (2012) computer-based matching task, in a single experimental testing session. The duration of the testing session ranged from 90–120 minutes. The matching task consisted of four blocks of blocked trials (one stimulus type per block; 80 trials per block) the order of which was counterbalanced across participants following a balanced Latin square design, followed by five blocks of randomly intermixed trials (all four stimulus types presented randomly with equal probability within each block; 96 trials per block). Familiarity with both the matching task and the 16 stimulus-response mappings (2 x Association x 2 Match-type x 4 stimulus types) from completing the blocked trials enabled participants to complete the intermixed trials which were otherwise too difficult. (See Appendix A6 for further details regarding task order.)

Following Sui et al.'s (2012) procedure, for the visual stimulus blocks (V+VL), participants were instructed (via onscreen text) to associate one of their allocated geometric shapes or sounds with themselves (specifically, as 'your' shape; e.g., 'the pentagon is your shape') and the second allocated shape or sound with 'a stranger' (as 'theirs'; e.g., 'the octagon is their shape'). Order of instructions pertaining to 'self' and 'stranger' associations were counterbalanced across participants. Following this, the participants carried out the matching task in which participants used their right hand to depress one of two response keys (b or v) on the keyboard to indicate either a 'matching' or 'mismatching' judgment (the keys and match/mismatch mappings were counterbalanced across participants). The participants were instructed to make their responses to the stimuli as rapidly and accurately as possible. The main task was preceded by 24 practice trials, with a performance accuracy threshold set at 60% correct (that is, participants had to achieve at least 60% correct before they could proceed to the main task). Onscreen feedback was presented (*Correct*, *Incorrect*, *Too Slow*) during the practice trials, with the ‘*Correct*’ feedback omitted during the main task (following Schäfer, Wesslein et al., 2016).

The procedure was the same for all blocks except that in the A+VL block, participants matched instrumental sounds with visual labels (e.g., clarinet-‘your’, violin-‘their’), in the V+AL block they matched shapes with auditory labels, in the A+AL block they matched the instrumental sounds with the auditory labels. In intermixed blocks, the participants matched the visual and auditory labels with the shapes and sounds that they had been allocated in the previous blocks, with all stimulus modality types intermixed within each block of trials. Prior to carrying out the intermixed-trial blocks, the participants completed 32 practice trials. There was an 8-second break between each block of trials. There were 800 trials in total (320 blocked trials, and 480 intermixed trials), across 32 conditions—2 block types (blocked/intermixed) x 4 stimulus types (V+VL, A+AL, A+VL, V+AL) x 2 associations (self/stranger) x 2 matching types (match/mismatch), 20 trials per condition in blocked trials, and 30 trials per condition in intermixed trials. Each condition occurred equally often in a random order. The participants were informed of their overall accuracy at the end of each block of trials. A schematic representation of an experimental trial in the matching task is shown in Figure 2.2.

2.3.5.2. Detection task

After completing the matching task, the participants in Group 2 completed a simple detection task in which they were asked to respond as rapidly and accurately as possible to the auditory (instrumental sounds), visual (shapes), and audio-visual (shape-sound) stimuli used in the matching task. In a modified version of the typical detection task, a short response time limit of 300 ms was used to ensure that participants did not delay their responses (to avoid the intentional evaluation of the stimuli), and to keep participants alert to the task, responding as rapidly as they could (< 3% of RTs were excluded based on this response limitation). Only the shape and sound stimuli were used (the labels were not used). As such, the stimuli pairs in the detection task differed from those in the matching tasks (which used labels with individual shape/sound stimuli).

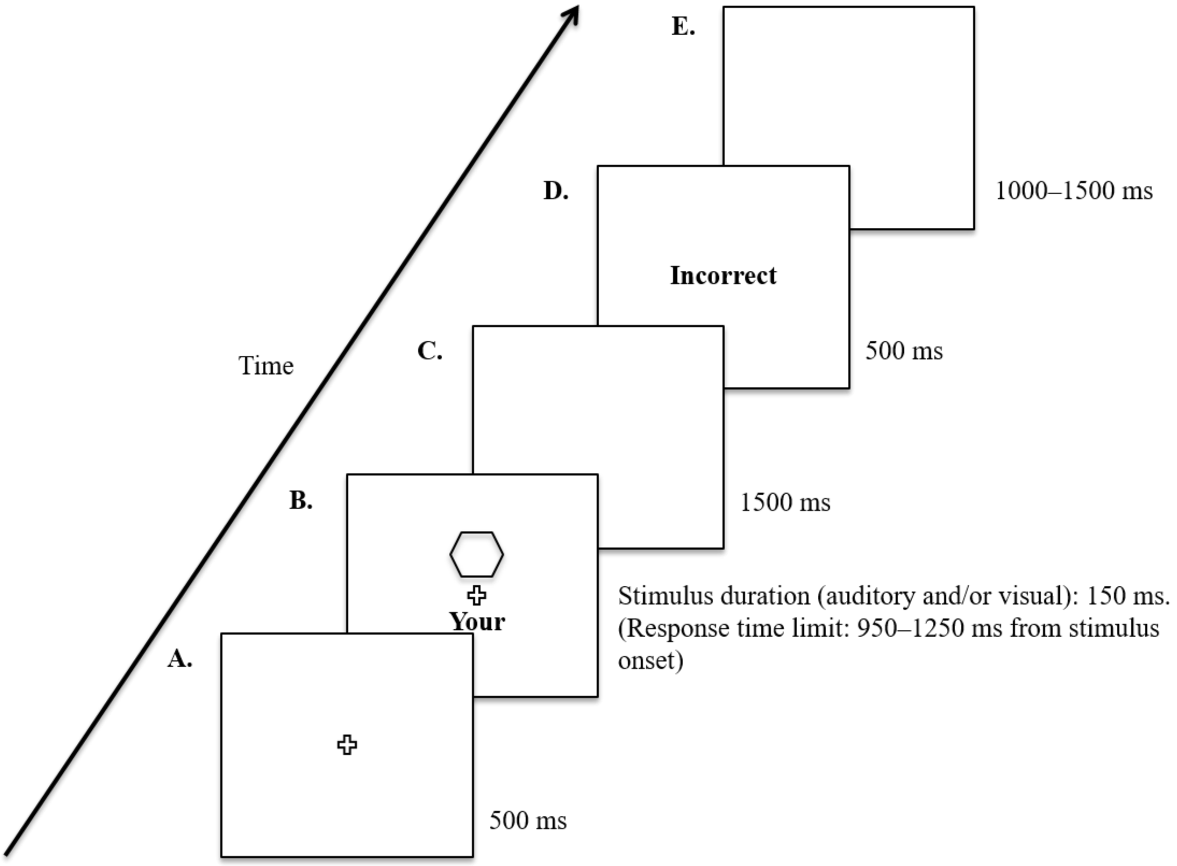

Figure 2.2 Schematic overview of an experimental trial sequence for the matching task in Study C2. (Displayed elements not to scale). **A**. Fixation cross. **B**. Visual, auditory, or audiovisual stimulus onset. Shape-label (*Visual Task*) stimulus shown. **C**. Blank screen. **D**. Written feedback displayed on screen – “Incorrect” / “Too slow” (for a ‘correct’ response a blank slide was displayed, following Schäfer, Wesslein, et al., 2016). **E**. Inter-trial intervals generated at random.

The unisensory auditory (self- or stranger-associated), unisensory visual (self- or stranger-associated), and audio-visual stimuli (self-match, stranger-match, stranger-mismatch, and self-mismatch) were presented in a random order across four blocks of 80 trials. Self-match trials consisted of the self-associated shape and self-associated sound stimuli, and stranger-match trials consisted of the stranger-associated shape and stranger-associated sound stimuli. The stranger mismatch trials consisted of the stranger-associated shape and self-associated auditory stimuli, while the self-mismatch trials consisted of the self-associated shape and stranger-associated sound stimuli. There was a total of eight conditions: a self-associated unisensory auditory stimulus type, a stranger-associated unisensory auditory stimulus type, a self-associated unisensory visual stimulus type, a stranger-associated unisensory visual stimulus type, two self-associated audiovisual stimulus types, and two stranger-associated audiovisual stimulus types. There were 40 trials per condition. Sixteen practice trials preceded the main blocks with a performance threshold set at 80% accuracy—participants could proceed to the main blocks once their performance (responding within 300 ms of stimulus onset) reached or exceeded 80% accuracy. To discourage anticipatory responses, "Too early" feedback was presented if the participant responded during the presentation of the fixation cross and "too slow" was displayed if they responded outside of the time limit, or not at all (such responses were also recorded as incorrect and excluded from the analysis). If participants responded correctly within the time-limit, no feedback was presented. (After the computer tasks, a sub-group of participants completed questionnaires measuring individual differences on self- and other-related dimensions (for example, 'personal distance'; Sui & Humphreys, 2015b). The data from these instruments will be analysed and hopefully presented as part of a separate future study).

2.3.6. Data analysis

The data were analysed using IBM SPSS version 27.0 (Armonk, NY: IBM Corp). The data in all following experimental chapters were also analysed using IBM SPSS 25–27.

2.3.6.1. Matching tasks

There were two main output measures: reaction times (RT; measured from stimulus onset to the depression of the keyboard key), and percentage of correct responses (accuracy). Following previous research (Sui et al., 2012), a signal detection approach was used to calculate an index of sensitivity (D-prime; *d′*; Green & Swets, 1966). Hits were coded as *yes* responses to match trials, and false alarms were coded as *yes* responses to mismatch trials with the same shape. Mismatch conditions were defined as either shape- or sound-based (i.e., a self-mismatch trial consisted of the self-associated shape or sound and the stranger-associated label, a stranger-mismatch trial consisted of the stranger-associated shape or sound and the self-associated label). RTs were based on correct responses. RTs above or below 2.5 SDs from individual means were trimmed (Ratcliff, 1993), with less than ~1% of RTs excluded. See Table 2 for absolute measures of RT, percentage accuracy, and *d′* data.

Self-bias index scores were calculated using RTs and *d′*. Normalized self-bias scores in RT were calculated using the matching-condition RTs (e.g., Constable et al., 2021; Desebrock & Spence, 2021; Sui & Humphreys, 2017c). Match-trial stimuli (e.g. a self-associated object and self-associated label) involve one association, thus in behavioural paradigms where effects in mismatch trials cannot be disentangled, matching-trial responses index self- and stranger-related processing (Sui et al., 2012). Mismatch trials are typically treated as fillers in the literature on the SPE (see Desebrock & Spence, 2021; Schäfer, Wesslein, et al., 2020). Therefore, in accordance with the aims of the present study, and following the rationale of previous research, the focus of the analysis reported here was on match-trial RT data. Self-bias scores were given by the formula: "(stranger − self)/(stranger + self)" for response times. For *d′*, self-bias was indexed by the differential scores (self – stranger) between self-associated and stranger-associated conditions (following Sui & Humphreys, 2017c). Positive values indicate an advantage for self. (NB: Since auditory stimulus intensity influences RTs and *d′*, main effects of dB level on RT and *d′* across Groups 1 and 2 were assessed. There was no main effect of auditory stimulus intensity on RTs or *d′* (see Appendix A2), therefore *d′* self-bias index scores were not normalised.)

Normalised differential scores—self-bias index scores (e.g. Constable et al., 2021; Desebrock & Spence, 2021; Schäfer, Wesslein, et al., 2016; Sui & Humphreys, 2017c)—were analysed to examine whether the magnitude of the self-advantage in the matching task responses was modulated by stimulus type, block type, and auditory stimulus intensity. These scores provide an index of the relative magnitude of the difference in performance between self- and stranger-related responses. The present study follows previous studies that have examined contextual factors (both stimulus- and task-design related) that moderate the well-established self-advantage in the matching task using different task parameters (Golubickis et al., 2017; Golubickis & Macrae, 2021; C.-P. Hu et al., 2020; Stolte et al., 2021; Verma et al., 2021; Woźniak & Knoblich, 2019). The hypotheses of the present study thus spoke to the modulation rather than the emergence of the SPE in the matching paradigm, so the focus was on analysing differences in the magnitude of the SPE rather than absolute RTs (e.g., see Constable et al., 2021). See Appendix A1 for the analyses of absolute RTs and *d′* measures. A significant advantage for self-associated responses was documented in both the Group 1 (η_p^2 = .62) and Group 2 samples (η_p^2 = .23).

To further assess the self-advantage in responses to unisensory as compared with multisensory stimuli in the matching task, multisensory gains/costs in RTs and sensitivity (*d′*) in the self- and stranger-associated matching conditions were compared. Multisensory facilitation in both the blocked and intermixed trials in the matching tasks was assessed in RTs and *d′* by subtracting the RTs / *d′* scores of responses in the multisensory conditions from the fastest/highest of the counterpart unisensory conditions (e.g. Barutchu et al., 2018; Barutchu & Spence, 2020). For example, multisensory facilitation in RT for the self-associated responses to the A+VL stimulus type was calculated by deducting A+VL self-associated matching-trial RTs from the fastest of the V+VL and A+AL self-associated matching-trial RTs. Multisensory facilitation in RT for self-associated responses to the V+AL stimulus type was calculated by deducting V+AL self-associated matching-trial RTs from the highest of the V+VL and A+AL self-associated matching-trial RTs. Multisensory facilitation in *d′* scores for self-associated responses to the A+VL stimulus type was calculated by deducting A+VL self-associated condition *d′* scores from the highest of the V+VL and A+AL self-associated condition *d′* scores (and then multiplying by −1 so that positive values indicated gains). Multisensory facilitation in *d′* scores for self-associated responses to the V+AL stimulus type was calculated by deducting V+AL self-associated condition *d′* scores from the highest of the V+VL and A+AL self-associated condition *d′* scores (and then multiplying by −1 so that positive values indicated gains). Thus, the multisensory gain value was the difference between the multisensory and unisensory responses. A positive value indicated faster RTs/higher *d′* and a negative value indicated slower RTs/lower *d′* (multisensory costs) for multisensory self- or stranger-associated responses as compared with the fastest/highest unisensory self- or stranger-associated responses. (NB mean SPE gains were also calculated but not analysed. They are depicted in Figure 2.5c. SPE gains were calculated by deducting the self-associated multisensory condition—Matching- or Mismatching-trial—RTs from the stranger-associated multisensory condition RTs. Positive values indicate a self-advantage.) In order to compare multisensory gains/costs in RTs across Group 1 and Group 2, the multisensory gain/cost measures were converted into percentage gains/costs to control for differences in processing speed, and were given by the formula: [(faster of unisensory – multisensory)/faster of unisensory)] x 100.

2.3.6.2. Detection task

RTs < 100 ms and > 2.5 SDs above individual means were trimmed, excluding < 0.5% of total RTs. Percentage detection rates (accuracy), RTs, and central tendencies of the RT distributions were examined. There were two within-participant factors: Association on two levels (self, stranger) and Condition with four levels (Auditory, Visual, AV Mismatch, AV

Match). Cumulative Distribution Frequency plots (CDFs; Ratcliff, 1979) were also constructed using CDF-XL (Houghton & Grange, 2011) to further assess distributional information and examine differences throughout the whole RT distributions. Percentiles (deciles) for the rank-ordered RTs by condition, for each participant, were calculated. For each condition, cumulative probabilities were calculated from 0.1 up to 1.0 in increments of 0.10. The CDF plots were then drawn using MATLAB. To preserve power, every second probability was included in the analyses. There were three within-participant factors: Association on two levels (self, stranger), Condition on four levels (A, V, AV Mismatch, and AV Match), and Probability on five levels (0.1, 0.3, 0.5, 0.7, 0.9).

Central tendencies were similarly calculated for MS gains (calculated by subtracting the RTs of responses in the multisensory conditions from the fastest of the counterpart unisensory conditions). There were two within-participant factors: Association on two levels (self, stranger) and AV Condition on two levels (Match, Mismatch).

Effect sizes were calculated using Cohen’s *dz* for t-tests and partial eta-squared (η_p^2) for ANOVAs (Cohen, 1988; Lakens, 2013). To adjust for multiple comparisons, Holm-Bonferroni corrections at an α value of .05 were applied (Holm, 1979) with unadjusted significance values reported. For violations of sphericity, Greenhouse-Geisser corrections were applied where appropriate.

2.4. Results

In the 50 dB group (Group 1), the data from two participants were excluded for having chance accuracy (*M* < 50%) and < 30% correct in more than one condition. The data were assessed for outliers in the match-trial and mismatch-trial RT data, and the *d′* data (studentized residuals outside ∓ 3.0 in absolute value in one or more conditions), and one participant’s data was identified as an outlier and thus removed from the analysis (mean RTs and *d′* data are presented in Table 2). In the 70 dB group (Group 2), five participants were excluded for having chance levels of accuracy, and the data from two participants were excluded as they constituted outliers. The data from a total of 50 participants (twenty-eight in Group 1 and twenty-two in Group 2) were therefore used in the analysis. Self-bias index scores for RT and *d′*, and multisensory RT, *d′*, gains and costs, are presented in Figure 2.3.

2.4.1. Self-prioritization in the matching task

2.4.1.1. Self-bias in RT

The self-bias in *RT* data is presented in Figure 2.3a. There were two outliers (studentized residuals outside ∓ 3.0 in absolute value). Both outliers were removed (N=48), and since the majority of the data were normally-distributed (two conditions not normally distributed), the data were not transformed. The assumption of homogeneity of variances was violated for one condition, as assessed by Levene's test for equality of variances. Given that the sample sizes of the two groups were roughly equal (ratio 1.29) and ANOVA is generally robust to violations of this assumption if group sizes are roughly equal, ANOVA was carried out on the data. A 2 (Auditory stimulus intensity: 50 dB, 70 dB) x 2 (Block type: Blocked, Intermixed) x 4 (Stimulus type: V+VL, A+AL, A+VL, V+AL) mixed ANOVA was conducted on the RT self-bias index scores. The analysis revealed main effects of Stimulus type, $F(2.21, 101.47) = 4.76$, $p = .009$, $\eta_p^2 = .09$, and Block type, $F(1, 46) = 24.74$, $p < .001$, $\eta_p^2 = .35$. Overall, the magnitude of self-bias in the Blocked trials ($M = .05$, $SE = .006$) was greater than in the Intermixed trials ($M = .03$, $SE = .005$). For Stimulus type, the magnitude of the normalised self-bias in the RT data was significantly greater ($p = .002$) in responses to V+AL ($M = .05$, $SE = .007$) as compared with A+AL ($M = .02$, $SE = .006$) (See Figure 2.4). There were no significant differences between any other pair of Stimulus types (*ps* > .01). There were no other significant effects. (The analysis was also conducted with the outliers included—see Table A3.1, Appendix A3. The findings were replicated.)

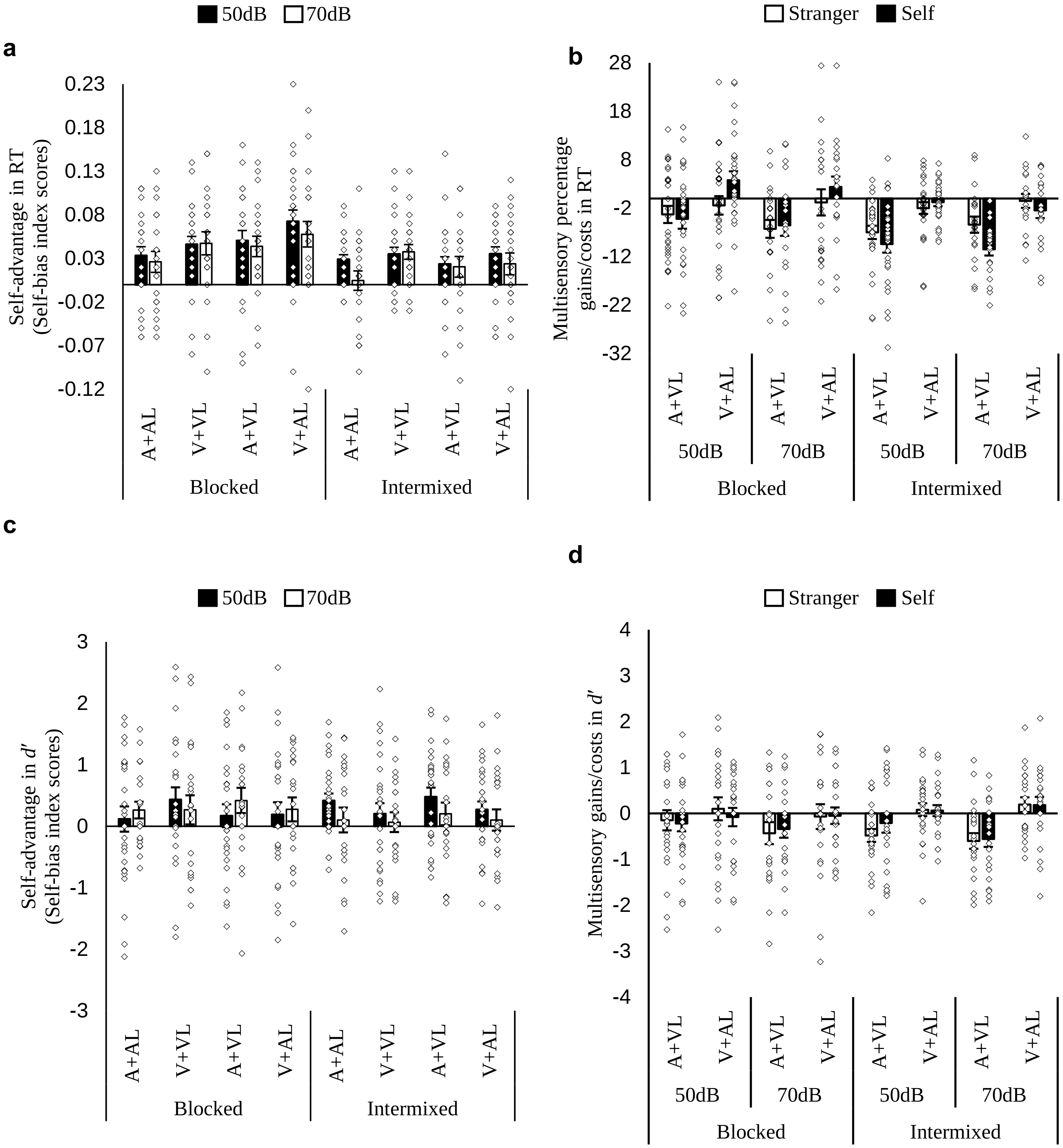

Figure 2.3. Bar graphs with individual data points (outliers excluded). Error bars represent SE. **a.** Self-bias in RT index scores in the shape-label Matching trials as a function of Block type (blocked vs intermixed), Stimulus type, and Auditory stimulus intensity. **b.** Multisensory percentage gains/costs in RT as a function of Block type, AV stimulus type, Association, and Auditory stimulus intensity. **c.** Self-bias in sensitivity index scores (*d′*; D-prime) as a function of Block type, Stimulus type, and Auditory stimulus intensity. **d.** Multisensory gains/costs in *d′* as a function of Block type, AV stimulus type, Association, and Auditory stimulus intensity, in Study C2. V = visual shape stimulus, A = auditory stimulus, VL = visual (text) label, AL = auditory (spoken) label.

Table 2
Mean RT, accuracy (percent correct), and sensitivity (D-Prime; *d′*) index scores with standard deviations in parentheses, as a function of Stimulus Type (Visual-shape+Visual-Label, A+AL, A+VL, V+AL), Association (self, stranger), Block Type (blocked, intermixed), and Match Condition (match, mismatch) in the matching tasks in Study C2.

Stim. type	Assoc.	RT				Percent correct				*d′*	
		Blocked		Intermixed		Blocked		Intermixed		Blocked	Intermixed
		Match	Mismatch	Match	Mismatch	Match	Mismatch	Match	Mismatch		
Group 1 (50 dB) (N=28)											
V+VL	Self	674 (57)	752 (68)	720 (63)	808 (62)	92 (9)	81 (14)	86 (10)	82 (13)	2.65 (0.93)	2.27 (0.87)
	Stranger	735 (76)	763 (62)	771 (71)	791 (57)	80 (16)	84 (11)	81 (14)	83 (11)	2.20 (1.05)	2.06 (0.95)
A+AL	Self	714 (88)	791 (69)	805 (60)	862 (48)	86 (12)	77 (18)	79 (17)	71 (17)	2.12 (1.11)	1.55 (1.02)
	Stranger	757 (64)	764 (56)	853 (61)	844 (53)	79 (17)	83 (15)	63 (17)	74 (18)	2.02 (1.05)	1.12 (1.06)
A+VL	Self	673 (88)	744 (59)	776 (63)	835 (60)	91 (11)	87 (12)	85 (16)	77 (19)	2.87 (1.08)	2.08 (1.19)
	Stranger	732 (71)	721 (56)	812 (71)	814 (57)	86 (11)	89 (9)	75 (16)	78 (17)	2.69 (0.89)	1.71 (1.06)
V+AL	Self	627 (83)	717 (55)	719 (57)	790 (56)	92 (9)	90 (10)	87 (10)	86 (11)	3.00 (0.83)	2.49 (0.83)
	Stranger	720 (78)	715 (58)	780 (70)	772 (53)	86 (10)	93 (6)	81 (14)	87 (11)	2.91 (0.97)	2.20 (0.89)
Group 2 (70 dB) (N=22)											
V+VL	Self	664 (75)	769 (71)	700 (46)	784 (56)	90 (15)	80 (11)	87(10)	80 (19)	2.48 (0.94)	2.22 (1.00)
	Stranger	716 (82)	758 (64)	745 (68)	775 (54)	80 (17)	85 (14)	83 (15)	82 (15)	2.38 (1.35)	2.23 (1.21)
A+AL	Self	714 (79)	794 (55)	809 (84)	858 (73)	87 (10)	81 (17)	73 (17)	65 (20)	2.38 (1.24)	1.18 (1.03)
	Stranger	746 (105)	769 (71)	811 (96)	841 (67)	78 (20)	82 (16)	65 (23)	70 (22)	2.06 (1.34)	1.15 (1.34)
A+VL	Self	683 (71)	781 (78)	777 (68)	836 (71)	93 (7)	84 (14)	86 (10)	72 (17)	2.76 (1.09)	1.84 (0.84)
	Stranger	735 (96)	746 (65)	801 (94)	819 (64)	82 (13)	89 (9)	73 (19)	80 (15)	2.41 (0.84)	1.72 (1.09)
V+AL	Self	628 (79)	726 (97)	713 (64)	771 (73)	95 (5)	86 (15)	89 (9)	84 (19)	3.05 (0.99)	2.58 (1.05)
	Stranger	696 (111)	711 (101)	744 (73)	763 (75)	87 (12)	90 (9)	82 (16)	88 (16)	2.77 (1.09)	2.51 (1.28)

Note. RT = Reaction time. Stim. type = Stimulus type. Assoc. = Association.

2.4.1.2. Self-bias in sensitivity index scores (D-prime; *d′*)

The self-bias in *d′* data is presented in Figure 2.3c. There were two studentized residuals outliers. Both outliers were removed. The assumption of homogeneity of variances was violated for two conditions. As with the analysis of self-bias in the RT data, given that the group sizes were roughly equal, an ANOVA was carried out on the data (N=48). A 2 (Auditory stimulus intensity: 50 dB, 70 dB) x 2 (Block type: Blocked, Intermixed) x 4 (Stimulus type: V+VL, A+AL, A+VL, V+AL) mixed ANOVA was conducted on self-bias index scores for *d′*. There were no significant effects. The self-advantage in sensitivity did not differ significantly across conditions. (The analysis was also conducted with the outliers included—see Table A3.1, Appendix A3. The findings were replicated.)

2.4.1.3. Multisensory percentage gains/costs in RT

The data are presented in Figure 2.3b. There were two studentized residuals outliers whose removal produced a third outlier. With the three outliers removed, the data were submitted to a 2 (Auditory stimulus intensity: 50 dB, 70 dB) x 2 (Block type: blocked, intermixed) x 2 (AV Stimulus type: A+VL, V+AL) x 2 (Association: self, stranger) mixed ANOVA. There was a significant main effect of Block type, $F(1, 45) = 8.85$, $p = .005$, $\eta_p^2 = .16$, and AV Stimulus type, $F(1, 45) = 50.14$, $p < .001$, $\eta_p^2 = .53$. Negative gain values indicated that there were costs for responses to multisensory relative to unisensory stimuli. Multisensory costs were greater in participants' responses to intermixed trials (*M* = -4.75 ms, *SE* = 0.66) as compared with blocked trials (*M* = -1.96 ms, *SE* = 1.05), and greater in responses to the A+VL stimulus type (*M* = -6.34 ms, *SE* = 0.88) as compared with responses to the V+AL stimulus type (*M* = -1.37 ms, *SE* = 0.83). There was a significant interaction between Block

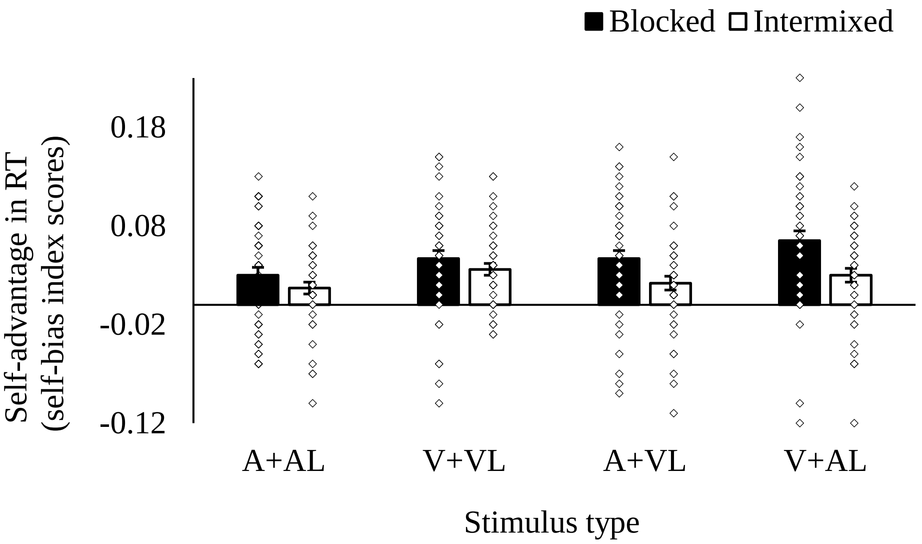

Figure 2.4. Bar graphs with individual data points (outliers excluded). Estimated marginal means of self-bias in RT index scores in shape-label Matching trials as a function of Block type and Stimulus type (with the Auditory stimulus intensity condition collapsed) in Study C2. Error bars represent SE. V = visual shape stimulus, A = sound stimulus, VL = visual (text) label, AL = auditory (spoken) label.

type and Association, *F*(1, 45) = 8.04, *p* = .007, η_p^2 = .15, and between AV Stimulus type and Association, *F*(1, 45) = 5.07, *p* = .03, η_p^2 = .10. None of the other effects was significant.The interaction between the AV stimulus type and Association was probed revealing a significant difference between stranger-associated responses to the A+VL (*M* = -5.38 ms, *SE* = 1.02) and V+AL (*M* = -1.44 ms, *SE* = 0.99) stimulus types, *p* = .003, and a significant difference between self-associated responses to the A+VL (*M* = -7.30 ms, *SE* = 1.13) and V+AL stimulus types (*M* = 0.70 ms, *SE* = 0.97), *p* < .001. There was no significant difference between self- and stranger-associated responses to the A+VL stimulus type, *p* = .13, or to the V+AL stimulus type, *p* = .05. However, it is worth noting that for A+VL stimuli, costs were descriptively greater for the self-associated than for the stranger-associated responses, while for the V+AL stimuli, costs were observed for the stranger-associated responses, and gains were uniquely observed for self-associated responses.

Probing the Block type and Association interaction revealed greater multisensory costs for self-associated responses (*M* = -5.78 ms, *SE* = 0.80) than for stranger-associated responses (*M* = -3.71 ms, *SE* = 0.78) in intermixed trials, *p* = .02. There was no significant difference between self-associated responses (*M* = -0.82 ms, *SE* = 1.24) as compared with stranger-associated responses (*M* = -3.11 ms, *SE* = 1.18) in blocked trials, *p* = .07. However, costs were descriptively greater in stranger-associated as compared with self-associated responses. In addition, stranger-associated responses in blocked trials (*M* = -3.11 ms, *SE* = 1.18) as compared with intermixed trials (*M* = -3.71 ms, *SE* = 0.78) were not significantly different, *p* = .63. In contrast, multisensory costs in self-associated responses in blocked trials (*M* = -0.82 ms, *SE* = 1.24) as compared with intermixed trials (*M* = -5.78 ms, *SE* = 0.80) were significantly different, *p* < .001. Multisensory costs in self- as compared with stranger-associated responses were differentially modulated by block type. (The analysis was also conducted with the outliers included—see Table A3.2, Appendix A3. The findings were replicated except that there was no significant difference between self- and stranger-associated responses in intermixed trials, $p = .06$.)

2.4.1.4. Multisensory gains/costs in sensitivity index scores (D-prime; *d′*)

The data for multisensory gains/costs in *d′* are presented in Figure 2.3d. There were four studentized residuals outliers. With the outliers excluded, the data were submitted to a 2 (Auditory stimulus intensity: 50 dB, 70 dB) x 2 (Block type: blocked, intermixed) x 2 (AV stimulus type: A+VL, V+AL) x 2 (Association: self, stranger) mixed ANOVA. The analysis revealed a significant main effect of AV Stimulus type, $F(1, 44) = 18.30$, $p < .001$, $\eta_p^2 = .29$. Negative gain values indicated that there were costs for responses to multisensory relative to unisensory stimuli. There was some multisensory facilitation in responses to the V+AL stimuli ($M = 0.06$, $SE = 0.08$), and costs in responses to A+VL stimuli ($M = -0.36$, $SE = 0.08$). There was a significant interaction between Block type and AV stimulus type, $F(1, 44) = 6.21$, $p = .02$, $\eta_p^2 = .12$. There were no other significant effects. The interaction between Block type and AV stimulus type was probed revealing that costs in responses to the A+VL stimulus type ($M = -0.28$, $SE = 0.13$) as compared with the V+AL stimulus type ($M = -0.02$, $SE = 0.13$) in blocked trials were not significantly different ($p = .05$). There were multisensory gains in responses to the V+AL stimulus type ($M = 0.14$, $SE = 0.08$) as compared with multisensory costs in responses to the A+VL stimulus type ($M = -0.45$, $SE = 0.09$) in the intermixed trials ($p < .001$). (The analysis was also conducted with the outliers included—see Table A3.2, Appendix A3. The findings were replicated, except that there was a significant difference between multisensory costs in responses to the A+VL and V+AL stimulus types.)

2.4.2. The simple detection task motor responses

This chapter assessed, for the first time (Desebrock, Spence, et al., 2022), whether the SPE can transfer to a simple detection task whereby, in contrast to the matching task, the self-associations were irrelevant to the task at hand (Orellana-Corrales et al., 2021; Stein et al., 2016; Woźniak & Knoblich, 2019). After completing the matching task, the participants in Group 2 made motor RT responses (single keypress) irrespective of the stimuli presented (Hecht et al., 2008; Miller, 1982; Wundt, 1910) which consisted of unisensory and multisensory combinations of the self- and stranger-associated auditory objects and visual shapes allocated to the participant in the matching task (without the labels). Completing the blocked and then the intermixed trials of the matching task ensured that the participants were equally familiar with all stimulus modality types before completing the detection task.

The data from four participants were excluded for achieving >2.5 SDs below the group percentage detection rate mean for any one condition, or, for achieving <50% accuracy in any one condition. The data from 22 participants were used in the analysis. Percentage detection rate data, RT data, CDFs of RTs, and multisensory RT gains are all presented in Figure 2.5.

2.4.2.1. Accuracy (percentage detection rate)

See Figure 2.5a for the percentage accuracy data on the detection task. The studentized residuals for one condition were not normally distributed. Since the majority of the data were normally distributed, the decision was made not to transform the data. Percentage detection rate scores were submitted to a 2 (Association: Self, Stranger) x 4 (Stimulus type: Visual, Auditory, AV Mismatch, AV Match) repeated-measures ANOVA. There was a significant main effect of Stimulus type, $F(3, 63) = 50.15$, $p < .001$, $\eta_p^2 = .71$. There were no other significant effects. Pairwise comparisons between stimulus types revealed that detection rates in matching ($M = 89.77$, $SE = 1.27$) and mismatching ($M = 89.77$, $SE = 1.63$) multisensory trials were significantly greater than in the unisensory visual ($M = 73.35$, $SE = 2.23$) and unisensory auditory ($M = 77.39$, $SE = 2.53$) trials ($ps < .001$). There was no significant difference between AV Mismatch and AV Match Stimulus types ($p > .99$), or between

Auditory and Visual conditions (p = .05; unadjusted significance value reported, Holm-Bonferroni correction, see Section *2.3.6 Data analysis*). Detection rates on AV trials were significantly higher than detection rates in unisensory trials.

2.4.2.2. RT

One condition was not normally distributed. Since the majority of the data were normally distributed, the decision was made not to transform the data. RTs were submitted to a 2 (Association: Self, Stranger) x 4 (Stimulus type: Visual, Auditory, AV Mismatch, AV Match) repeated-measures ANOVA. There was a significant main effect of Stimulus type, $F(2.20, 46.23) = 115.95$, $p < .001$, $\eta_p^2 = .85$ (Greenhouse-Geisser correction). There were no other significant effects. Pairwise comparisons between stimulus types revealed a significant difference between all stimulus types (*ps* < .001) except for between AV Mismatch and AV Match conditions (p = .14). Responses in AV trials were faster than in unisensory trials, and responses in the Auditory trials were faster than in the Visual trials (see Figure 2.5b).

2.4.2.3. Multisensory facilitation in RT

Multisensory gain/cost values (faster of unisensory – multisensory) were submitted to a 2 (Association: self, stranger) x 2 (AV stimulus type: match, mismatch) repeated-measures ANOVA. There were no significant effects (Figure 2.5c, left graph). SPE gains (see Section *2.3.6 Data analysis*) can also be seen in Figure 2.5c (right graph). Multisensory percentage gains/costs were also calculated to control for any differences in RTs across the conditions, the analysis re-run, and the findings were replicated.

2.4.2.4. CDFs: RTs

Three of the forty conditions (2 Association x 4 Stimulus type x 5 Probabilities) were not normally distributed, and there was one studentized residuals outlier. With the outlier excluded, studentized residuals for two of the forty conditions were not normally distributed. Since the majority of the data were normally distributed, the decision was made not to

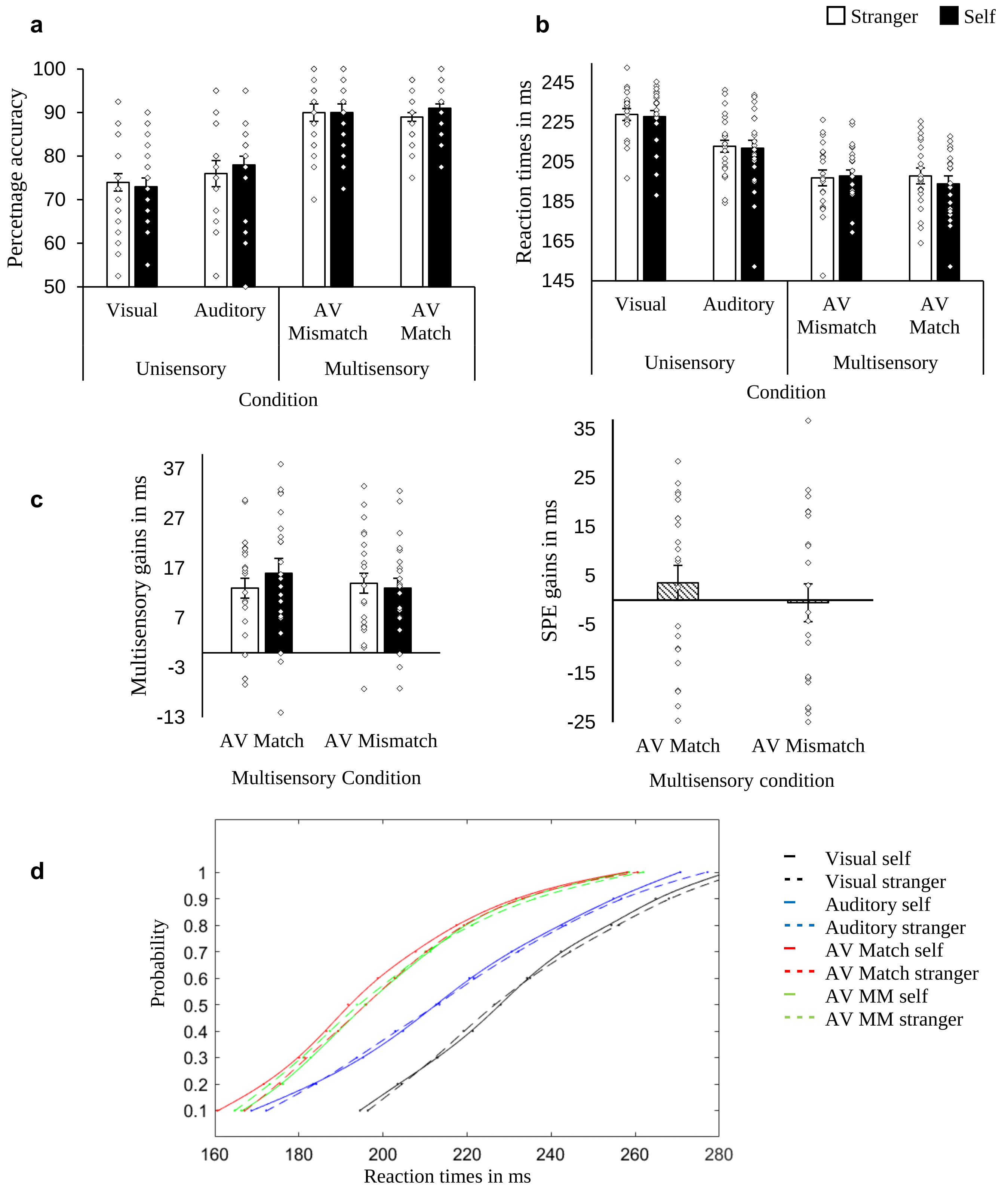

Figure 2.5. Detection task in Study C2. N = 22 (Group 2). Bar graphs (a–c) with individual data points (outliers excluded). Error bars represent SE. **a.** Mean percentage accuracy (detection rate) as a function of Association and Stimulus type. **b.** Mean RTs as a function of Association and Condition (Stimulus type). **c**. Mean multisensory RT gains in ms as a function of Association and Multisensory Condition (left). Mean SPE RT gains in ms as a function of multisensory condition (right). SPE gains = the difference between self- and stranger-associated responses. Positive values indicate a self-advantage. **d**. Cumulative Distribution Functions (CDFs) of percentiles of the rank-ordered RTs (PC grand RT means) as a function of Condition (uni- and multisensory). AV Match self = the sound and shape associated with the self in the preceding matching task. AV Match stranger = the sound and shape associated with the stranger in the preceding matching task. MM = mismatch. AV self MM = self-associated shape and stranger-associated sound used in the preceding matching task. AV MM stranger = stranger-associated shape and self-associated sound used in the preceding matching task.

transform the data. With the outlier excluded (N=21), RTs were submitted to a 2 (Association: self, stranger) x 4 (Stimulus type: A, V, AV Mismatch, AV Match) x 5 (Probability: 1, 3, 5, 7, 9) repeated-measures ANOVA. There were main effects of Stimulus type, $F(2.17, 43.40) = 117.55$, $p < .001$, $\eta_p^2 = .86$, and Probability, $F(1.34, 26.70) = 773.53$, $p < .001$, $\eta_p^2 = .98$. There was a significant interaction between Stimulus type and Probability, $F(5.48, 109.63) = 9.13$, $p < .001$, $\eta_p^2 = .31$. (Greenhouse-Geisser correction used for all effects with more than two factors.) There were no other significant effects. Pairwise comparisons for Stimulus type revealed significant differences between the unisensory and multisensory conditions (*ps* < .001), and the auditory (*M* = 215.17 ms, *SE* = 2.28) and visual conditions (*M* = 230.79 ms, *SE* = 2.25), (*ps* < .001), but no significant difference between AV Mismatch (*M* = 199.37 ms, *SE* = 2.42) and AV Match (*M* = 197.84 ms, *SE* = 2.69) conditions, *p* = .11 (see Figure 2.5d). (The analysis was also conducted with the outlier included. The findings were replicated.)

The participant data exclusion criteria for the detection task analysis (N=22 sample) were based on the participant’s performance in the detection task (irrespective of their performance in the matching task). This could potentially confound the transfer of the social associations because any participants with lower performance in the matching task may not have properly integrated the associations for access during the detection task. To check whether performance in the matching task could have impacted the influence of self-associations in the detection task, a supplementary analysis of RTs and multisensory percentage gains was conducted. This time the analysis excluded participant data that had been excluded from both the matching and detection task analyses combined (N=16; see Appendix A4). The findings replicated the findings with the N=22 sample.

2.5. Discussion

The present study investigated the influence of both stimulus- and task-design related factors on the extent of self-bias in the matching task, and its emergence across tasks, in keypress motor responses. Self-bias in the matching task was modulated by whether the simultaneously-presented label and object pairs were visual, auditory, or a combination of the two modalities. Specifically, the extent of self-bias in RT was significantly greater in responses to the visual shape and auditory label stimuli (V+AL) than to the auditory object and auditory label (A+AL) stimuli. There was also a significant interaction between association (self- vs. stranger-associated responses) and audiovisual stimulus type (A+VL vs. V+AL) for multisensory gains/costs in terms of RT. Multisensory costs were descriptively greater for self- than stranger-associated A+VL stimuli, while for the V+AL stimuli, there were costs for stranger, and multisensory gains were observed in responses to the self-associated stimuli. As such, self-bias interacted with the combination of the object and label stimulus modalities. The extent of self-bias in RT was also diminished when stimuli were intermixed as compared with blocked by stimulus modality type. Furthermore, no significant self-advantage was found in simple detection task motor responses to the unisensory and multisensory stimuli in which the learnt self-associations were not relevant to the task at hand. Taken together, the present findings therefore indicate that self-bias can be modulated by both stimulus- and task-related parameters within the matching task, but the self-associations formed in the matching task do not automatically result in similar motor speed gains to unisensory and multisensory stimuli in simple reaction-time motor responses.

2.4.1. Self-bias in the matching tasks

The present study findings are both consistent with, and also depart from, the findings reported by previous research. It was hypothesized that the extent of self-bias would be moderated by block type. Consistent with this prediction, and previous research (Golubickis & Macrae, 2021) block type moderated self-bias in RT: the self-advantage was reduced in intermixed trials. One possibility however is that increasing fatigue may have reduced the self-advantage since the intermixed condition was always presented after the blocked condition. An additional analysis was therefore conducted to examine the magnitude of the self-advantage across individual blocks within the blocked and intermixed conditions. The analysis confirmed that the extent of self-bias did not significantly decrease within either the blocked or intermixed condition (see Appendix A6). Multisensory costs in self- as compared with stranger-associated responses were also differentially modulated by block type in the present study. Costs in terms of RT were significantly reduced in blocked as compared with intermixed trials for self-associated responses, whereas costs in stranger-associated responses across block types did not differ. Taken together, these finding therefore suggest that self- and stranger-associated responses were differentially modulated by block type.

It was also hypothesized that the self-advantage would be reduced with audiovisual as compared with visual stimuli, but that the latter may depend on the block type and the auditory stimulus intensity (in line with the pattern of findings across Stolte et al.'s (2021) and Schäfer, Wesslein, et al.'s (2016) studies, collectively). Specifically, using intermixed trials and auditory stimuli presented at 75 dB, Stolte et al. (2021) documented that the self-advantage was diminished in those responses made to audiovisual stimuli (i.e., auditory tones with visual labels, and particularly diminished in the absence of labels with audiovisual objects) as compared with visual-only stimuli with labels. Meanwhile, using blocked trials and auditory stimuli presented at 50 dB, Schäfer, Wesslein, et al. (2016) documented that the self-advantage was of equivalent magnitude in responses to visual, auditory, and tactile stimuli paired with visual labels. In the present study, the self-advantage in RT was significantly attenuated with auditory as compared with visual objects (consistent with Stolte et al., 2021), but only when paired with auditory labels. (NB. Stolte et al. only paired their stimuli with visual labels.) Furthermore, there was an interaction between association (self-vs. stranger-associated responses) and audiovisual stimulus type (A+VL vs. V+AL) for multisensory gains/costs in RT. The multisensory (A+VL) stimuli were associated with ‘costs’ rather than gains over unisensory stimulation (in line with expectations, and consistent with Stolte et al., 2021), with descriptively greater costs for self- than stranger-associated responses. However, while costs were also observed in participants’ responses to stranger-associated multisensory (V+AL) stimuli, multisensory gains were observed in responses to the self-associated multisensory (V+AL) stimuli. Thus, the present study provides the first evidence that the combination of the label and object modality (auditory vs. visual) can modulate self-bias in the matching task.

Contrary to predictions, auditory stimulus intensity did not moderate the extent of self-bias in the present study. Further analyses confirmed that there were no significant main nor interaction effects of auditory stimulus intensity on the SPE in the absolute RTs either—analysis reported in Appendix A5. It is important to note, however, that dichotomous supra-threshold stimulus intensities (50 dB vs. 70 dB) were used in order to replicate the intensities used in previous studies (Schäfer, Wesslein, et al., 2016; Stolte et al., 2021). It could therefore not be ruled out that self-bias may be modulated across a greater range of auditory stimulus intensities from near-threshold levels to upper limits.

Taken together, these patterns of results suggest that self-bias is influenced by both the task design (blocked vs. intermixed trials) and by stimulus parameters (the modality of the object and label stimuli) in the matching task. However, the present findings did not support the notion that the block type (i.e., intermixed trials) or auditory stimulus intensity or their combination could account for the reduced self-advantage observed with audiovisual stimuli in Stolte et al.’s (2021) study. Stolte et al. used pure tones (of low, medium, and high frequency) as auditory stimuli, whereas the present chapter and Schäfer, Wesslein et al.’s (2016) study used neutral categorical sounds. Stolte et al. also demonstrated that self-bias and, in turn, visual dominance, was modulated by the hierarchical relations between the tones (i.e., the multisensory self-advantage was akin to the visual self-advantage if the high tone was paired with the self). The reduced self-advantage observed with audiovisual stimuli in Stolte et al.'s study can therefore most likely be attributed to the interaction between self-bias and the hierarchical relations between pure tones of different frequencies.

It was also hypothesized in the present study that a reduced self-advantage with audiovisual stimuli would lend support to the contention that under certain conditions, it may be easier to form self-associations with visual representations of objects than audiovisual representations (Stolte et al., 2021). Conversely, a self-advantage of equivalent magnitude across all stimulus types would support the notion that the self-advantage is underpinned by modality-general processes (Schäfer, Wesslein, et al., 2016). As noted, the present study documented that the magnitude of the self-advantage in the matching task was moderated across stimulus modality types (which included in Blocked trials). Thus, this study did not find evidence to support the notion that the self-advantage was underpinned by modality-general processes in the present task context (although a modulation by self-bias of modality-general processes could not be ruled out). In addition, the self-advantage was not consistently reduced with auditory or audiovisual stimuli, thus the data did not support that it may be easier to form visual self-associations *per se*. (These points are discussed further in Section *2.5.3 Wider implications.*)

One further consideration is that in the matching tasks of the present study, geometric shapes were used as visual stimuli, while the sound stimuli were bursts of musical instruments. These stimuli were chosen in order to keep the stimuli consistent with previous research (Schäfer, Wesslein et al., 2016). Alternatively, drawings of musical instruments could be used as visual stimuli (i.e., a different exemplar of the same category; Schäfer et al., 2015). Using different categories across visual and auditory stimuli may have amplified the working memory load in intermixed trials and further reduced the self-advantage in these trials. Notably, however, if increased working memory load reduces the self-advantage, then a reduced self-advantage would still be expected in intermixed trials even with conceptually more similar stimuli. Furthermore, the short 150 ms bursts were not typical of the characteristic sounds made by those instruments, and although recognisable as belonging to their respective categories (when narrowed down to two possibilities), the sound bursts were not typical of the instruments, or familiar. This would be more likely to facilitate the forging of self/other associations with sensory rather than conceptual or supramodal features of the sounds. Conversely, using drawings of the instruments and sounds of the instruments would encourage the use of ‘conceptual’ associations as this would be the optimal strategy to maximise responding across modality types in intermixed trials. Future studies could examine whether matching the semantic content of the stimuli (other than the person associations) across stimulus types modulates the self-advantage in intermixed trials.

2.5.2. Self-bias in the detection task

Previous studies have demonstrated that task instructions and whether the meaning of the stimuli are relevant to the task at hand can also modulate the effects of self-relevance and multisensory processes (Barutchu & Spence, 2021; Caughey et al., 2021; Dalmaso et al., 2019; Falbén et al., 2019; Macrae et al., 2017; Woźniak & Knoblich, 2021). Indeed, in contrast to the matching task, and as predicted, multisensory gains were consistently observed in the detection paradigm, but no statistically significant self-advantage was detected in either RTs or gain measures. Previous studies using other tasks have similarly documented that a self-advantage did not arise when the stimuli were not semantically-evaluated (Caughey et al., 2021; Dalmaso et al., 2019; Falbén et al., 2019; Stein et al., 2016), or at least when the associations were not represented by the participant as task relevant (Woźniak & Knoblich, 2021). Anticipation of task-relevant stimuli in visual tasks have been demonstrated to rapidly alter neural processes (Corbetta et al., 2000; Nobre & van Ede, 2018; Stokes et al., 2009), and task instructions have been shown to alter multisensory gains and costs across consecutive tasks (Barutchu & Spence, 2021; Sinnett et al., 2008). Such top-down processes may interact with self-bias and multisensory processes to modulate gains and costs to task relevant and irrelevant stimuli. (These points are discussed further in Section *2.5.3 Wider implications*).

It could be argued however that the absence of a significant self-advantage in the detection task may be related to other factors. The RT gains were much smaller than those typically reported (on average, in the order of 20 ms) as compared with past studies (e.g. Barutchu et al., 2009; Miller, 1982). RTs in the present study were limited to 300 ms which may have reduced the RT gain measures. Responses in detection tasks are more typically limited to response times of 800–2000 ms. On the other hand, simple-reaction-times for young participant samples (18–34 years of age) have been documented at around 180–220 ms for visual stimuli, and around 133–160 ms for sound stimuli (Fieandt, 1956; Gottsdanker, 1982; W. T. Welford et al., 1980; Woodworth & Schlosberg, 1954). The short response time limit in the present study was therefore set to ensure that: (1) participants did not delay their responses, to avoid the intentional evaluation of the stimuli; (2) any self-advantage would not be absorbed into delays prior to movement onset (RTs can include unnecessary delays that can account for up to one third of their duration; Haith et al., 2016; see Chapters 3 and 4); and (3) participants kept alert to the task, and responded as fast as they actually could, rather than simply relying on instructing the participants to respond as fast as possible. In the present study, less than 3% of RTs were excluded based on the 300 ms response time-limit, indicating that participants were performing within their capabilities.

Another possibility is that fatigue or reduced motivation may have influenced the participants’ performance in the detection task since it always followed the matching task to allow for optimal learning of the stimulus associations. Multisensory enhancement effects are partly dependent on attention (e.g. Barutchu & Spence, 2021; Talsma, 2015; Talsma et al., 2010; Zuanazzi & Noppeney, 2019). As noted, however, the short response time limit encouraged participants to stay alert to the task. Furthermore, additional analyses (see Appendix A6) indicated that the self-advantage did not significantly decrease across individual blocks within either the blocked condition or the intermixed condition in the preceding matching task. Importantly, and as noted, the detection task findings are consistent with previous studies using other task paradigms in which the newly self- and other-person associated stimuli were not semantically-evaluated (Caughey et al., 2021; Dalmaso et al., 2019; Falbén et al., 2019; Stein et al., 2016), or, at least, perceived as task relevant (Woźniak & Knoblich, 2021).

2.5.3. Wider implications

In Section *2.2 Introduction,* it was suggested that attentional or memory-related processes may account for the differential modulation of self-bias documented across previous studies using multisensory stimuli (Schäfer, Wesslein, et al., 2016; Stolte et al., 2021). Task-induced modulations of attention may influence self-bias; or, for example, it may be easier to form self-associations with certain unisensory or multisensory representations than others, in certain contexts. Notably, in the present study, there was no significant difference between the self-advantage arising in responses to the visual (V+VL) stimuli and the multisensory (A+VL) stimuli (consistent with Schäfer, Wesslein, et al. (2016), who also used categorical sounds for auditory stimuli). In the context of blocked trials (conditions of focused attention), therefore, differences in the strength of auditory versus visual object self-associations could not account for these findings. Similarly, top-down or bottom-up modulations of attentional processes induced by stimulus object modality *per se* could not explain these findings.

Collectively, these findings suggest that neither task-design (i.e. block type) nor the sensory modality of the stimulus object moderated self-bias across visual and auditory stimulus objects in the context of visual labels. They suggest that associations between the visual objects and visual labels are not more easily formed than associations between the auditory objects and visual labels, at least when the stimulus objects are neutral in terms of their relative hierarchies (cf. Stolte et al., 2021). Indeed, the processes underpinning self-bias in responses to the visual labels and visual and auditory stimulus objects in the matching task may be equivalent, and may be supported by functional connectivity between the vmPFC and LpSTS, as has been documented for V+VL stimuli (Sui, Rotshtein, et al., 2013).

Notably, however, self-bias *was* moderated across visual and auditory stimulus objects when they were presented with auditory labels. As discussed, there did not appear to be an advantage in forming visual object associations over auditory objects *per se*. Another possibility postulated in Section *2.2 Introduction* was that modality switching, or visual dominance, for example, could potentially modulate self-bias in intermixed trials. However, such processes could not account for the diminished self-bias with A+AL as compared with V+AL stimuli in the present study since the modulation also emerged in blocked trials. Alternatively, self-bias may have been modulated by the differential processing strategies underlying responses to the different stimulus object and label modality combinations. Differential neural processing mechanisms appear to underlie responses to visual and auditory linguistic and object stimuli carrying seemingly equivalent information (Arana et al., 2020; Y.-C. Chen & Spence, 2018). Similarly, differential neural circuitry has been documented to underlie self- and other-related responses in the matching task (Sui, Rotshtein, et al., 2013). In a very recently published study (Scheller & Sui, 2022a), it has been further suggested that self-bias across unisensory and multisensory processes may be differentially supported by the dorsal and ventral attention networks.

Processing the simultaneously-presented A+AL stimuli as compared with V+AL stimuli may also be supported by differential mechanisms. Indeed, overall response times were consistently longer for the unisensory auditory stimuli than for the other stimulus types. In the present study, the greater self-advantage in responses to the V+AL stimuli as compared with the A+AL stimuli was driven by greater facilitation in responses to self-associated V+AL stimuli relative to the self-associated A+AL stimuli (see Table 2). Furthermore, while multisensory costs were documented for self- and stranger-associated A+VL stimuli, for the V+AL stimuli, there were costs for stranger, and gains were uniquely observed for self. One possibility is that such facilitation in responses to the self-associated multisensory (V+AL) stimuli arises from the integration of the multisensory object and label at the perceptual-level. Indeed, self-relevance has been suggested to modulate multisensory integration in perceptual processes (Scheller & Sui, 2022a).[7]

Self-bias has also been demonstrated to operate at a supramodal level. Studies have shown that self-associations formed with modality-general attributes of the stimuli (such as numerosity) using one modality can elicit a self-advantage in other sensory modalities (Schäfer, Wesslein, et al., 2020; Scheller & Sui, 2022a). Scheller and Sui (2022a) further suggest that attention is then "funnelled" towards the more reliable sensory modality for the task at hand, increasing the self-advantage in relation to that modality. In the context of the present matching task, attention may be more strongly-funnelled towards visual object and auditory linguistic processing streams, perhaps because such input in conjunction is perceived as more 'reliable'.

Alternatively, self-related motor responding may be more congruent with certain object and label modality combinations (e.g. V+AL). As infants we encounter spoken words while viewing or interacting with visual objects earlier in development than we do objects and visual text. Such combinations may be more automatically processed. Conjunctions not

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[7] Perceptual-level processes in this context refer to those processes of "translation from peripheral sensory input into a coherent internal representation (percept) of the external environment", as such involving influence from top-down as well as bottom-up processes (see Scheller & Sui, 2022; pp. 4–5).

features bind to the self, paralleling automatic face processing (Schäfer et al., 2015; Schäfer, Frings, et al., 2016), and once learned, conjunctions can modulate bottom-up perceptual processing of the stimulus (Reavis et al., 2016). Thus certain object-label conjunctions may provide further conditions for integration of these stimuli and drive bottom-up self-related enhancements. Notably, the absence of a significant self-advantage in the detection task however suggests that self-bias relies on the (perceived) relevance of the self-associations to the task at hand (Woźniak & Knoblich, 2021); in other words, on the task set. It may be that anticipation of relevant self-associations in the matching task prime neural processes for certain object and label combinations (e.g. V+AL), as such facilitating self-related responses. One possibility, then, is that greater facilitation in responses to the self-associated V+AL stimuli as compared with A+AL stimuli may involve differential underlying mechanisms. Indeed, self-relevance can flexibly modulate different levels and stages of unisensory and multisensory processing depending on the context (Schäfer, Wesslein, et al., 2016, 2020; Scheller & Sui, 2022).

2.5.4. Limitation and conclusions

As discussed, the findings of the present chapter (Desebrock, Spence, et al., 2022) in conjunction with the findings of other recent studies examining unisensory and multisensory self-bias (Schäfer, Wesslein, et al., 2016; Scheller & Sui, 2022; Stolte et al., 2021) increase our understanding of the contextual constraints on the emergence and extent of the self-advantage in manual motor responses. The question of whether self-associations involve sensory or modality-general representations, or whether differential perceptual or later-stage processes underpinned responses across stimulus type are outside the scope of the present study, however (cf. Schäfer, Wesslein, et al., 2020; Scheller & Sui, 2022a). Future behavioural and neuroimaging studies are needed to systematically determine the differential processing strategies underlying responses to unisensory and multisensory object and label stimuli in the matching task.

As noted in Section *2.1 Chapter overview,* self-bias may constitute a measure of the minimal self (Gallagher, 2000; Schäfer & Frings, 2019b). As discussed, the present findings in conjunction with previous studies suggest that self-bias does not dominate in a sensory modality per se. Such operation would be consistent with the adaptive function of this subcomponent of self at a fundamental level, since the minimal self must necessarily rely on efficiently processing information across the senses. However, if self-bias reflects the operation of the minimal self, one might expect that the influence of these self-associations would arise more automatically and therefore emerge in simple detection motor responses. It may be that rather than reflecting the operation of the minimal self, self-bias reflects the operation of a somewhat higher-level subcomponent of self. (This notion is discussed and examined further in Chapters 6 and 7.)

In line with traditions in the self-prioritization literature, the matching and detection task motor responses in the present chapter were treated holistically; that is, using total response time measures. Total response time is measured from stimulus onset and is the time taken to process the stimulus information and make a task-designated motor response that is ‘correct’. In other words, the motor response in its entirety is measured from stimulus onset to the completion of the overt movement. Commonly, manual motor responses in tasks such as the matching task are used as a proxy measure of cognitive (or premotor) processes, largely based on tradition and the implicit assumption that the motor-stage of responses is influenced by target and not stimulus features (see Chapter 1; and also, Chapters 3–5). As noted, self-bias has been suggested to modulate both perceptual and later-stage cognitive processes in the matching task. However, no studies have examined the influence of self-bias beyond response selection.

In alignment with research that considers that the motor stage can also (theoretically) be influenced by self-relevance (Barton et al., 2020; Desebrock et al., 2018; Desebrock & Spence, 2021; Golubickis et al., 2017; Janczyk et al., 2019; Macrae et al., 2017), the following chapters further examine self-bias in motor responses using a novel movement adaptation of Sui et al.'s (2012) matching task (Desebrock, Barutchu, et al., 2022; Desebrock et al., 2018; Desebrock & Spence, 2021). Given that the newly-learned self-associations did not lead to motor speed gains in simple reaction time motor responses, the following chapters focus on the matching task. Since the studies reported in the following chapters are the first to examine self-bias in motor responses beyond their selection, the visual object and label stimuli are used for comparability with previous research on self-bias, and as a first point of departure. The V+VL stimuli are also a well-established and reliable method for eliciting a large self-advantage. Accordingly, in Chapter 3, self-bias is examined for the first time in visuomotor arm-movement responses. The initiation and execution of these motor responses are measured separately in order to examine the influence of self-bias beyond response selection, and further address the overarching question: what are the contextual constraints on the self-advantage in motor responses?

Chapter 3—Self-bias beyond response selection (Study C3)

3.1. Chapter overview

In Chapter 2, the self-advantage in manual motor responses to visual, auditory, and audiovisual stimuli in matching and detection tasks was investigated using keypress motor responses. As such, the effects of unisensory and multisensory novel self-associations were examined holistically in total response time measures in line with traditional research using the matching task (e.g. Golubickis et al., 2017; Stolte et al., 2017; Sui et al., 2012). The present chapter examines whether the effects of the novel self-associations in Sui et al.'s (2012) matching task extend beyond response selection to modulate the execution as well as initiation of the motor responses.

Using a novel movement adaptation of the matching task, movement execution was measured separately from movement initiation (Barton et al., 2020; Houlihan et al., 1994; Jensen & Munro, 1979; Praamstra et al., 2014; Robinson et al., 2014). A response box recorded 'home'-button-releases measuring movement initiation time (IT) from stimulus onset, and the percentage of accurately-selected movements; and a target-key positioned 14 cm from the response box recorded MT from 'home'-button-release to target-key depression, and the percentage of correctly-completed movement executions. MTs as well as ITs of responses to self-related as compared with stranger-related stimuli were faster, with a higher percentage of correctly-initiated and executed movements for self-related responses. The extent of self-bias was also altered across the two-stage response.

This chapter thus presents a novel demonstration (Desebrock et al., 2018) that an advantage in responses to the self-associated stimuli emerges in the execution, as well as the initiation, of manual motor responses (i.e. rapid-aiming arm-movements), providing preliminary evidence that self-bias can modulate movement execution. These findings contrast with those of Janczyk et al. (2019) who documented that neither perceptual-level processes nor the duration of the motor-stage were modulated in the matching task, and are aligned with research suggesting that self-bias has an influence at multiple-stages (Humphreys & Sui, 2016; Scheller & Sui, 2022b; Sui & Humphreys, 2015a; Woźniak et al., 2018).

3.2. Introduction

3.2.1. Self-prioritization in motor-related processes

Prior to the research presented in this chapter (Desebrock et al., 2018), no studies had directly examined the effects of novel self-associations on processes beyond response selection. In an action-related adaptation of Sui et al.'s (2012) matching task, Frings and Wentura (2014) documented a self-advantage in matching action representations of arm-movements with the text labels. The authors instructed their participants to associate an arm movement (moving a cursor with a mouse up, down, left, or right on a screen) with the self- and other-person labels. A directional cursor indicated to participants which of the arm movements to execute. On reaching the side of the screen, the participants had to judge whether the label that appeared matched the allocated arm-movement or not by pressing one of two mouse buttons. Judgements were faster and more accurate in self-associated trials. Given that participants' arm-movements terminated before a judgment response was made, the authors thus demonstrated a *motor-related SPE*—a prioritization effect in matching a self-associated label and action representation (i.e., self-associated movements encoded at a 'conceptual level'; Frings & Wentura, 2014; p. 1740; perhaps at the level of internal verbal description or as motor imagery). The authors did not, however, examine whether self-bias could modulate the overt arm-movement response itself. In a study designed to assess the influence of novel self-associations on access to visual awareness, Macrae et al. (2017) used a continuous flash suppression paradigm in which participants reported the identity of newly self- and other-person-associated geometric shapes as they were revealed to conscious awareness. The authors documented that self-associated shapes were prioritized in visual awareness. A hierarchical-diffusion-model analysis to decompose task performance revealed that both decisional as well as non-decisional processes in the button-press motor responses were influenced (Macrae et al., 2017). However, since non-decisional processes can include stimulus encoding or response execution or both, it remained unclear whether movement execution can be modulated by novel self-associations. It is therefore not known whether self-relevance in the matching task could modulate processes beyond response selection.

The question of whether or not self-relevance in the matching task can modulate movement execution is related to the broader question of what the boundary conditions are for the emergence of the self-advantage, and what contextual constraints moderate the *extent* of the self-advantage—the overarching theme of this thesis. In particular, if self-relevance in the matching task can modulate movement execution, these findings would support and extend research suggesting that self-prioritization in the matching task has a multiple-stage influence (Humphreys & Sui, 2016; Scheller & Sui, 2022b; Sui & Humphreys, 2015a; Woźniak et al., 2018). As outlined in the earlier section *1.13 Significance of this thesis*, examining self-bias in arm-movements also increases understanding of the operation of sub-components of the self in action, with longer-term relevance for understanding self-processing across diverse groups, such as in disorders of the self, and in those with motor deficits.

3.2.2. Self-bias and the motor stage: Null hypothesis

As noted in Chapter 1, manual motor responses in tasks such as the matching task (Sui et al., 2012) are commonly used as a proxy measure of cognitive (or premotor) processes, largely based on tradition and the implicit assumption that the motor-stage is influenced by target rather than stimulus features (e.g., Doucet & Stelmack, 1999; Fitts, 1954; Frowein & Sanders, 1978). RT in SPE studies is typically understood within an interpretative framework that appeals to stage model theory (e.g., see Sui et al., 2012—Experiment 4). The main tenet of traditional stage-model theory (Donders, 1969; Sternberg, 1969) is that stimulus processing proceeds sequentially from the sensory 'input', through the perceptual, then central or decision-making stage, and finally to motor-specific preparation and execution of the response or 'output' (the motor-stage). The durations of each stage additively make up the RT. Two assumptions typically characterise the conceptualization of the motor-stage. First, that this stage consists in the motor-specific preparation of the response and also its execution. In other words, it begins at the point at which the response is selected and motor-specific activity commences, and ends with the completion of the overt task response. A second assumption (supported by earlier studies; e.g., Donders, 1969; Doucet & Stelmack, 1999; Fitts, 1954; Fitts & Radford, 1966; Frowein & Sanders, 1978; Glencross, 1976; Posner, 2005; Sternberg, 1969) is that the motor-stage of a short rapid movement to a target follows the premotor processing stages and is influenced by features of the target (e.g. size, location). In other words, there should be no differences in motor-stage processing across stimulus conditions providing that the requisite task motor response is kept constant. Similarly, traditional optimal feedback control (OFC) models in the sensorimotor control literature hold that a control policy that minimizes the cost of the movement in terms of effort, inaccuracy, and regularization determines movement planning and execution, highlighting an emphasis on feed*back* rather than feed*forward* processing (see Gallivan et al., 2018; cf. Yeo et al., 2016). Both lines of research predict that in Sui et al.'s speeded task, the overt movement response in the matching trials (that have the same movement goal and use the same effector) should not differ across self- and stranger-related conditions. In other words, the self-advantage can arise in processes up to and including, but not beyond, response selection. The findings of a study by Janczyk et al. (2019) are consistent with this contention.

Using Sui et al.'s (2012) matching task within the context of a dual-task Psychological Refractory Period (PRP) paradigm and central bottleneck framework (Janczyk et al., 2018; Pashler, 1994; A. T. Welford, 1952), Janczyk et al. (2019) aimed to pinpoint the processing locus of the SPE. Across three experiments, these researchers ruled out an SPE in perceptual processes. In their fourth experiment (using effect propagation logic; see Janczyk et al., 2018), the authors also documented that the motor stage did not contribute to the SPE. Instead, they suggested that the SPE arose in central-stage processes, which include encoding into short-term memory (Jolicoeur & Dell'Acqua, 1998), selection into and switching between items in working memory (Janczyk, 2017), and response selection (Janczyk & Kunde, 2020; A. T. Welford, 1952). On this evidence, then, it might be expected that in rapid-aiming arm-movements to a target, the motor output (or motor-stage of the response) should not differ across responses to self- and other-associated stimuli in the matching task.

3.2.3. Self-bias in action: Alternative hypothesis

On the other hand, in other literatures (e.g. Bangert et al., 2012; T. Schmidt & Seydell, 2008), those factors affecting perceptual processing have been demonstrated to influence the movement response. For example, in studies examining response priming—a paradigm that has been used extensively to explore visuomotor processing or perceptual processing effects on response generation—effects of perception on movement execution have been well-documented (F. Schmidt et al., 2011). If self-prioritization modulates perceptual processes, as has been evidenced (Golubickis et al., 2017; Humphreys & Sui, 2016; Svensson et al., 2021), as well as assumed by a number of studies (Enock et al., 2018; Jones et al., 2017; Nijhof et al., 2020; Sui et al., 2012), this leaves open the possibility that self-relevance in the matching task could also modulate movement execution.

Mechanistic understanding of the SPE is still in its infancy, and currently there is no theoretical model available which explicitly links mechanisms of self-relevance with those of response execution. Accordingly, this chapter briefly reviews and identifies potential mechanisms of action drawn from the response priming (F. Schmidt et al., 2011; T. Schmidt et al., 2006; T. Schmidt & Seydell, 2008) and motor control and neuroscience literature (Haith et al., 2016; Reynaud et al., 2020; Thura & Cisek, 2017; Weinberg, 2016).

3.2.3.1 Perceptual effects in action

‘Rapid chase theory’ (T. Schmidt et al., 2006) posits two components of visuomotor processing: an initial bottom-up, feed-forward activation of the visual system in stimulus processing which leads to rapid and direct motor activation, that is independent of visual awareness. This is contrasted with a slower, top-down-controlled, ‘recurrent processing’ component, arising in later processing, that feeds back to influence re-entrant activity, as well as developing visual awareness (T. Schmidt & Seydell, 2008). Researchers using response priming paradigms have been able to dissociate effects of the two modes of visual processing on response execution, by varying task parameters in terms of the stimulus onset asynchrony (SOA) of the ‘prime’ (a stimulus presented below the threshold of awareness) and target stimuli (available to conscious perception), and their response compatibility and incompatibility mappings (see e.g., F. Schmidt et al., 2011).

In particular, a strand of response priming research (which investigates the time-course of primed pointing movements) has enabled researchers to dissociate early pre-conscious versus late processing effects on visual motor control. The initial “feedforward sweep” triggered by the prime stimulus (T. Schmidt et al., 2006) has been shown to drive early parts of the movement (or, under certain conditions, even the whole response—e.g., generating overt errors on stimulus-response incompatibility trials). The slower (top-down) target-stimulus processing can take over movement control mid-flight (with this time-point tightly-linked to the SOA), and further influence response execution 'online' as it unfolds (F. Schmidt et al., 2011; T. Schmidt & Seydell, 2008). Novel self-associations have been proposed to modulate both bottom-up processes and top-down attentional control mechanisms (Humphreys & Sui, 2016), and also to modulate access to visual awareness in identification tasks (Macrae et al., 2017; although cf. Stein et al., 2016). The effects of self-relevance in the matching task, then, could potentially operate within either or both of these modes of visual processing and exert an influence on movement execution.

3.2.3.2 Mechanisms of movement preparation, onset, and execution

In sum, assumptions about the motor stage drawn from stage model theory (also consistent with OFC models in the sensorimotor control literature; Gallivan et al., 2018) predict that self-prioritization should not influence response execution. Conversely, theoretical frameworks within response priming paradigms indicate potential mechanisms for an influence of self-prioritization on response execution. The aim of this chapter is to test the hypothesis that self-relevance in the matching task can modulate movement execution. In order to form predictions with which to test this hypothesis, specific mechanisms of action drawn from the motor control and neuroscience literature are first identified.

Three key components of motor processing in this literature stand as potential candidates for modulation by self-relevance in the matching task. These are: motor planning[8] (Khan et al., 2006; Orban de Xivry et al., 2017) influencing the quality or accuracy of the movement (Haith et al., 2016), a movement onset (initiation) signal linked to movement vigour[9] (Haith et al., 2016; Reynaud et al., 2020) and thus MT but not endpoint accuracy

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[8] Motor planning refers to the process of preparing the requisite motor commands for achieving a particular movement goal (Orban de Xivry et al., 2017).

[9] Movement vigour (or vigor; Dudman & Krakauer, 2016; Opris et al., 2011; Panigrahi et al., 2015; Reppert et al., 2018; Turner & Desmurget, 2010) refers to the dynamics of the motor performance, "the interplay between

(Reppert et al., 2018), and online action-control (Allsop et al., 2017; Khan et al., 2006) influencing endpoint accuracy and also MT though trajectory corrections. It is generally accepted that the planning and online control of movement are distinct processes (Glover, 2004; Khan et al., 2006). Movement preparation and the movement onset signal are also thought to be independent (Franz et al., 1996; Haith et al., 2016; Ivry, 1997).[10] Specifically, movement onset can be delayed post preparation, resulting in longer-than-necessary ITs for achieving accurate responses on speeded tasks. Conversely, movement onset can be brought forward and the movement commence before preparation is fully complete (e.g., resulting in increased error rates; Haith et al., 2016). The movement vigour signal is thought to arise in the basal ganglia and regulates the vigour (speed and size) of movements (NB this signal is to be distinguished from the *decision urgency* signal, see Section *3.6 Discussion*). Therefore, the influence of a factor on movement execution must operate through one or more of motor planning, the movement vigour signal, and online action-control (e.g. Yeo et al., 2016).

3.2.4. The present study

In accordance with the overarching aim of this thesis, this chapter asks *whether* the overt movement is modulated in the matching task, using simple outcome measures of movement initiation and execution. Importantly, the aim of the present chapter is not to systematically test *how* self-bias in the matching task influences movement execution (which would implicate techniques such as kinematic analysis; Khan et al., 2006). Therefore, in a movement adaptation of Sui et al.'s (2012) matching task, response time was divided into: (i) IT, measured from stimulus onset to release of a 'home' button, and (ii) movement time (MT)

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amplitude, speed, duration or frequency of movements" (Berret et al., 2018, p. 1). The movement vigour signal is independent from but interacts with a decision urgency signal and is thought to arise in the basal ganglia (Reynaud et al., 2020).

[10] Haith et al. (2016) note that the assumption still persists in some paradigms that movement preparation and onset are yoked. In other words, the onset of the overt movement is thought to be triggered on completion of movement preparation, and thus movement initiation time (IT) reflects preparation time. On the contrary, Haith et al. (2016) argue that a movement initiation signal determines IT.

measured from home-button release to the depression of a target key, located 14 cm from the home button. This set-up permitted separate measurements of IT and movement initiation accuracy (*PC-1*; the percentage of correctly-initiated movements), and MT and movement execution correct-completion (*PC-2*; the percentage of correctly-completed movement executions).

First, it was expected that if self-prioritization were robust in this set-up, ITs for self- as opposed to stranger-matching responses should be faster, thereby replicating findings of previous studies (e.g. Sui et al., 2012). The null hypothesis was that motor planning, the movement vigour signal, and online action-control are equivalent across self- and stranger-related responses, consistent with motor-stage theory and previous findings (Janczyk et al., 2019). In other words, MTs and the percentage of correctly-completed movement executions (PC-2) should be equivalent across the two matching-trial conditions. This finding would be consistent with the notion that shorter RTs (total response times) for self- over stranger-related responses observed in previous studies were underpinned by a modulation of premotor processes. Alternatively, if MTs in self- as compared with stranger-related matching trials were shorter or a greater percentage of movement executions were completed, or both, then it can be concluded that one or more of the three motor-related mechanisms were modulated.

3.4. Methods

3.4.1. Participants

No previous studies have examined self-bias in a movement adaptation of Sui et al.'s (2012) matching task. In the standard version of the matching task, the effect size for the self-advantage is typically *dz* > .80 ($\eta^2 > .25$; Sui et al., 2012). MT has not been measured previously. A sample size of 35 participants allowed for the detection of an effect size of *dz*

=.49 (η^2 = .20) with a probability of 1 - β = .80, and an alpha value of .05 (G*Power; Faul et al., 2009).

Thirty-five right-handed participants (13 male; age range 19–40 years; mean age and standard deviation, 24.17 ± 5.27) with normal or corrected-to-normal vision took part. They were recruited via the 'Participate' page of Oxford University's Experimental Psychology departmental website, the Oxford University Research Participation Scheme, and social media. They received course credit or monetary reimbursement for their time and effort. All participants completed a written consent form approved by the Oxford Research Ethics Committee (MSD-IDREC-C1-2013-209 and R49190/RE001).

3.4.2. Stimuli and apparatus

The experiment was conducted on a PC with a 24-in. LCD monitor (1920 × 1080 pixels at 100 Hz refresh rate) using E-Prime software (Version 2.0). A Cedrus RB-530 response-box, positioned in front of the PC monitor and PC QWERTY-keyboard, recorded home-button-releases (measuring IT from stimulus onset), and the keyboard recorded target-key presses (measuring MT from release of the home-button). (See Figure 3.1.)

The stimuli consisted of two geometric shapes from the following set (circle, square, triangle, hexagon, pentagon, or octagon, each subtending 3.2 × 3.2 deg. of visual angle), and two written-text self- and stranger-related word-labels (i.e., 'yours', 'theirs'). The shape was positioned above (and the label below) a central fixation cross. The associations between the two shapes allocated to each participant and the written labels they were paired with were counterbalanced across participants. The shapes and labels were presented in the centre of the PC-screen against a grey background.

The words 'yours' and 'theirs' were chosen as labels due to their similar word length and equivalent number of syllables (durations), and low ratings for 'word concreteness'. As noted in Chapter 2, word concreteness gives rise to SPE-like prioritization effects, although

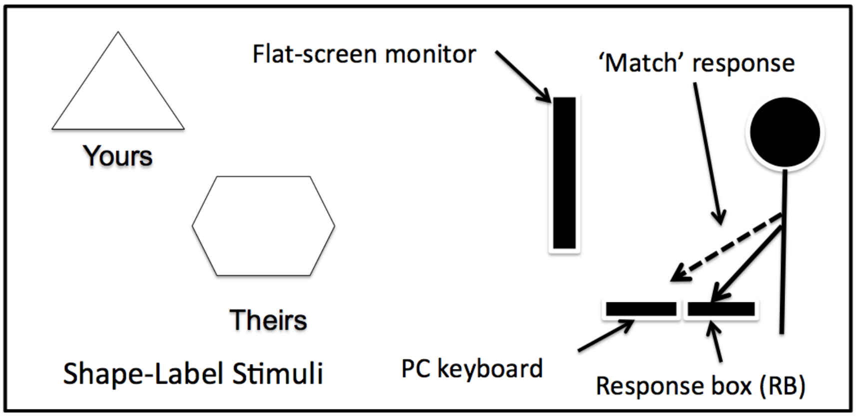

Figure 3.1. The experimental set-up and example stimuli. Participants used one hand to make 'match'-judgment responses, and the other hand to make 'mismatch'-judgment responses. (Adapted from: Desebrock et al., 2018, *Acta Psychologica*, **190**, 258–266, Elsevier.)

effects of self-relevance go beyond those of word concreteness (Wade & Vickery, 2017). Previous studies have used a range of different labels to denote oneself and a stranger in Sui et al.'s (2012) matching task (e.g., you, self, I, stranger, other; Frings & Wentura, 2014; Golubickis et al., 2017; Hu et al., 2020; Sui et al., 2012). The well-established database of concreteness ratings for 40,000 English lemmas (Brysbaert et al., 2014) provides the following ratings for: 'You' (*M* = 4.11, *SD* = 1.22), 'Self' (*M* = 3.13, *SD* = 1.71), 'I' (*M* = 3.93, *SD* = 1.44), 'Stranger' (*M* = 3.76, *SD* = 1.39), 'Other' (*M* = 2.04, *SD* = 1.22). Notably, 'Yours' (*M* = 2.14, *SD* = 1.33) and 'Theirs' (*M* = 2.40, *SD* = 1.40) attracted amongst the lowest ratings for concreteness, and very similar ratings to each other.

3.4.3. Procedure

Each participant completed two experimental testing sessions, 24-h apart. In both sessions, the participants carried out a movement-time adaptation of Sui et al.'s (2012) computer-based matching task[11]. The participants first read onscreen text instructing them to memorize two shape and identity pairings. They associated one of the allocated geometric shapes with themselves (e.g., ‘the triangle is yours’), and a second shape with a named stranger (e.g., ‘the circle is theirs’). The order of instructions pertaining to ‘self’ and ‘stranger’ associations were counterbalanced across participants. The participants then completed the matching task, judging whether simultaneously-presented shape and label pairs matched or mismatched the associations that they had learnt. Before the first trial, and continuously throughout the task, the participants held down both response-box ‘home’ buttons with their index fingers, except when making a response. To make a response, the participants released a response-box ‘home’ button by lifting an index finger and moving the hand forward to depress a target key on the PC keyboard with that index finger. The participants were instructed to make their response to the stimuli as rapidly and accurately as possible, and told that there would be a short response time-limit.

Participants released the right-positioned response box button using their right hand and pressed ‘m’ on the PC keyboard with their index finger for those shape-label pairs they judged as matching. For those pairs judged to be mismatching, participants released the left-positioned response-box button with their left hand and pressed ‘b’ on the PC keyboard with their index finger. Participants thus used their right-hand for match judgements; and their left-hand for mismatch judgements. Hand-match judgment assignments were swapped in the second session. The order of hand-match sessions was also counterbalanced across participants. The setup elicited an arm movement away from the body, at a 20-degree tilt toward the body midline, along the axial plane covering a distance of 14 cm (see Figure 3.1).

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[11] At the start of the first session, participants completed questionnaires measuring individual differences on self-related dimensions (for example, the Self-esteem scale; Rosenberg, 1965). The data from these instruments are not included in this thesis.

Preceding the main task, there was a block of 24 practice trials with a performance-accuracy threshold set at 60% correct (that is, the participants had to achieve 60% correct before they could proceed to the main task). Onscreen feedback was presented (*Correct*, *Incorrect*, *Too Slow*) at the end of each trial. At the end of each block, the participants were informed of their overall accuracy for the block that they had just completed. The matching task consisted of four blocks of 80 trials separated by 8000 ms breaks. There were 320 trials, and four conditions (self-matched, self-mismatched, stranger-matched, stranger-mismatched, with mismatched trials defined by the shape presented); thus, there were 80 trials per condition. Across the two sessions, there were 640 trials, and 160 trials per condition. Each condition occurred equally often, generated at random. A schematic representation of an experimental trial in the matching task is shown in Figure 3.2.

3.4.4. Data analysis

There were four main output measures in the two-stage response: movement initiation time (IT; measured from stimulus onset to the release of the response-box home button) for correctly-initiated movements, and movement execution time (MT; measured from the release of the response-box home-button to the depression of the target key on the PC keyboard) for correctly-initiated and completed arm-movement responses. Also assessed were movement initiation accuracy (*movement initiation PC-1*; the percentage of correctly-initiated movements), and movement execution correct-completion (*movement execution PC-2*; the correctly-completed movement executions, following correct movement initiation, as a percentage of the total number of trials).

In total, there were five possible response outcomes in relation to accuracy in this task: (1) incorrect movement initiation, and incorrect movement execution (i.e. the finger on the incorrect home button was lifted and moved to the incorrect target button, or missed the incorrect target button); (2) correct movement initiation, but incorrect movement execution

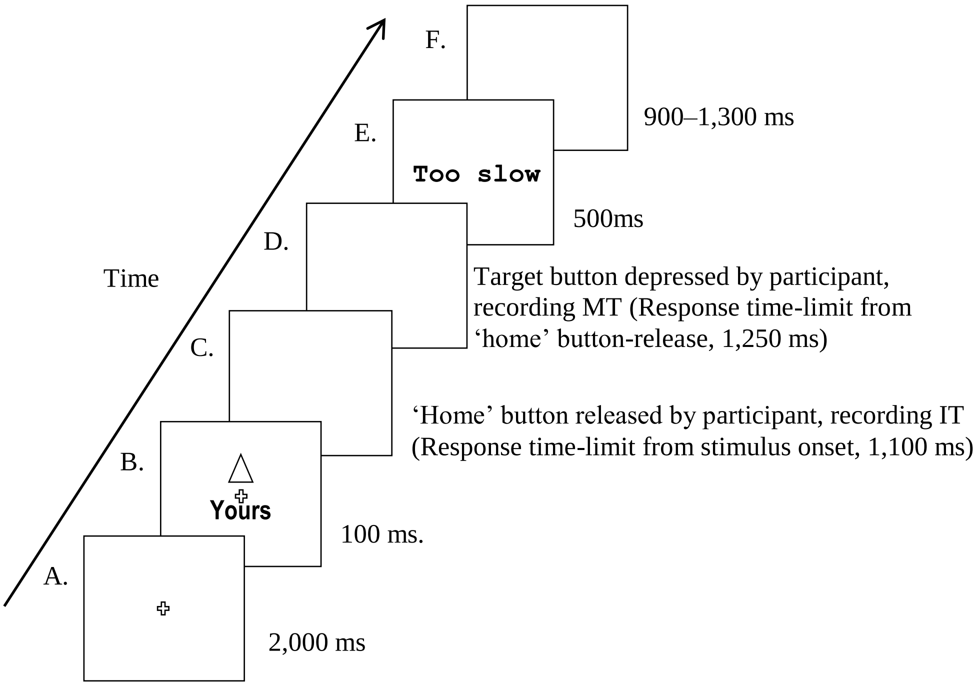

Figure 3.2. Schematic overview of an experimental trial sequence (displayed elements not to scale). **A**. Fixation cross. **B**. Stimulus onset (example shape-label pair shown). **C**. Blank screen. IT = movement initiation time. **D.** Blank screen. **E**. Onscreen feedback— "Correct" / "Incorrect" / "Too slow". **F.** Inter-trial intervals generated at random. IT response time-limit = the time limit measured from stimulus onset within which a participant had to select their response and initiate the onset of the movement by releasing the 'home' button. MT response time-limit = the time limit measured from the release of the 'home' button within which a participant had to complete their movement response by depressing the 'target' button. (Adapted from: Desebrock et al., 2018, *Acta Psychologica*, **190**, 258–266, Elsevier.)

(i.e. the finger on the correct home button was lifted, but the incorrect target button was pressed); (3) incorrect movement initiation, but correct movement execution (i.e., the finger on the incorrect home button was lifted, but the correct target button was pressed); (4) correct movement initiation, and incorrect movement execution (i.e., the finger on the correct home button was lifted, but did not depress the target button, e.g., landed shy of the target button (over- or under-shooting, or slightly to one side)); (5) correct movement initiation, and correct movement execution (i.e. the finger on the correct home button was lifted, and moved to the correct target button). Movement executions were only considered valid and thus analysed if following correct initiation. Across both sessions and the matching and mismatching trials, movement execution errors following correct movement initiation that involved hitting the incorrect target button (i.e. relating to response outcome type 2) constituted <0.03% of the total number of trials, thus suggesting a floor effect and were not analysed further. Errors in valid movement responses thus constituted missing the target key (i.e. response outcome type 4), rather than constituting successfully hitting the wrong target button. For movement initiation accuracy (PC-1), response types 2, 4, and 5 were defined as accurate, and for movement execution correct-completion (PC-2) only response 5 was defined as accurate.

Following previous research (Sui et al., 2012), a signal detection approach was used to calculate an index of sensitivity (D-prime; *d′*; Green & Swets, 1966). Hits were coded as *yes* responses to match trials, and false alarms were coded as *yes* responses to mismatch trials with the same shape; thus, sensitivity scores were derived from right (match)-hand responses only (namely, the same effector). Mismatch conditions were defined as shape-based (i.e., a self-mismatch trial consisted of the self-associated shape and the stranger-associated label, a stranger-mismatch trial consisted of the stranger-associated shape and the self-associated label). ITs were based on correct responses, and ITs faster than 200 ms were trimmed (Golubickis et al., 2017; Lee et al., 2021; Sui et al., 2012), excluding < 2% (220) of the trials. MTs were based on correct movement executions following a correct initiation-response, and MTs greater than 2.5 standard deviations above individual means were excluded (Ratcliff, 1993), eliminating < 2% (173) of the trials in the MT data. MTs faster than 2.5 SDs below individual means were retained since correct MTs could not be executed erroneously too quickly.

Normalised differential scores—self-bias index scores (e.g., Constable et al., 2021; Desebrock & Spence, 2021; Schäfer, Wesslein, et al., 2016; Sui & Humphreys, 2017c)—

were analysed to examine the extent of the self-advantage across the initiation and execution response stages. These scores provide an index of the relative magnitude of the difference in performance between self- and stranger-related responses. Self-bias index scores were calculated using matching-trial ITs, MTs, and the percentage of correctly-initiated and -executed responses (following Sui & Humphreys, 2017c), and are given by the formula: self-bias = "(stranger − self) / (stranger + self)" for the IT and MT metrics, and "(self − stranger) / (self + stranger)" for the percentage of correct scores. Positive values indicate an advantage for self over stranger.

Effect sizes were calculated using Cohen's *dz* for t-tests and partial eta-squared (η_p^2) for Analysis of Variance (ANOVAs; Cohen, 1988; Lakens, 2013). To adjust for multiple comparisons, Holm-Bonferroni corrections at an α value of .05 were applied (Holm, 1979), with unadjusted significance values reported.

3.5. Results

The data from five participants were excluded—one participant completed only one session, two were multivariate outliers (Mahalanobis, 1930), and two performed at chance level ($M <$ 55% accuracy). The data from 30 participants (11 male; age range 19–34 years; mean age and standard deviation, 23.30 ± 3.72) were therefore used in the analyses. A sample size of 30 participants allowed for the detection of an effect size of $\eta^2 = .22$ with a probability of $1 - \beta = .80$, and an alpha value of .05 (MorePower 6.0.4 program; Campbell & Thompson, 2012). For absolute measures in IT, MT, *d'*, movement initiation accuracy (percent correct; PC-1), and movement execution correct-completion (movement execution PC-2), see Table 3.

3.5.1. Movement initiation

Movement initiation times (ITs) were assessed using a 2 (Association: Self vs. Stranger) × 2 (Match condition: Matched vs. Mismatched) × 2 (Hand: Left vs. Right) repeated-measures

Table 3
Mean movement initiation times (IT) and movement times (MT) in ms, percentage of correctly-initiated movements (PC-1), percentage of correctly-completed movement executions (PC-2), and D-prime index scores (*d′*), with standard deviations in parentheses, as a function of Association (Self vs. Stranger), Hand (Left vs. Right), and Match Condition (Matched vs. Mismatched) in Study C3.

			Match condition	
Performance indices	Association	Hand	Matched	Mismatched
IT	Self	Left	657 (73)	752 (66)
	Self	Right	637 (63)	754 (64)
	Stranger	Left	758 (77)	765 (64)
	Stranger	Right	763 (67)	763 (59)
PC-1	Self	Left	99 (2)	95 (6)
	Self	Right	97 (3)	94 (6)
	Stranger	Left	89 (8)	93 (5)
	Stranger	Right	90 (7)	93 (6)
MT	Self	Left	838 (90)	924 (76)
	Self	Right	807 (67)	914 (78)
	Stranger	Left	930 (96)	936 (74)
	Stranger	Right	922 (73)	921 (76)
PC-2	Self	Left	95 (4)	88 (8)
	Self	Right	97 (3)	90 (7)
	Stranger	Left	85 (11)	89 (9)
	Stranger	Right	84 (12)	89 (7)
d′	Self	Left	4.38	
	Self	Right	3.89	
	Stranger	Left	3.10	
	Stranger	Right	3.11	

Note: Adapted from: Desebrock et al., 2018, *Acta Psychologica*, **190**, 258–266, Elsevier.

ANOVA. The analysis revealed a significant main effect of Association, *F*(1, 29) = 149.78, *p* < .001, η_p^2 = .84. ITs for self-related responses were shorter than for stranger-related responses. There was also a significant main effect of Match, *F*(1, 29) = 151.21, *p* < .001, η_p^2 = 0.84. Responses on matched-pair trials were initiated more quickly than on mismatched-pair trials. There was no significant main effect of Hand (*p* = .28); and no interaction between Hand and Match (*p* = .63), or between Association and Hand (*p* = .329). However, there was a significant interaction between Association and Match, *F*(1, 29) = 109.69, *p* < .001, η_p^2

= .79. The hand condition was collapsed, and pairwise comparisons revealed a significant advantage in IT for self- versus stranger-associated shape-label matching pairs, $p < .001$, $dz = 2.44$. There was a significant difference between self-matched and self-mismatched trials, $p < .001$, $dz = 2.78$. Responses to self-associated matched-pair trials were faster than to self-associated mismatched-pair trials. There was no significant difference between self- versus stranger-associated shape-label mismatching pairs, $p = .04$, $dz = 0.39$ (after Holm-Bonferroni correction), or stranger-related matched and mismatched pairs ($p = .59$). There was no three-way interaction between Association, Hand, and Match ($p = .13$). These findings (see Figure 3.3A) replicate the original RT paradigm studies (Sui et al., 2012). Responses were initiated more quickly when responding to self- as compared with stranger-related matching shape-label pairs.

Given that ANOVA is fairly robust to violations of normality (Blanca et al., 2017; Meyners & Hasted, 2021; Schmider et al., 2010), ANOVA was conducted on the PC-1 data (see Section *3.4.4 Data analysis*). The analysis revealed a significant main effect of Association, $F(1, 29) = 49.53$, $p < .001$, $\eta_p^2 = 0.63$, with greater accuracy in self-related responses as compared with stranger-related responses. There was also a significant interaction between Association and Match, $F(1, 29) = 30.70$, $p < .001$, $\eta_p^2 = 0.51$. There was no main effect of Hand ($p = .33$) or Match ($p = .94$), and no interaction between Association and Hand ($p = .16$) or Hand and Match ($p = .86$), and no three-way interaction ($p = .40$). The Hand condition was collapsed and the interaction between Association and Match was probed. Pairwise comparisons revealed a significant difference between self-related and stranger-related matching trial responses, $p < .001$, $dz = 1.33$, between the self-related matching and mismatching trials, $p < .001$, $dz = 0.83$, and between the stranger-related matching and mismatching trials, $p = .001$, $dz = 0.69$. There was no significant difference between stranger-related and self-related mismatching trial responses ($p = .11$). Responses

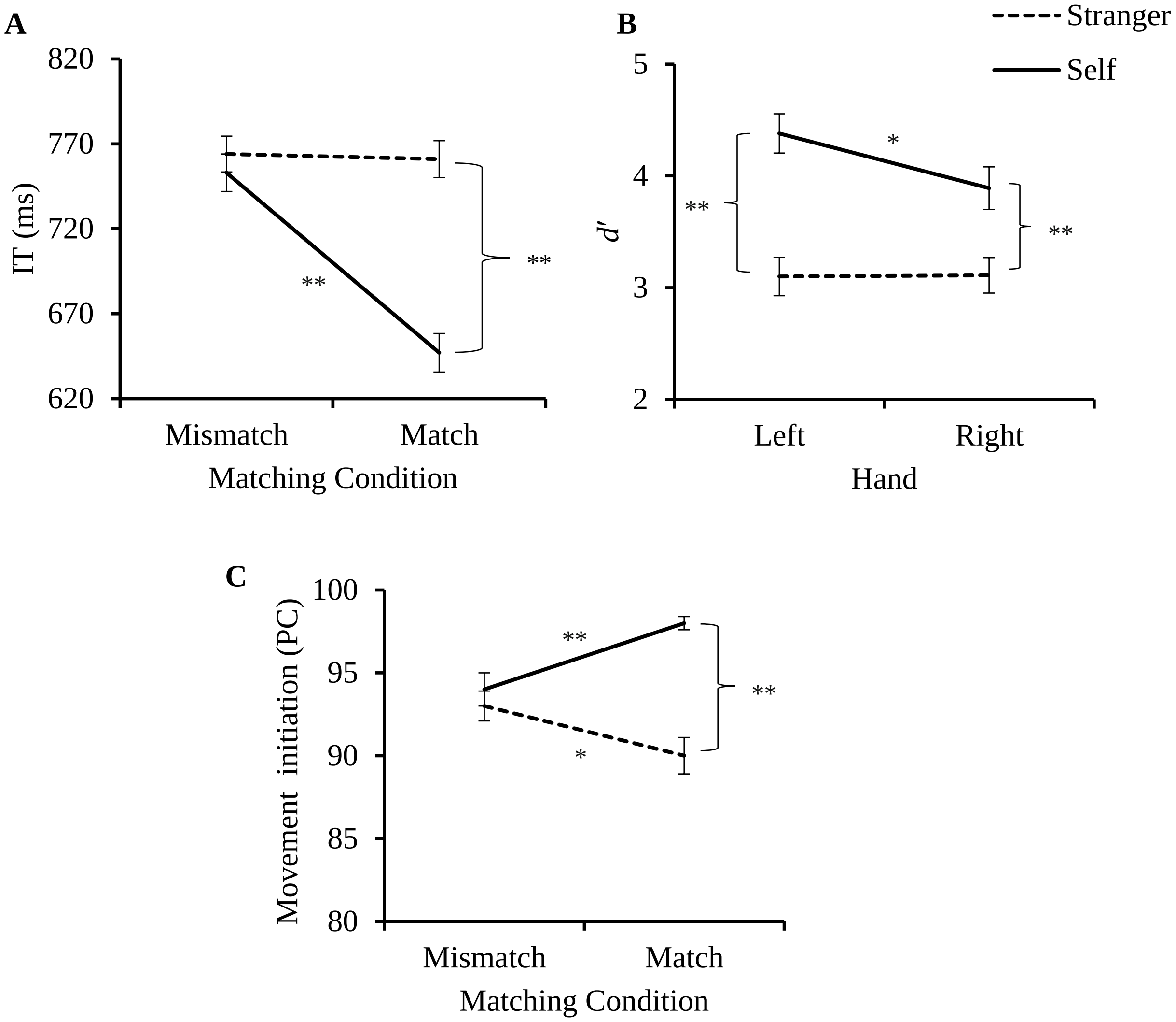

Figure 3.3. A. Estimated marginal means (with Hand condition collapsed) of movement initiation time (IT) as a function of Association (Self vs. Stranger) and Matching condition (Matched- vs. Mismatched-pair trials); **B.** Estimated marginal means of D-prime index scores (*d′*) as a function of Association (Self vs. Stranger) and Hand condition (Left- vs. Right-hand). **C.** Estimated marginal means (with Hand condition collapsed) of movement initiation percent correct (PC) as a function of Association (Self vs. Stranger) and Matching condition (Matched- vs. Mismatched-pair trials) in Study C3. Error bars represent standard errors. *$p < .01$.**$p < .001$. (Adapted from: Desebrock et al., 2018, *Acta Psychologica*, **190**, 258–266, Elsevier).

were most accurate on self-related matching trials, and least accurate on stranger-related matching trials (see Figure 3.3C). Non-parametric tests confirmed the parametric pairwise comparisons.

Following Sui et al. (2012), accuracy performance in movement initiation was also analysed using a signal detection approach. Performance in the match conditions was contrasted with performance in the mismatch conditions (with the same shape) to compute the sensitivity index D-prime (*d′*; see Sui et al., 2012). The *d′* indices were submitted to a 2 (Association: Self vs. Stranger) × 2 (Hand: Left vs. Right) repeated-measures ANOVA which revealed a significant main effect of Association, $F(1, 29) = 58.99$, $p < .001$, $\eta_p^2 = 0.67$. Sensitivity for the self-related condition was higher than on stranger-related trials. There was no significant main effect of Hand ($p = .07$). However, there was a significant interaction between Association and Hand, $F(1, 29) = 5.27$, $p = .03$, $\eta_p^2 = 0.15$. The interaction was decomposed, and pairwise comparisons revealed a significant advantage in sensitivity for right-handed stranger-associated (*M* = 3.11, SD = 0.87) versus right-handed self-associated (*M* = 3.89, *SD* = 1.04) responses, $p < .001$, *dz* = 0.85; between left-handed stranger- (*M* = 3.10, SD = 0.94) versus left-handed self-related (*M* = 4.38, *SD* = 0.96) responses, $p < .001$, *dz* = 1.30; and between left-handed self- (*M* = 4.38, *SD* = 0.96) and right-handed self-related (*M* = 3.89, *SD* = 1.04) responses, $p = .01$, *dz* = 0.48. There was no significant difference between left- and right-handed stranger-related responses ($p = .91$). In sum, self-related responses had a sensitivity advantage over stranger-related responses, and there was a significant interaction across hands driven by an advantage for left-handed over right-handed self-related movement initiation responses. (See Figure 3.3B.)

3.5.2. Movement execution

Movement times (MTs) were assessed using a 2 (Association: Self vs. Stranger) × 2 (Match condition: Matched vs. Mismatched) × 2 (Hand: Left vs. Right) repeated-measures ANOVA. The analysis revealed a significant main effect of Association, $F(1, 29) = 154.90$, $p < .001$, $\eta_p^2 = 0.84$. MTs for self-related responses were shorter than for stranger-related responses. In contrast to the IT findings, there was a significant main effect of Hand, $F(1, 29) = 23.69$, $p <$

.001, $\eta_p^2 = 0.45$. MTs were shorter when participants used their right (dominant) hand as compared with the left (non-dominant) hand. As with the ITs, there was a significant main effect of Match, $F(1, 29) = 129.68$, $p < .001$, $\eta_p^2 = 0.82$. MTs to Matching pairs were faster than to Mismatching pairs. Similarly, there was a significant interaction between Association and Match, $F(1, 29) = 106.75$, $p < .001$, $\eta_p^2 = 0.79$. This indicated that, as with the ITs, there was a different pattern in the execution of responses to the self- versus stranger-associated shapes dependent on whether they were presented in Matched- or Mismatched-pair trials. As with ITs, there were no other significant interaction effects (see Figure 3.4A). These results show that MT followed the same pattern across hands as IT in terms of an advantage for self, except that, in contrast to the IT findings, left-hand responses were slower across conditions (a finding consistent with research documenting that dominant (right)-hand aiming movements tend to be faster; e.g., Olex-Zarychta & Raczek, 2008).

The Hand condition was collapsed and the Association and Match interaction probed using pairwise comparisons. The analysis revealed a significant difference in MTs for the matching self- versus stranger-associated shape-label pairs, $p < .001$, $dz = 2.46$. MTs for the matched self-associated pairs were faster than to the matched stranger-associated pairs. A significant difference was also revealed between MTs for self-associated matched and mismatched pairs, $p < .001$, $dz = 2.78$; responses to the matched self-associated pairs were faster than to the mismatched self-associated pairs. No significant difference was revealed between MTs for the mismatching self- versus stranger-associated shape-label pairs, $p = .05$, or MTs for stranger-associated matched and mismatched pairs, $p = .63$. MTs for self-associated matched pairs were faster than in any other condition. There was no difference in MTs between the stranger-match and mismatch conditions. (See Figure 3.4A.)

Movement execution PC-2 data (correctly-completed movement executions, following correct movement initiation, as a percentage of the total number of trials) were submitted to a 2 (Association: Self vs. Stranger) × 2 (Match condition: Matched vs. Mismatched) × 2 (Hand: Left vs. Right) repeated-measures ANOVA. The analysis revealed a significant main effect of Association, $F(1, 29) = 61.90$, $p < .001$, $\eta_p^2 = 0.68$, with greater accuracy in self-related as compared with stranger-related responses. In contrast to the MT data, there was no main effect of Hand ($p = .38$), or Match ($p = .13$). As with the MT data, there was a significant interaction between Association and Match, $F(1, 30) = 41.71$, $p < .001$, $\eta_p^2 = 0.59$, and no interaction between Association and Hand ($p = .19$), or Hand and Match ($p = .69$), and no three-way interaction between Association, Hand, and Match ($p = .71$).

The Hand condition was collapsed, and the interaction probed using pairwise comparisons. The analysis revealed greater accuracy in self-related than stranger-related matching-trial responses, $p < .001$, $dz = 1.33$, and in matching self-related than mismatching self-related responses, $p < .001$, $dz = 0.83$. In contrast to the MT data, there was also a significant difference between stranger-related matching and mismatching responses, $p = .001$, $dz = 0.69$, with greater accuracy in stranger-related mismatching responses. There was no significant difference between self-related versus stranger-related mismatching responses ($p = .18$). Non-parametric tests confirmed the parametric pairwise comparisons. A higher percentage of movements were correctly-executed in the self-related matching condition than in any other condition. Responses were least accurate in the stranger-matched-pair condition (i.e., when neither the self-label nor self-shape was presented). (See Figure 3.4B.)

3.5.3. Comparing self-bias in initiation and execution response stages

To assess whether the extent of the self-advantage was moderated across the two-stage response, the self-advantage in ITs and MTs, and in the percentage of correctly-initiated and correctly-executed movement responses, were compared using normalized self-bias index scores. A paired-samples *t* test revealed a significant difference in self-bias between IT

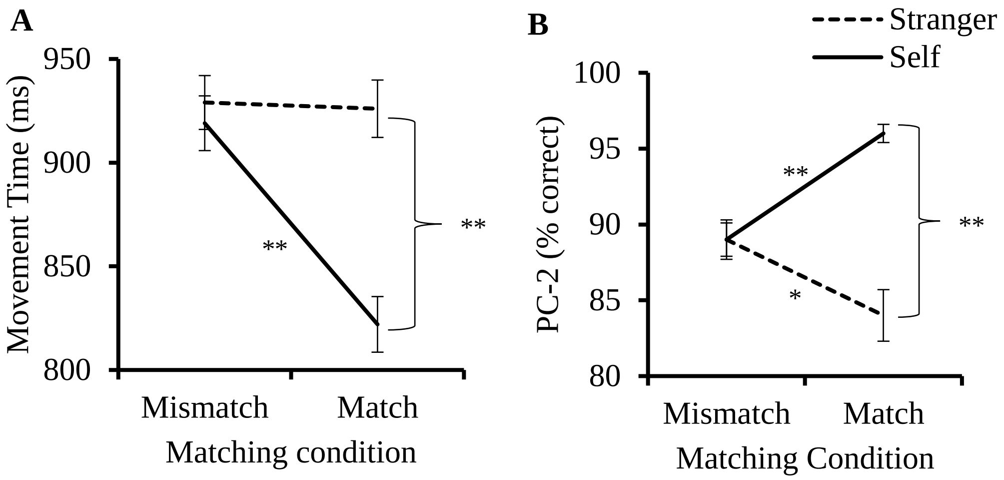

Figure 3.4. Estimated marginal means (with Hand condition collapsed) of: **A**. Movement Time (MT) as a function of Association (Self vs. Stranger) and Matching condition (Matched- vs. Mismatched-pair trials); **B.** Percentage of correctly-completed movement executions (PC-2) as a function of Association (Self vs. Stranger) and Matching Condition (Matched- vs. Mismatched-pair trials). Error bars represent standard errors. **p* < .01. ***p* < .001. (Adapted from: Desebrock et al., 2018, *Acta Psychologica*, **190**, 258–266, Elsevier.)

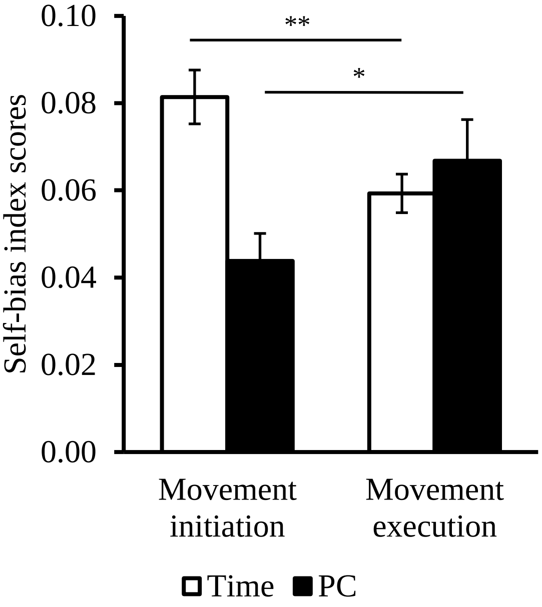

Figure 3.5. Time = IT/MT in ms, PC = percent correct. Extent of the self-advantage (self-bias index scores) in movement initiation time (IT), movement execution time (MT), percentage of correctly-initiated movements (PC-1), and percentage of correct movement executions (PC-2) as a function of response stage (movement initiation, movement execution). Error bars represent standard error. **p* < .01, ***p* < .001. (Adapted from: Desebrock et al., 2018, *Acta Psychologica*, **190**, 258–266, Elsevier.)

(*M* = 0.08, *SD* = 0.03) and MT (*M* = 0.06, *SD* = 0.02), *t*(29) = 9.86, *p* < .001, *dz* = 1.80. Self-bias in IT was significantly greater than in MT. A paired-samples *t* test confirmed by non-parametric tests was also used to assess the change in the extent of self-bias in percent correct across movement initiation (PC-1) and movement execution (PC-2; see Section *3.4.4 Data analysis*). A significant difference in self-bias was revealed between movement initiation accuracy (PC-1; *M* = 0.04, *SD* = 0.03) and the percentage of correctly-completed movement executions (PC-2; M = 0.07, SD = 0.05), *t*(29) = 3.50, *p* < .001, *dz* = 0.64, with a larger magnitude of self-bias in movement execution (see Figure 3.5). Non-parametric tests confirmed the results of the parametric test.

3.6. Discussion

This chapter examined whether self-relevance in Sui et al.'s (2012) matching task can influence the execution of rapid-aiming goal-directed arm-movement responses. Consistent with previous studies measuring the total response time of button-presses (Sui et al., 2012), a self-advantage in the speed and accuracy of button-*release* responses (movement initiation—i.e. ITs) was documented in the present study. In a novel result, a self-advantage was also revealed in MTs and the percentage of correctly-completed movement executions (PC-2). Furthermore, the extent of self-bias was altered across the two-stage response: the self-advantage in IT was greater than in MT, and the self-advantage in the percentage of correctly-completed responses was greater in movement execution than movement initiation. In line with the alternative hypothesis, these findings demonstrate an advantage in both button-releases and the execution of movement responses to the self-associated stimuli relative to the stranger-associated stimuli. This chapter thus provides preliminary evidence that self-bias can modulate the execution, as well as initiation, of manual responses in the matching task.

3.6.1. Self-bias and the motor-stage

In the one other study to examine self-bias in the motor-stage of responses in the matching task, Janczyk et al. (2019) documented that the motor-stage did not contribute to the self-advantage in total response times (RT)[12]. The null hypothesis of the present study was that the motor-stage of responses to self- and other-related stimuli should be equivalent. In other words, MTs and the percentage of correctly-completed movement executions should not differ significantly across the self- and stranger-match conditions. This scenario and Janczyk et al.'s findings in respect of the motor-stage are depicted in Figure 3.6.

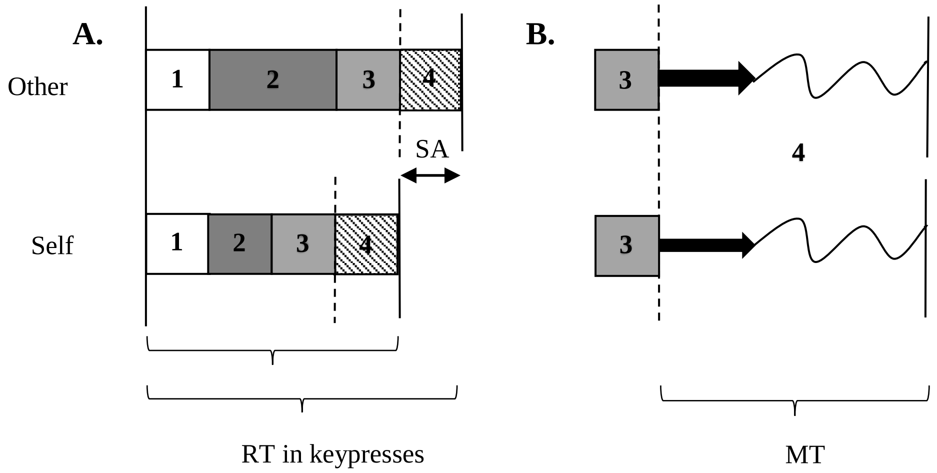

Figure 3.6. A. Representation of Janczyk et al.'s (2019) conception of where the self-advantage (SA) arises in keypress responses in Sui et al.'s (2012) matching task. Other = other-associated matched trial responses. Self = self-associated matched trial responses. RT denotes the interval between stimulus onset to response completion in keypress responses and includes 1. *perceptual;* 2. *central;* 3. *motor-specific preparatory;* and 4. *overt movement execution* stage processes. In the present study, IT is the interval between stimulus onset and button release (i.e. 1–3). movement execution processes include both (box 3) preparatory motor activity and (box 4) online correction control (Allsop et al., 2017; Khan et al., 2006). Dotted lines represent the moment at which the overt movement begins and IT ends. Solid lines represent stimulus onset or response completion. **B.** Representation of the motor-stage. MT denotes the interval from movement onset (button release) to movement completion. (NB. MT in keypresses is subsumed within RT). The one-way arrows represent the initial impulse of the overt movement reflecting motor planning processes that occur prior to movement onset. The wavy lines represent online correction processes that occur post-movement-onset during movement execution (Allsop et al., 2017; Khan et al., 2006). [NB. In speeded tasks, online correction of discrete keypress responses does not typically occur (Oulasvirta, Kim, & Lee, 2018)]. Shown here is the hypothetical case in which there is no modulation of movement execution processes by self-relevance, with movement preparation yoked to the initiation of the overt movement. (NB. That movement preparation and initiation are yoked is an implicit assumption of Janczyk et al.'s study and traditional stage-model theory (cf. Haith et al., 2016). (Adapted from: Desebrock et al., 2018, *Acta Psychologica*, **190**, 258–266, Elsevier).

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[12] Movement completion accuracy performance was not measured in this study (Janczyk et al., 2019) and would be at ceiling for the study's keypress responses.

In contrast to the hypothetical case depicted in Figure 3.6, the findings of the present study clearly demonstrate that a self-advantage arose in movement execution (cf. 4, Figure 3.6B). Thus this chapter provides the first evidence that movement execution processes can be modulated by the social relevance of the stimuli in the matching task. Theoretical accounts of why movement execution should be modulated in the task and why these effects may or may not differ across different types of motor response are discussed below.

3.6.2. Perceptual self-bias in action

It was theorized in the Introduction that self-bias may exert an influence on movement execution through bottom-up (rapid chase) processing, or via top-down later recurrent and online processing, as conceptualised in perception-to-action models in response priming paradigms (F. Schmidt et al., 2011; T. Schmidt et al., 2006; T. Schmidt & Seydell, 2008). For example, self-relevance is thought to 'prime' attentional responses in the pSTS to self-stimuli via activation of the vmPFC (Humphreys & Sui, 2016), and effects of self-associated stimuli have been compared to those of highly perceptually-salient stimuli (Humphreys & Sui, 2015; Sui et al., 2012; Sui, Liu, et al., 2013). Response priming research indicates that visual attention can intensify the first waves of bottom-up visuomotor processing (Schmidt & Seydell, 2008), and higher-intensity stimuli have been linked to increased feed-forward activity (Schmidt et al., 2006), and response force (Ulrich et al., 1998).

In one account, bottom-up processes in the form of an initial feedforward rapid sweep (Schmidt et al., 2006) may boost self- relative to stranger-related responses. Indeed, in response priming paradigms when the prime stimulus is mapped to the same keypress response as the target stimulus (i.e., in compatible trials), responses are faster and more accurately-selected than when different responses are mapped to these stimuli (i.e., incompatible trials; Bermeitinger & Wentura, 2016). Response priming theory also holds that when stimuli match expectations regarding their assigned response, the corresponding motor response is triggered directly (Kiesel et al., 2007). Self-associated stimuli may prime ‘match-hand’ motor responses. Indeed, movements initiated earlier tend toward default responses (Haith et al., 2016). It may be then that self-related responses are characterised by faster bottom-up processes, reflected in shorter ITs, which allow self-related movements to be fully-prepared prior to their onset, within the response time limit. Conversely, preparatory activity may build more slowly in stranger-related movements that are then not fully-prepared upon release; thus, a lower percentage of stranger-related movements are correctly-completed. An increased movement vigour signal (Reynaud et al., 2020) may then account for the shorter MTs in self-related as compared with stranger-related movement executions.

There are, however, a number of issues with this account. Given that stranger-related responses were released on average around 761 ms after stimulus onset and the response time limit was 1,100 ms it seems unlikely that stranger-related movements were not fully-prepared. Furthermore, faster responses are associated with increased EMG activity build up (in the late stages of motor processing) resulting in increased overt errors (Speiser et al., 2017), thus self-related movements should be less accurate. The notion that only movement vigour modulates movement execution across the self- and stranger-related conditions is also problematic. If one assumes that both self- and stranger-related movements are fully- and equivalently-prepared prior to their onset, then one would expect to observe faster MTs in the self-match condition and the same percentage of correctly-completed movement executions for both self- and stranger-match conditions. Alternatively, if increased movement vigour in self-related responses interacts with the motor plan causing, for example, overshooting of the target (increased errors; Speiser et al., 2017), one would expect to see faster MTs and a lower percentage of correctly-completed movement executions in the self-match condition, which was not observed.

Another possibility is that differential priming effects across the shape-label combinations may have impacted movement execution. For example, if the self-associated elements (shape or label) prime the match-hand response, a correct mismatch response would involve inhibition of the default response prior to movement onset and reselection of the mismatch-hand response. By contrast, a correct stranger-match response may involve inhibition of the mismatch-hand response—self-associations have been documented to interfere with associations between other stimuli and the self due to a glue-like binding effect (Humphreys & Sui, 2016; Sui, 2016; Wang et al., 2016); if this binding includes the self-linked response, a stranger-related response may tend to prepare the ‘not-match’ hand. In both cases, re-selection (prior to movement onset) in the stranger-match and mismatch conditions could account for the slower ITs (and also the lower movement initiation accuracy due to inhibition failures). However, it is not clear why such delays during movement initiation should impact both the duration and accurate completion of the overt movement responses.

If self- and stranger-related responses use the same motor preparation, then, as noted, the sped-up motor preparation (EMG recruitment) in self-related responses should result in less accurate movements relative to stranger-related responses (Speiser et al., 2017). Therefore, if the motor preparation is completed more quickly *and* more accurately in self-related responses, a different motor plan or online control policy must be implicated. Indeed, self- and stranger-related responses might differ in respect of the top-down control involved in their execution, and at what point this takes control of responses. In response priming, large priming effects are observed when factors such as saliency boost the initial rapid bottom-up processes of the ‘feedforward sweep’ (T. Schmidt et al., 2006). These processes drive movement execution for longer before top-down recurrent processing takes over control (e.g., Schmidt & Seydell, 2008). Conversely, in the slower stranger-related responses, recurrent processes may engage top-down control by the time of movement onset and, thus, throughout the movement. Slower responses are less likely to be feed-forward driven (Schmidt & Schmidt, 2009). Again, however, such differences in online control do not account for the significantly higher percentage of correctly-completed movement executions in the self-related condition. Increased online control would be expected to enhance endpoint accuracy in stranger- relative to self-related movements should their motor preparatory processes be equivalent.

3.6.3. Decisional self-bias in action

An alternative proposition is that self-bias in movement execution is not linked to a modulation of perceptual processes, and may instead reflect a top-down explicit bias in self-related movements. Although some recent studies support the view that self-bias does reflect a modulation at the perceptual level (Golubickis et al., 2017; C.-P. Hu et al., 2020; Svensson et al., 2021), other research has suggested that the self-advantage arises in later-stage decision-making or memory processes (Janczyk et al., 2019; Reuther & Chakravarthi, 2017; Siebold et al., 2015; Stein et al., 2016; Y. Zheng et al., 2022). Once the response is selected, movement execution may be under the control of a form of explicit, decisional response bias. Notably, self-ownership prioritization—a related phenomenon—has been found to constitute a top-down decisional response bias (Golubickis et al., 2018). Decisional processes may leak into, and thereby influence, movement responses. For example, modulations of movement in mouse-tracking studies are thought to reflect changes of mind on the part of the participant (Grage et al., 2019). In the present study, however, the button being released (the choice) indicated the motor decision (effector and target) with no possibility of correction once released. In such set-ups, response selection processes are understood to occur prior to the onset of the movement (Rubichi & Pellicano, 2004; Scorolli et al., 2015). Indeed, errors in valid movement responses constituted missing the target key, rather than reflecting a change-of-mind response and pressing the wrong target button (see Section *3.4.4. Data analysis*).

Notably, however, the movement response used in the present study was not ballistic (Glover, 2004; Khan et al., 2006). It is therefore possible that participants could have made *explicit* online adjustments to the movement to favour the self-related response[13]. Janczyk et al.'s (2019) findings appear to support this notion. As noted, the authors documented that the duration of the motor-stage was not modulated in button-press responses in the matching task. In speeded tasks, online correction of discrete keypress responses does not typically occur (Oulasvirta, Kim, & Lee, 2018). It may be that a self-advantage in overt movement in the matching task arises due to certain features of arm-movement responses that do not characterise keypress responses. Visual information pertaining to hand or target position was not relevant to, or requisite for, completing the discrete button-press responses in Janczyk et al.'s study (albeit that visual feedback was available in the sense that participants could see their fingers resting on the keys). Indeed, Janczyk et al. note that their finding pertaining to the motor-stage was "only preliminary given that [their participants made] discrete keypress responses, instead of, for example, continuous mouse movements" (Janczyk et al., 2019, p. 1080).

Another feature of the arm-movement responses in the present study is that they were directed toward the stimuli. Effects of self-relevance in arm-movements could potentially be driven by differences in *approach-avoidance motivation* (Elliot, 2006; Kozlik et al., 2015; Solarz, 1960). The evaluation of positive stimuli is thought to activate affective S-R compatibility mechanisms automatically which facilitate arm-movements that serve to *visibly* decrease the distance between the self and these stimuli (Kozlik et al., 2015; Krieglmeyer et al., 2013; Markman & Brendl, 2005; Piqueras-Fiszman et al., 2014; Seibt et al., 2008). Indeed, Barton et al. (2020) recently documented that effects of ownership arose in MT as

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[13] N.B. The ballistic phase or 'initial impulse' of arm-movements is subject to a form of automatic online control (Elliott et al., 2010); see Chapter 5.

well as IT only when responses were directed towards and not away from the stimuli. The modulation of movement execution in the present study may thus be underpinned by explicit biases (such as demand characteristics) or automatic affective compatibility (approach motivation). These possibilities are tested in Chapter 5.

3.6.4. The two-stage response

One key feature of the methodology used in the present study was the separate measurement of movement initiation and execution. There has been much debate concerning whether and how the two stages are linked (Frowein & Sanders, 1978; Haith et al., 2016; Phillips & Glencross, 1985; Reynaud et al., 2020; Weinberg, 2016). Haith et al. (2016) propose, for example, that movement preparation and movement onset are independent. Weinberg (2016) offers a modification of Haith et al.'s proposition entailing that the levels of two signals (a decision urgency signal and preparatory processes) instead combine to determine IT (and movement onset), drawing on Cisek et al.'s (2009) urgency-gating evidence accumulator model. The decision urgency signal is thought to arise in the basal ganglia and also regulates the vigour (speed and size) of movements (Thura et al., 2014; Thura & Cisek, 2017). Both decision-making and motor control were thought to be invigorated by this same signal, in the 'shared-regulation' hypothesis. However, more recently, Reynaud et al. (2020) have corrected this earlier contention, demonstrating that decision urgency and movement vigour signals are in fact independent, albeit interacting, signals, probably coordinated in the basal ganglia. This proposal is also consistent with earlier work documenting that lateralised movement-related EEG amplitudes at movement onset are independent of RTs but have a fixed relationship with movement onset (Gratton et al., 1988; Praamstra et al., 2014). Furthermore, Barton et al. (2020) documented that self-bias in an ownership paradigm emerged in IT and MT when arm-movements were directed towards the stimuli, but only in

ITs when movements were directed away from the stimuli, consistent with the notion that IT and MT are independent.

In the present study, the *extent* of the self-bias was also significantly different across the response stages. Self-bias in IT was greater than in MT, and self-bias in the percentage of correct responses was greater in movement execution than movement initiation. If the premotor processes (perceptual or decisional or both) are simply reflected in the overt movement response then one would expect to observe that correctly-selected responses should go on to be correctly-completed at an equivalent rate across self- and stranger-match conditions. Similarly, if the speed of premotor processing is directly reflected in MTs, again one would expect to observe an equivalent magnitude of self-bias in the normalised differential scores in IT and MT across stages. One objection to this contention is that the speed of initiation processes simply translates into movement speed which then interacts with the mechanics of the motor response, reducing the self-bias in movement execution relative to movement initiation. As noted, however, the decision urgency and movement vigour signals are independent. Furthermore, in Chapter 5, the type of motor response was manipulated across experiments, and the extent of self-bias in MT was not moderated (in contrast to self-bias in the accurate completion of the movement responses, which was modulated). If self-bias in IT interacts with the mechanics of the motor response, it should be expected to change across different types of motor response. These findings therefore suggest that the extent of self-bias in MT does not simply reflect an interaction of premotor self-bias in IT with the mechanics of the motor response.

3.6.5. Limitations and conclusions

As this is the first study to evidence that a self-advantage emerges in overt movement responses in the matching task, future studies are needed to test the robustness and reliability of these findings; for example, using different types of motor response (Chapter 5) and stimulus combinations (Chapter 6). In addition, other factors such as explicit online control or automatic affective compatibility may (part) account for the movement modulation—these possibilities are investigated in Chapter 5.

In sum, the present study demonstrates that arm-movement execution in the matching task is modulated by the newly self- and stranger-associated stimuli. Providing preliminary evidence that self-bias can modulate the execution as well as initiation of motor responses in the matching task, these findings are thus aligned with research suggesting that self-bias has an influence at multiple-stages (Humphreys & Sui, 2016; Scheller & Sui, 2022b; Sui & Humphreys, 2015a; Woźniak et al., 2018). The present findings contrast however with Janczyk et al.'s (2019) study which documented that the motor-stage of keypress responses was not influenced by self-bias. One might conclude then that self-bias does not modulate the motor-stage of keypress responses, and that effects must be specific to (certain kinds of) arm-movement responses. Before further examining self-bias in arm-movement responses in this thesis, however, Chapter 4 first takes a closer look at the theoretical framework and methodology of Janczyk et al.'s study to ascertain to what extent such a conclusion is warranted.

Chapter 4—The self-advantage at the motor stage: A single-study review (Study C4)[14]

4.1. Chapter overview

Chapter 3 demonstrated that self-bias influences the execution of arm-movement responses in Sui et al.'s (2012) matching task. In another study, however, the authors documented that the motor-stage was not influenced by self-bias (Janczyk et al., 2019). In contrast to Chapter 3, the latter study used discrete keypress responses rather than arm-movement responses. It might therefore be interpreted from these collective findings that the self-advantage in overt movement depends on response features that characterise arm-movements but not keypresses. Before this hypothesis was tested in Chapter 5, however, Chapter 4 reviews the findings of the contrasting study (Janczyk et al., 2019). The aim of the present study was to take a closer look at the extent to which the evidence supports the conclusion that a self-advantage does not arise in the motor-stage of keypress responses.

The contrasting study (Janczyk et al., 2019) is re-examined in terms of a theoretical framework in the motor-control and neuroscience literature which holds that movement preparation and movement onset constitute independent processes. Closer inspection of task processes reveals plausible alternative mechanistic accounts of the dual-task study's findings, supported by the data, which leave open whether self-bias influenced the motor-stage. Strengths of the methodology used in Chapter 3 (Desebrock et al., 2018) in respect of accommodating mechanisms of motor processes are also highlighted. This review finds that

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[14] It was determined by the Officer of the Oxford University Medical Sciences Interdivisional Research Ethics Committee that this theoretical review study did not require ethical review (Reference: R67916/RE001).

there is no clear evidence for the absence of a self-advantage in the motor-stage of keypress responses in the matching task.

4.2. Ostensibly inconsistent findings across two studies

Chapter 3 investigated self-bias beyond response selection and documented that self-relevance in the matching task influenced the execution of arm-movement responses. Contrasting with the findings of Chapter 3, another study documented that the duration of the motor-stage did not contribute to the self-advantage in keypress responses (Janczyk et al., 2019). Both studies used adaptations of the matching task, yet their findings were ostensibly inconsistent. Potential accounts for the null finding of the contrasting study (Janczyk et al., 2019), might be attributed to: (1) contextual specificity (e.g. the type of response used); (2) a methodological limitation (e.g. pertaining to the mechanistic framework against which the study was set); (3) insufficient power to detect the size of effects; or (4) other issues bearing on replicability.

Regarding sufficient power, the effect-size detectable in Janczyk et al.'s (2019) Experiment 4 with 24 participants, an alpha value of .05, and a probability of $1 - \beta = .80$ was $dz = 0.60$. Given that the self-advantage in previous studies was $dz > 0.81$ (Sui et al., 2012), this experiment was therefore sufficiently powered, at least to detect a smaller than standard self-advantage in the motor-stage of responses. The present chapter examines (2). Chapters 5 and 6 of this thesis speak to (1) and (4), and examine (1) across three experiments.

4.3. Reviewing preliminary findings of a single study

Convergent experimental work in tandem with theoretical review contribute to optimal progress of a research area. Arguably, reviewing inconsistent findings as they arise—even before replicability of (sufficiently powered) single-study findings has been established—also has added value in this endeavour. Janczyk et al. note that their findings pertaining to the motor-stage were “only preliminary given that [their participants made] discrete keypress responses, instead of, for example, continuous mouse movements” (Janczyk et al., 2019, p. 1080). However, a dedicated review of a single study affords a more in-depth analysis and inspection of task processes, mechanistic assumptions, and methodological issues than is typically possible in an experimental paper. Findings can serve to motivate and inform further investigation where, without query, preliminary findings can otherwise be tacitly adopted as established building blocks for future research. Null findings, for example, can be interpreted as signalling dead ends, prematurely curtailing research interest. The relative strengths and weaknesses of the methodologies used across studies can also be highlighted, informing future study planning. Therefore, the present study reviewed the preliminary findings of Janczyk et al.’s (2019) Experiment 4.

4.4. Self-relevance in the matching task does not influence the motor-stage: Dual-task findings

Since the introduction of the matching task (Sui et al., 2012), which was originally assumed to index perceptual processes, it has been highlighted that the gross behavioural outcome measures do not permit inferences to be made about the processes that are modulated in the task (Reuther & Chakravarthi, 2017; Scheller & Sui, 2022a). Janczyk et al. (2019) note that they attempt to overcome this limitation by using a dual-task Psychological Refractory Period (PRP) paradigm to pinpoint the processing locus of self-bias.

In the context of stage-model theory, dual-task (PRP) methodology helps to delineate contributions from the respective processing stages on RT. In one version of the dual-task procedure, participants carry out two tasks per trial elicited by two different stimuli that are presented at staggered onsets, or SOAs. For example, participants may be instructed to respond to auditory stimuli using left-hand button-presses, and to visual stimuli using right-hand button presses, within the same trial. Dual-task studies traditionally rely on a central-bottleneck-model theoretical framework (Janczyk et al., 2018; Pashler, 1984, 1994; A. T. Welford, 1952) against which to base interpretations of the RT outcome measures. The central-bottleneck model draws on traditional stage-model theory and assumes that information processing proceeds sequentially through the perceptual stage, central-stage (response selection), and the motor stage (response execution). When two tasks are underway, the central-bottleneck model holds that the perceptual-stage and motor-stage processing of one task can be carried out in parallel alongside any processing stage of the other task. By contrast, central-stage processing is ‘capacity limited’, and only one task response can be processed through the central stage at any one time. Priority is given to the task response that gets to this stage first.

In Janczyk et al.'s (2019) particular procedure (drawing on the central-bottleneck framework), participants carried out two tasks per trial in a fixed order. Each task required a particular response to a single stimulus (i.e., a depression of one of two designated buttons), and the two stimuli were separated by either a short (50 ms) or long (1,000 ms) SOA. Responses for Task 1 used the right-hand, while Task 2 responses used the left hand. Thus, at the long SOA, the response in Task 1 is assumed to proceed without interference, followed by the response in Task 2, which is similarly unobstructed. However, at the short SOA, the perceptual-stage processing of Task 2 is assumed to finish before the Task 1 response has cleared the central stage, and so the response processing associated with Task 2 is delayed. This ‘waiting time’ is referred to as the PRP or *cognitive slack* (Janczyk et al., 2019; Van Selst & Jolicoeur, 1994). The waiting time that arises before Task 2 processing can proceed through the central stage eliminates any response time advantages in relation to perceptual processes for Task 2. Effects in perceptual processing in Task 2 responses are thus absorbed into the cognitive slack. Therefore, if Task 2 effects persist undiminished at the short SOA, one can conclude that the locus of the effect in question does not reside in the perceptual stage.

Janczyk et al. (2019) used this logic in their first three experiments to examine whether there was a self-advantage in perceptual processing and found no evidence of a perceptual modulation (cf. Golubickis et al., 2017). Their fourth experiment investigated whether the motor stage contributed to the self-advantage. The authors assigned the matching task as Task 1, and an auditory discrimination task (discriminating a high from a low frequency sound stimulus) as Task 2. Following Sui et al.'s (2012) procedure, the participants were instructed to associate three geometric shapes (i.e., neutral stimuli) with 'self', 'stranger', and 'friend' labels (e.g., self = triangle, stranger = square, friend = circle). The participants then carried out the matching task (Task 1) in which they indicated using discrete button-presses whether the sequentially-presented shape-label pairs matched (e.g., self–triangle) or if they did not (e.g., self–square). As per the standard matching task, evidence of an SPE in total response time consisted in the observation of a significant advantage in RT, or both RT and accuracy, for matching self- as compared with stranger- and friend-associated matching responses. Janczyk et al. reasoned (following *effect propagation logic*; Janczyk, Renas, et al., 2018) that a manipulation affecting only the motor-stage of Task 1 responses should not be observed in Task 2 responses at either SOA. If, however, the SPE arises in central processes, then one should see this manipulation reflected in Task 2 RTs at the short SOA. As outlined in Chapter 1, however, research has suggested that self-relevance in the matching task can act across multiple stages of information processing (e.g. Sui & Humphreys, 2015a). Accordingly, Janczyk et al. note that self-bias could potentially influence both the central and motor stages. If so, then the manipulation should again be observed in both task responses at the short SOA, but the extent of the self-bias should be more marked in Task 1 responses given that self-associated responses would receive an additional boost through the motor stage not available to Task 2 responses.

Janczyk et al. (2019) documented that at both the short and long SOA there was a self-advantage in Task 1 responses. Most importantly, the authors observed a corresponding pattern in responses in Task 2 at the short SOA (although, as they note, surprisingly also at the long SOA—a point returned to below in Section 4.6. *Alternative processes underlying the dual-task responses*). The differences between self-related versus friend-related and self-related versus stranger-related responses were not significantly different in magnitude across Tasks 1 and 2. In other words, they did not find a larger self-bias in Task 1 than in Task 2. In line with their conceptual framework, the authors therefore concluded that no self-advantage arose in the motor-stage. The authors concluded that the self-advantage arises neither in perceptual processing (Experiments 1–3) nor in the motor stage (Experiment 4), but rather in the central-stage of information processing. This stage is thought to include encoding into short-term memory (Jolicoeur & Dell'Acqua, 1998), selection into and switching between items in working memory (Janczyk, 2017), and response selection (Janczyk & Kunde, 2020; A. T. Welford, 1952), but excludes the motor stage (Janczyk et al., 2019; Pashler, 1994). Janczyk et al.'s findings in respect of the motor-stage are depicted in Figure 3.6 (Chapter 3).

4.5. (Tacit) assumptions about the motor-stage

PRP paradigms and the dual-task methodology outlined above rely on traditional stage-model theory which holds that processing proceeds in a serial manner, directly from one stage to the next. Thus a tacit assumption of stage-model theory is that preparatory motor activity and movement onset are necessarily yoked (cf. Haith et al., 2016). That is, movement onset is assumed to be triggered directly upon the completion of the preparatory motor activity. On the contrary, other research in the neuroscience and motor-control literature has highlighted that this is not necessarily the case (Franz et al., 1996; Haith et al., 2016; Ivry, 1997).

Movement onset can be delayed post preparation, resulting in longer-than-necessary ITs for achieving accurate responses on speeded tasks (e.g. Haith et al., 2016). Furthermore, decision-to-motor processing itself is not serial (Cisek, 2007; Kaufman et al., 2015). Preparatory 'motor' activity can also reflect vacillation, or hesitation, during the decisional process (Kaufman et al., 2015). The moment when neural activity begins to activate the motor cortices is not necessarily the moment a decision is finalized (Schurger et al., 2012). In other words, responses can be selected, unselected, and re-selected and held for a period of time before a commitment to a response is made. Therefore, these findings raise a caveat with regard to making inferences about motor-stage processes from total response time measures, even within a dual-task context. Notably, Kaufman et al. (2015) documented in their study that 'change of mind' processes were specific to free choice trials, and were never observed in forced-choice trials. As such, change-of-mind processes were less likely to have occurred in the speeded matching tasks. However, it remains that the dual-task methodology outlined above did not allow for independence of movement preparation and movement onset. One implication of this is that if movement onset is delayed relative to movement preparation, a self-advantage in motor preparation could have been absorbed into the time period of delay before movement onset in Janczyk et al.'s study (see Figure 4).

Haith et al. (2016) suggest that movement onset can be delayed relative to the *mean* time needed for preparation (to avoid the risk of initiating a response before preparation has been completed). Weinberg (2016) argues that such delays can also be adjusted on a response-by-response basis. Therefore, across the studies of Chapter 3 and Janczyk et al. (2019), and across the separate conditions (e.g., self- versus stranger-associated), differential movement onset delays post-preparation could have arisen. These adjustments can be influenced by time-pressures; in particular, delays tend to arise under loose time constraints

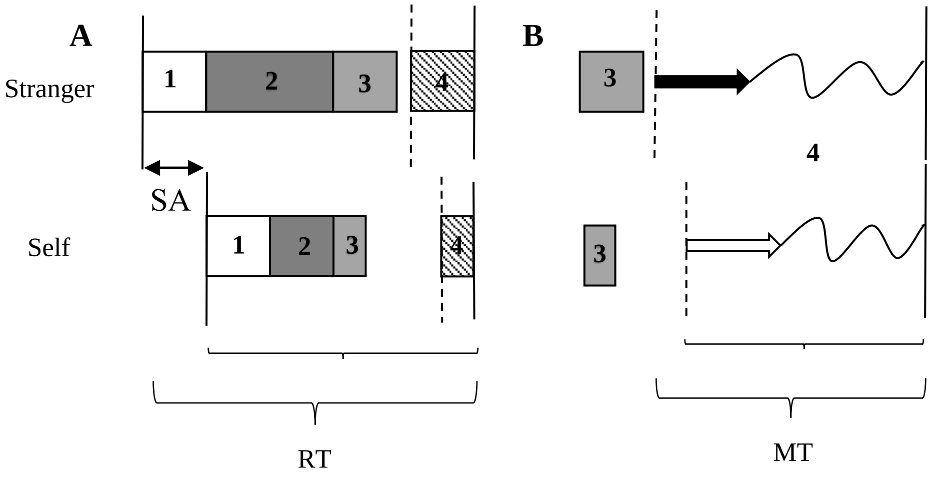

Figure 4. A. Representation of a potential mechanism in Janczyk et al.'s (2019) matching task showing movement onset as independent from movement preparation (Haith et al., 2016) and depicting a modulation of both preparatory motor activity ('3') and online correction processes ('4') by self-relevance. SA = self-advantage. Stranger = stranger-associated shape-label matching-trial responses. Self = self-associated shape-label matching-trial responses. Dotted lines represent movement onset. RT denotes the duration from stimulus onset to response completion and includes 1. *perceptual* 2. *central* 3. *motor-specific preparatory* and 4. *overt movement execution* stage processes. Solid lines represent stimulus onset or movement completion. **B.** Representation of the motor-stage. MT denotes the duration from movement onset to completion and reflects overt movement execution processes (measured separately in Chapter 3 but not in Janczyk et al.'s study). The black and the white one-way arrows represent differential initial impulses of the overt movement across the self- and stranger-associated responses, reflecting differential motor planning that occurs prior to movement onset and is reflected in the overt movement. The wavy lines represent the online correction processes that may occur post movement-onset (Allsop et al., 2017; Khan et al., 2006). The masking of enhanced motor preparation by delayed movement onset depicted here would be somewhat akin to perceptual effects being absorbed in the *cognitive slack* thought to occur at the perceptual-central-stage junction at short SOAs in dual-task paradigms.

(Haith et al., 2016). The response time-limit for the matching task in Janczyk et al.'s (2019) study (i.e., 3,000 ms from the Task 1 stimulus onset) was substantially longer than in Chapter 3 (i.e., 1,100 ms from stimulus onset), indicating that there was scope for delayed movement onset in the former study. Indeed, it can be seen in Table 4 that self-associated matching-trial RT/ITs were substantially longer in Janczyk et al. (2019—Experiment 4) than in Sui et al. (2012—Experiment 1), and Chapter 3. In other words, RTs in Janczyk et al.'s study were more "sluggish" (Haith et al., 2016, p. 3007). This evidence again suggests that the matching task responses were not completed as fast as they might have been, with scope for delayed movement onset.

Table 4

Comparison across studies of Mean RT/ITs (in ms) and movement initiation accuracy (percentage of correct responses), with standard deviations in parentheses, as a function of Association (self vs. stranger) in the Matching condition.

	Sui et al. (2012—Experiment 1)		Chapter 3 (Desebrock et al., 2018; right-hand responses averaged across two sessions)		Janczyk et al. (2019—Experiment 4; at the long SOA)	
Assoc.	Self	Stranger	Self	Stranger	Self	Stranger
RT/IT	674 (77)	850 (149)	637 (63)	763 (67)	818*	1020*
ACC	95 (4)	71 (18)	97 (3)	90 (7)	96	95

Note. RT/IT = duration from stimulus onset to button-press or button–release. ACC = movement initiation accuracy. *SDs not reported.

As noted above, Janczyk et al. (2019) documented that self-bias in Task 1 was not more marked than it was in Task 2 at the short SOA. In other words, the magnitudes of the difference between the SPE in Task 1 and Task 2 did not significantly differ, thus self-associated responses in Task 1 did not receive an additional boost through the motor stage. This finding should also be accounted for in the hypothetical case depicted in Figure 4 in which both movement preparation and execution are modulated by self-relevance. (NB Figure 4 depicts just one possibility). Another possibility, not depicted, is that a form of SAT mechanism could arise across movement preparation and execution processes; for example, faster preparation, slower execution, or vice versa.) Within a central bottleneck framework, to account for the finding of a non-significant difference between Task 1 and Task 2 SPEs, the duration between the onset of preparatory processes (once commitment to the response is made) and completion of the overt movement should remain equivalent across self- and stranger-associated conditions. In other words, faster movement preparation, or execution processes, or both, for self-associated relative to stranger-associated responses would need to be levelled out by an adjusted time-point of movement onset. In other words, the net result should entail that the duration between the onset of ‘3’ and termination of ‘4’ (see Figure 4) was equivalent across conditions irrespective of modulations of movement preparation or execution processes.

While the compensatory mechanisms in timing suggested above are theoretically possible, they would involve fairly rigorous control of the relative timings across self- and stranger-associated responses during the motor-stage in order to maintain and not reduce or increase the central-stage advantage for self. However, if we do not accept that the dual-task processing in Janczyk et al.'s (2019) task necessarily had to proceed in accordance with central bottleneck stage-model theory, an alternative account of the authors' findings is available.

4.6. Alternative processes underlying the dual-task responses

So far it has been assumed that at the short SOA both task responses in the dual-task paradigm were processed in a serial manner along the same pathway, in line with the central bottleneck model. However, research has demonstrated that alternative processing strategies can arise in dual-task paradigms. For example, the two tasks may be processed in parallel throughout, bypassing the central bottleneck. They may also be processed via different pathways, such as through "slow" (analytical, perceptual) or "fast" automatic pathways (e.g. Harrar et al., 2017; Hommel, 1998). Research taking a strategic rather than structural view has also suggested that movement onset bottlenecks rather than response selection bottlenecks may arise (Hazeltine et al., 2002; Klapp et al., 2019). Response grouping can also occur, which refers to the strategy of processing Task 1 and then Task 2 up to response selection before executing the respective motor responses as a single motor sequence (Ulrich & Miller, 2008). This chapter suggests that plausible alternative accounts of Janczyk et al.'s (2019) findings regarding the motor-stage are therefore also available.

4.6.1. Slower deliberative processing in Task 1—the matching task

Janczyk et al. (2019) note in their first experiment (Experiment 1a) that the participants reported difficulties with Task 1 (auditory discrimination) when the matching-task stimulus was 100 ms duration. Specifically, the participants reported difficulties in performing Task 1 quickly due to this short Task 2 stimulus presentation time. Therefore, in subsequent experiments in their study (including in their fourth experiment), the authors used a 300 ms stimulus duration for the matching task. Studies using the matching task in single-task settings typically use a 100 ms stimulus duration with no issues for young control groups. The dual-task setting therefore impacted on the Task 1 (matching task) processing.

More specifically, the matching task required increased stimulus information in the dual-task context. Stimulus duration is a determining factor in stimulus consolidation and whether processing enters a more flexibly-controlled late phase resource allocation in working memory (Ye et al., 2019). Simultaneously processing both tasks may require that the shape-label stimulus is processed explicitly in working memory. Further support for this contention can be found in the authors' fourth experiment. RTs were substantially longer in the matching task (Task 1) at both the short and long SOA relative to single-task findings (Desebrock et al., 2018; Sui et al., 2012), yet participants were instructed to respond as rapidly and accurately as possible, and to focus on Task 1 responses. Furthermore, overall accuracy was also higher in Janczyk et al.'s (2019) study relative to single-task studies (Desebrock et al., 2018; Sui et al., 2012), and the accuracy of responses in stranger-associated trials much closer to that in self-associated trials. Both the longer RTs and increased accuracy in the dual-task study are consistent with slower and more deliberative responding in the matching task.

4.6.2. Parallel processes and fast-route automatic Task 2 responding

There is much evidence to support the contention that a response selection bottleneck does indeed arise in dual-task contexts. However conditions of its emergence are thought to be determined by the difficulty of the respective tasks, practice opportunities, and participants' optimization of task processing, attention allocation, and coordination (Hazeltine et al., 2002; Strobach & Torsten, 2017). A response selection bottleneck tends to arise when both tasks engage slower deliberative processing. When one task is substantially easier than the other and well-practised, however, automatic retrieval of S-R bindings can arise in those task responses (Hommel, 1998; in line with episodic direct-link automatic activation (Giammarco et al., 2016). Task 1 (matching nine possible combinations of shapes and labels) was substantially more difficult than Task 2 (discriminating a high from a low sound). The dual-task trials were also well-practiced (82 practice trials) in relation to the difficulty of Task 2. It is therefore plausible that automatic S-R bindings were retrieved in Task 2 responses, in contrast to slower deliberative processing in Task 1.

Janczyk et al. (2019) rule out that parallel processing could have occurred in their task. They note that "…retrieval from semantic and episodic memory has been shown to happen in parallel to other processes…" but discount that self-relevance modulated these processes in their task because they did not find an "underadditive interaction" (Janczyk et al., 2019, p. 1080). In other words, the authors inferred that the self-advantage in their task did not involve processes prior to central-stage processes. Furthermore, the authors argue that a central capacity sharing model—in which overlapping central-stage processes can run in parallel, but less efficiently—is also consistent with their findings. However, if central processing runs in parallel (Janczyk et al., 2014; Tombu & Jolicoeur, 2003), one would expect to see detrimental effects on Task 1 RTs (Janczyk et al., 2014). Indeed, this is what appears to arise in Janczyk et al. (2019—Experiment 4). Task 1 RTs were slower at the short than long SOA.

In sum, both the 'serial central bottleneck model' and 'parallel processing as two independent streams' predict that Task 1 responses should not be affected by Task 2 responses. If Task 1 responses proceed as they would in a single-task setting and are unaffected by Task 2 responses, RTs in the Task 1 matching task would be expected to reflect those in the matching task generally. However, RTs across all conditions were substantially longer in Janczyk et al.'s (2019) study than in Sui et al. (2012) and the matching task of Chapter 3 (ITs). Furthermore, Task 1 RTs (Janczyk et al., 2019—Experiment 4) were longer at the short SOA than at the long SOA. These findings imply that Task 2 interfered with the processing of the Task 1 matching task, increasing latencies in Task 1. In other words, there may have been crosstalk between the two tasks (Hommel, 1998; Töllner et al., 2012). This suggests that the two tasks were not processed in independent parallel streams, nor did they proceed serially along the same processing pathway and response selection bottleneck. (Such possibilities highlight the limitations of such 'black box' models and the advantages of methodological approaches such as the event-related potential (ERP) technique, see Appendix D.)

4.6.3. Response grouping

Response grouping has been well-established as a "ubiquitous phenomenon" in the PRP paradigm (Ulrich & Miller, 2008, p. 116). Response grouping strategies have been documented to arise when participants anticipate a fixed (predictable) task order of a more difficult task followed by a much easier task. As noted, the difficulty level of Task 2 was low relative to Task 1 (matching). In traditional response grouping accounts, the response of Task 1 is thought to be selected and held until the Task 2 response is also ready to be executed (Ulrich & Miller, 2008). In Janczyk et al.'s (2019) short SOA trials, Task 2 (i.e. audiomotor) responses in self-associated trials were completed 377 ms after the Task 1 response, and in stranger-associated trials, 374 ms after the Task 1 response. Response grouping is consistent with timing regularity in the sequential motor response. However, inter-response times (IRTs) are typically assumed to be shorter than 100 ms (Ulrich & Miller, 2008). The short

IRTs have been attributed to the increased pressure to quickly execute the grouped response while Task 1 processing waits for Task 2 (delayed by the bottleneck).

To reduce the likelihood of participants adopting a response grouping strategy, Janczyk et al. (2019) state that they instructed their participants to respond as rapidly and accurately as possible, and to focus on Task 1 responses. The authors also exclude response grouping from their first three experiments because, they argue, this would entail that Task 1 (here, auditory discrimination) responses in the long SOA trials would be longer than in the short SOA trials. Task 1 (auditory discrimination) responses were not longer in the long SOA trials. However, the authors' interpretation relies on the assumption that there is a *response selection* bottleneck and on a traditional conceptualization of response grouping. It also assumes that participants would use the same response-grouping strategy across short versus long SOA trials, which does not have to be the case. There was also evidence of cross-talk between the two tasks at the long SOA because a self-advantage also appeared in these Task 2 (audiomotor) responses. In sum, it is possible therefore that in Janczyk et al.'s (2019; Experiment 4) dual task, a *response selection* bottleneck did not arise, participants used a response grouping strategy, and that processing was altered across the short and long SOA trials, deviating from assumptions of the central bottleneck model.

4.6.4. A hypothetical alternative account

A number of mechanisms and strategies alternative to the processes assumed by the central bottleneck model can arise at short SOAs in dual tasks. Indeed, an alternative account of the dual-task processing may be reconciled with Janczyk et al.'s data. For example, processes may have involved a movement-onset-related bottleneck rather than response-selection bottleneck (Hazeltine et al., 2002; Klapp et al., 2019) and a form of response grouping. In such a scenario, the matching task (Task 1) response could be processed up to a stimulus representation held in working memory, while the auditory discrimination (Task 2) response is processed up to response selection via the automatic retrieval of an S-R binding. The Task 2 response then waits, prior to its execution, for the Task 1 response to be selected. Potentially after some delay, the Task 1 and Task 2 motor responses are then executed, in task order, as a deliberate and controlled two-part sequential motor response (response grouping strategy).

Notably, if consolidation of the stimulus representation and response selection processes are more efficient in self-associated trials (consistent with Janczyk et al., 2019), then the waiting time until the Task 2 response is executed is shorter in the self-associated condition. As such, the Task 2 responses still reflect differences in the self- and other-person-associated conditions of Task 1 in this account.

4.6.5. Evidence for the alternative account

Even in strongly ‘stimulus-driven’ tasks, the stimulus presentation does not directly trigger a full motor response but an endogenous decision about whether to make a movement (Haith et al., 2016). In other words, responses can be activated up to their preparation, but not executed (Haith et al., 2016; Hommel, 1998). In addition, the onset of the Task 2 stimulus was also only 50 ms after the onset of the Task 1 stimulus (Janczyk et al., 2019—Experiment 4). It is therefore feasible that the fast automatic Task 2 response could be prepared before that of Task 1, but movement execution be delayed. Indeed, nonspecific ‘stop codes’ can be bound to stimuli such that when retrieved they inhibit responses in the current task (Henson et al., 2014). Such ‘stop codes’ could be bound to response selection, and facilitate ‘automatic preparation’ but not execution of Task 2 responses.

Response grouping typically manifests in near instantaneous Task 1 and Task 2 responses due to time pressures. In Janczyk et al.’s (2019) dual-task, however, time pressures were comparatively low. In the form of response-grouping outlined above therefore, there is no reason why, post-preparation, the selected response for each task could not be executed decisively and unhurried, in task order. (Response order had to follow task order, in Janczyk et al.'s (2019) task requirements.) Other research has shown that IRTs greater than 100 ms do not negate the possibility of response grouping. Data trimming and eliminating trials with short IRTs, for example, does not necessarily remove effects of response-grouping (Ulrich & Miller, 2008). The regular IRT of 377/374 ms (i.e. substantially greater than 100 ms) is also consistent with careful execution within a response-grouping strategy.

In sum, it is hypothetically possible that parallel processing and a movement onset bottleneck in conjunction with a version of response grouping could feasibly have been the dominant strategy in Janczyk et al.’s (2019—Experiment 4) dual-task at the short SOA.

4.6.6. Modulation of motor processes in the alternative account

The looser time constraints of Janczyk et al.’s matching task as compared with the matching task of Chapter 3 would not have pushed participants to execute a Task 1 response as soon as it had been prepared. Thus, this account also accommodates the possibility that in the self-associated condition, enhanced motor preparation, or execution processes, or both, could have been masked by delayed movement onset (see Figure 4). For example, Task 2 responses are executed sequentially after Task 1 responses. Thus, the speed advantage for Task 2 responses in self-associated trials may be further increased by a faster execution of the Task 1 response. This could account for the finding that the self-advantage in Task 1 (181 ms) and Task 2 (176 ms) responses at the short SOA was not significantly different, while allowing for the possibility that movement preparation or execution or both were modulated by self-relevance. Such an interpretation would offer another plausible account for the unchanged magnitude of self-bias across Tasks 1 and 2 at the short SOA, but without the requirement for the strict timing maintenance during the motor-stage described in the previous section. The hypothetical account of task processes suggested here thus provides one alternative interpretation.

4.7. Conclusions and limitations

Chapter 3 (Desebrock et al., 2018) documented a self-advantage in the execution of responses in a movement adaptation of the matching task. Using a dual-task PRP paradigm, Janczyk et al. (2019—Experiment 4) documented that the motor-stage did not contribute to the self-advantage in the matching task. At the start of this chapter, it was suggested that one potential account for the null finding of the contrasting study (Janczyk et al., 2019), might be attributed to a methodological limitation (e.g. the mechanistic framework against which the study was set). The latter study was reviewed in relation to such a possibility. In line with earlier research (Franz et al., 1996; Ivry, 1997), more recent findings in the motor control and neuroscience literature have highlighted that movement preparation and movement onset are separate processes (Haith et al., 2016). The central bottleneck model within the dual-task PRP paradigm on which Janczyk et al. based their study does not take this framework into account. It was argued that an alternative interpretation is also supported with regard to the motor-stage processes. Two hypothetical accounts of dual-task processing at the short SOA in Janczyk et al. (2019 Experiment 4) were suggested. It was argued that parallel processing and response-grouping could have arisen in the task, also accommodating that movement preparation and execution could have been modulated. For example, enhancements in the speed of movement preparation (Speiser et al., 2017) could be absorbed into the time-period of delay prior to movement onset. The present review thus indicates that Janczyk et al.'s findings leave open the possibility that self-relevance can modulate the motor-stage of discrete keypress responses in the matching task.

The findings of this review chapter also highlight an advantage of the methodology used in Chapter 3 (Desebrock et al., 2018) over behavioural total-response-time measures[15].

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[15] N.B. Electrophysiological measures such as electromyography can be used to assess motor processes in tasks examining keypress movement responses.

Modulations of overt movement execution in the outcome measures could be *directly* assessed. In addition, the measure of correct movement completion (a gross outcome measure of movement accuracy) provides further indication of optimization processes in the overt movement.[16] By contrast, endpoint accuracy in button-press responses is at ceiling.

Notably, both hypothetical accounts of the dual-task processes suggested in this review allow that a self-advantage arose in ‘central stage’ processes, such as working memory processes and response selection, consistent with Janczyk et al. Other research has also suggested that novel self-associations can modulate internal attentional prioritization and maintenance in working memory (Yin et al., 2019; although cf. Constable et al., 2019).

This review also allows that self-relevance in the matching task may only modulate movement execution in the context of certain kinds of motor response. Socio-cultural factors and ontogenetic underpinnings which distinguish keypresses and arm-movements may differentially activate a movement self-advantage (see Chapters 6 and 7). Arm-movement and keypress responses have different real-world functions and associated uses, for example.

Alternatively, the movement self-advantage may be related to other, non-self-specific, processes. In Study C3, the arm-movement responses were directed towards the stimuli using non-ballistic action and visual feedback. Therefore, effects may be driven by a non-self-specific factor such as approach motivation and affective stimulus-response compatibility. Alternatively, effects may rely on an explicit response bias in visual-feedback-guided arm-movement responses to a target. Accordingly, the next chapter (Chapter 5) tests whether effects are specific to the motor response used in Chapter 3, and further examines the

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[16] In Chapter 7 of this thesis, more advanced techniques for assessing modulations of movement execution, beyond gross outcome measures are discussed. Kinematic analysis, for example, has been used to measure directional error in the initial impulse (Khan et al., 2006) which can provide insight into differences in the quality of movement planning processes in self- as compared with stranger-associated responses. Such techniques, permit inferences about whether *and how* a factor modulates movement execution. The focus of Chapters 3–6 is on *whethe*r overt movement responses are modulated by self-bias in the matching task, and as such lay the groundwork and justification for such future studies.

replicability and generalisability of Chapter 3’s findings. Specifically, Chapter 5 examines whether key differences in the respective motor responses used by the two studies (Desebrock et al., 2018; Janczyk et al., 2019) could account for the inconsistent findings of the two studies, and gathers further evidence that self-bias has a multiple-stage influence.

Chapter Five—Self-bias in arm-movements highlights modulation at multiple stages (Study C5)

5.1. Chapter overview

Chapter 3 documented an advantage in the execution, as well as the initiation, of arm-movement responses to self- relative to stranger-associated stimuli. In contrast, Janczyk et al. (2019) documented that the motor-stage of discrete button press responses was not influenced in the matching task. In Chapter 4, a methodological limitation of the latter authors' study was discussed, highlighting an advantage of the methodology used in Chapter 3. It was concluded that it remains an open question as to whether self-bias modulates the motor-stage of button press responses. The present chapter (Desebrock & Spence, 2021) examined whether features of the arm-movement response that were reported in Chapter 3 that are not common to keypresses could account for the self-advantage in movement execution.

In the first study of the present chapter (C5.1), the task set-up was modelled on Chapter 3 (Study C3), except that visual feedback was removed, and the travel distance was shortened. The participants made ballistic responses to the target. In the second study of the present chapter (C5.2), the set-up was identical to Study C3, except that movement responses were executed sideways, and framed as 'away' from both the participant's body and the stimuli.

It was hypothesized that if the self-advantage documented in Chapter 3 does not solely reflect the explicit online control of movements, favouring the self-related response, and the use of visual feedback in planning and guiding responses, a self-advantage should arise in Study C5.1. The evaluation of appetitive or positive stimuli is thought to activate affective stimulus–response (S–R) compatibility mechanisms automatically which, in turn, facilitate those movements that serve to visibly decrease the distance between the self and these stimuli

(Kozlik et al., 2015; Krieglmeyer et al., 2013; Markman & Brendl, 2005; Piqueras-Fiszman et al., 2014; Seibt et al., 2008). Perceivable (i.e., visible) action effects (in terms of distance regulation between the participant and the stimuli) are thought to be a precondition for automatic affective S–R compatibility effects to arise (Kozlik et al., 2015; Krieglmeyer et al., 2010; Rougier et al., 2018; van Dantzig et al., 2008). It was therefore further hypothesized that if the movement self-advantage does not solely reflect the activation of affective stimulus-response (S–R) compatibility mechanisms which facilitate arm-movements that serve to *visibly* decrease the distance between the self and these stimuli (Kozlik et al., 2015; Krieglmeyer et al., 2013), a self-advantage should arise in Study C5.2.

A self-advantage in MTs and the percentage of correctly-completed movements was documented in both experiments. These findings thus demonstrate that self-bias in movement execution does not depend on an explicit decisional response bias or a modulation of automatic visual-feedback-driven processes. The findings also suggest that the self-advantage does not depend on approach motivation through affective S–R compatibility. Study C5.1 also demonstrates that self-bias can emerge in ballistic movement responses using predominantly proprioceptive, kinaesthetic, and tactile information in their planning and execution, and potentially self-generated visual imagery (see Section *5.6 Chapter Discussion*). These findings thus support and extend those of Chapter 3, highlighting a multiple-stage influence of self-bias (Sui & Humphreys, 2015a; Woźniak et al., 2018), and increase our understanding of the effects of self-relevance at the motor-stage (Frings & Wentura, 2014; Huang et al., 2022; Janczyk et al., 2019; Macrae et al., 2017).

5.2. Introduction

In line with the more widely reported effects of self-relevance (Humphreys & Sui, 2016), self-bias is thought by some researchers to influence multiple stages of information processing within the matching task—the allocation of attention, perceptual processes, memory (the retrieval of a self-representation), and decision-making processes (Humphreys & Sui, 2016; M. Liu et al., 2016; Scheller & Sui, 2022b; Sui & Humphreys, 2015a). Contrasting with the view that self-relevance can modulate perceptual processes, a growing number of researchers have suggested that self- and other-related processing may only be distinguished in higher-order, cognitive processes (Janczyk et al., 2019; Miyakoshi et al., 2007; Siebold et al., 2015; Stein et al., 2016; Y. Zheng et al., 2022). Another line of research emerging in the literature considers that the motor stage can also (theoretically) be influenced by self-relevance (Barton et al., 2020; Desebrock et al., 2016, 2018; Desebrock & Spence, 2021; Janczyk et al., 2019; Macrae et al., 2017).

In the first study (Chapter 3) to directly assess effects of self-relevance on movement execution in the matching task, an advantage was documented in the execution as well as initiation of arm-movement responses to the self- relative to stranger-associated stimuli (Desebrock et al., 2018). As such, Chapter 3 provided preliminary evidence that self-bias could modulate movement execution as well. By contrast, another study documented that a self-advantage did not arise in the motor-stage of discrete button press responses in the matching task (Janczyk et al., 2019). It may be that a self-advantage in overt movement responses in the matching task arises due to certain features of arm-movements that do not characterise button-presses. If self-relevance can modulate the motor-stage of responses in the matching task, this would provide further support for the contention that self-relevance can influence multiple stages of information processing (M. Liu et al., 2016; Sui & Humphreys, 2015a). A limitation of Chapter 3 is, however, that non-self-specific factors may (part) account for the movement modulation observed.

5.2.1. Self-bias at the motor-stage: An explicit response bias

One of the salient differences between the task responses of Janczyk et al. (2019) and Chapter 3 was the use of visual information in movement planning and execution. Visual information pertaining to hand or target position was not relevant to, or required for, completing the discrete button-press responses in Janczyk et al.'s study (albeit that visual feedback was available in the sense that participants could see their fingers resting on the keys). In speeded tasks, online correction of discrete keypress responses does not typically occur (Oulasvirta et al., 2018). Indeed, Janczyk et al. note that their findings pertaining to the motor-stage were "only preliminary given that [their participants made] discrete keypress responses, instead of, for example, continuous mouse movements" (Janczyk et al., 2019, p. 1080). By contrast, Chapter 3 used rapid-aiming arm movements through a travel distance of 14 cm to a target button. It may be that effects of self-relevance in movement execution operate exclusively through visual-feedback-driven processes, or their integration with other sensory information, in the planning or execution of movements. If so, such an influence may operate through automatic processes (whether top down or bottom up; Gaspelin & Luck, 2018) constituting a genuine effect of self-relevance (for example, in sensorimotor feedforward planning; Yeo et al., 2016; see Section *5.6 Chapter Discussion*). A non-ballistic response, however, also leaves open the possibility that a form of explicit decisional response bias could modulate the overt movement. Notably, self-ownership prioritization—a related phenomenon—has been found to constitute a top-down decisional response bias (Golubickis et al., 2018). Decisional processes have been shown to leak into, and thereby influence, movement responses. For example, modulations of movement in mouse-tracking studies are thought to reflect changes of mind on the part of the participant (Grage et al., 2019).

In the present chapter, however, the button being released (the choice) indicated the motor decision (effector and target) with no possibility of correction once released. In such set-ups, response selection processes are understood to occur prior to the onset of the movement (Rubichi & Pellicano, 2004; Scorolli et al., 2015). Indeed, errors in valid movement responses in Chapter 3 constituted missing the target key, rather than reflecting a change-of-mind response and pressing the wrong target button. However, the movement response used in Chapter 3 was not ballistic and visual feedback was available (Glover, 2004; Khan et al., 2006; Tremblay et al., 2013). Such goal-directed movements can be adjusted online during the later phases of movement execution to improve endpoint accuracy and consistency (Tremblay et al., 2013). Although rather difficult to control, given the speeded nature of the task, it is theoretically possible then that participants could have made explicit online adjustments to the movement (e.g. reflecting the demand characteristics of the task).

5.2.2. Self-bias at the motor-stage: Affective evaluation processes

Alternatively, modulations of the movement response could be driven by automatic processes that may not pertain specifically to those of self-relevance. The evaluation of appetitive or positive stimuli is thought to activate affective stimulus–response (S–R) compatibility mechanisms automatically which, in turn, facilitate those movements that serve to visibly decrease the distance between the self and these stimuli (Kozlik et al., 2015; Krieglmeyer et al., 2013; Markman & Brendl, 2005; Piqueras-Fiszman et al., 2014; Seibt et al., 2008). The effects of positive emotional valence have been dissociated from those of self-relevance (e.g., (Li et al., 2019; Stolte et al., 2017). However, stimuli can automatically be evaluated positively even if affective evaluation happens to be irrelevant to the task (Krieglmeyer et al., 2010; Stolte et al., 2017). In Chapter 3, whole arm-movement responses were visibly executed toward the stimuli, in contrast to button-press task responses in previous studies (Stolte et al., 2017), and in Janczyk et al.'s (2019) research. Perceivable (i.e., visible) action effects (in terms of distance regulation between the participant and the stimuli) are thought to be a precondition for automatic affective S–R compatibility effects to arise (Kozlik et al., 2015; Krieglmeyer et al., 2010; Rougier et al., 2018; van Dantzig et al., 2008). Discrete button presses leave the visible distance between the hand and the stimuli unchanged, and so Janczyk et al.'s task responses were comparatively 'approach neutral' relative to those used in Chapter 3. Effects of self-relevance in arm-movements could thus potentially be driven by differences in approach-avoidance motivation (Elliot, 2006; Kozlik et al., 2015; Solarz, 1960).

5.2.3. The present study

Unimodal visual processing and integrated visual and proprioceptive feedback are used to estimate hand position in arm-movement responses, while visual feedback is exclusively used to estimate target position (Gallivan et al., 2018; Krüger & Hermsdörfer, 2019; Scott, 2016). Therefore, in Study C5.1, visual feedback pertaining to both the hand and the target position was occluded in a task setup modelled on Study C3 (see Figure 5.1). The movement travel distance was also substantially shortened to 6 cm (as compared with 14 cm in Chapter 3), in order to elicit fast reactive (ballistic) movement responses (Glover, 2004; Khan et al., 2006; Tremblay et al., 2013). By such means, it was therefore possible to determine whether the self-advantage in movement was contingent on an explicit response bias using visual-feedback during execution of the movement, and/or on automatic visual-feedback-driven processes.[17] In addition, removal of visual feedback would remove those 'visible action effects' thought to activate the automatic approach motivation that facilitates arm movements. It was therefore hypothesized that if the self-advantage in movement was not contingent on an explicit decisional response bias, visual-feedback-driven processes, or visible action effects (approach motivation), a self-advantage should arise in Study C5.1 (in terms of shorter MTs and a higher or equivalent proportion of correctly-completed movement responses in the self- relative to stranger-related condition). An advantage for self would further suggest that self-relevance in the matching task can modulate movement responses

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[17] Ballistic movement reflects movement planning and a form of automatic online control (Elliott et al., 2010). Such *impulse control* compares an internal model of the expected sensory consequences of the movement with continuous visual, kinematic, and proprioceptive information. However, movement planning in relation to the internal model occurs prior to movement onset, and, in the absence of visual feedback, movements rely heavily on pre-planning of the movement (Elliott et al., 2010; Tremblay et al., 2013).

using (predominantly) proprioceptive, kinaesthetic, and tactile information, and potentially self-generated visual imagery (see Section *5.6 Chapter Discussion*), but not relevant exogenous visual information.

In Study C5.2, the participants executed movement responses sideways, framed as ‘away’ from their own body and the stimuli, and which did not decrease the distance between their hand and the stimuli. In order to amplify potential avoidance-motivation effects, visual feedback and the original movement travel distance (Chapter 3) were reintroduced. Thus, executing sideways movement responses visibly *increased* the distance between the participant’s hand and their body, while being represented as ‘away’ from the stimuli and the body. Therefore, if the movement self-advantage in Chapter 3 was *solely* underpinned by affective S–R compatibility and approach motivation, self-associated responses in Study C5.2 should be relatively disadvantaged, and responses to more negatively-evaluated stranger-associated stimuli should be relatively facilitated. Therefore, if approach motivation through automatic affective S–R compatibility effects do not wholly account for the self-advantage in Study C3, a self-advantage should also arise in the movements responses in Study C5.2.

In Section *5.5 Comparing the extent of the self-advantage across experiments (Studies C3 and C5),* a further (preliminary) analysis was carried out to assess whether effects may be *partly* dependent on visual feedback and an arm-movement response directed toward the stimuli. The extent of the self-advantage is examined across Study C5.1, C5.2, and C3. If a self-advantage arises in Study C5.2, but is reduced relative to Study C5.1 and Study C3, this would suggest that the movement self-advantage may be partly-driven by approach motivation.

5.3. Study C5.1

5.3.1. Methods

5.3.1.1. Participants

The effect size for the self-advantage in MT in Chapter 3 (Desebrock et al., 2018) was large (paired-samples *t*-test; *dz* = 2.46). However, in the present experiment, responses were ballistic and not guided by visual-feedback which are features of button-press responses. In Sui et al.'s (2012) original task using button press responses, an effect size of *dz* = 0.80 was documented. To allow for the detection of such an effect size, with a probability of $1 - \beta = .80$, and an alpha value of .05, a minimum sample size of 15 participants was required (G*Power; Faul et al., 2009). To accommodate the possibility that the self-advantage in movement execution may be further reduced, but not extinguished, the aim was to double this number of participants to allow for the detection of a smaller effect size, after attrition and participant data exclusions (see Section *5.3.2 Results*).

Thirty-four right-handed participants (15 males, ages 18–40 years, mean age 24 ± 5.55 years) with normal or corrected-to-normal vision took part in Study C5.1. They were recruited via the Oxford University Research Participation Scheme and online university-group social media. They received course credit or monetary reimbursement for their time and effort. All of the participants completed a written consent form approved by the University of Oxford Central University Research Ethics Committee (MS-IDREC-R49190-RE002).

5.3.1.2. Apparatus and stimuli

The experiment was conducted on a PC with a 23-in. LCD monitor (1,920 × 1,080 pixels at 60 Hz refresh rate) using E-Prime software (Version 2.0). A Cedrus RB-530 response box recorded home-button-releases (measuring IT) and target key-press (measuring MT) responses. The response box was positioned in front of a PC monitor. A cardboard box was placed over the response box, occluding the participant's hands from direct sight. The response box was placed inside a custom-built wooden holder such that the 'home' and ‘target’ buttons were 6 cm apart (see Figure 5.1). The stimuli consisted of two geometric shapes from the following set (circle, square, triangle, hexagon, pentagon, and octagon, each subtending 3.2 × 3.2 deg. of visual angle) and two self–other word labels (‘yours’, ‘theirs’, subtending a visual angle of 3.1 × 1.6 deg.). These stimuli/labels were counterbalanced across participants. Shape–label pairs (a geometric shape and personal label) were presented against a grey background in the centre of the PC screen. The shape was positioned above (and the label below) a central fixation cross.

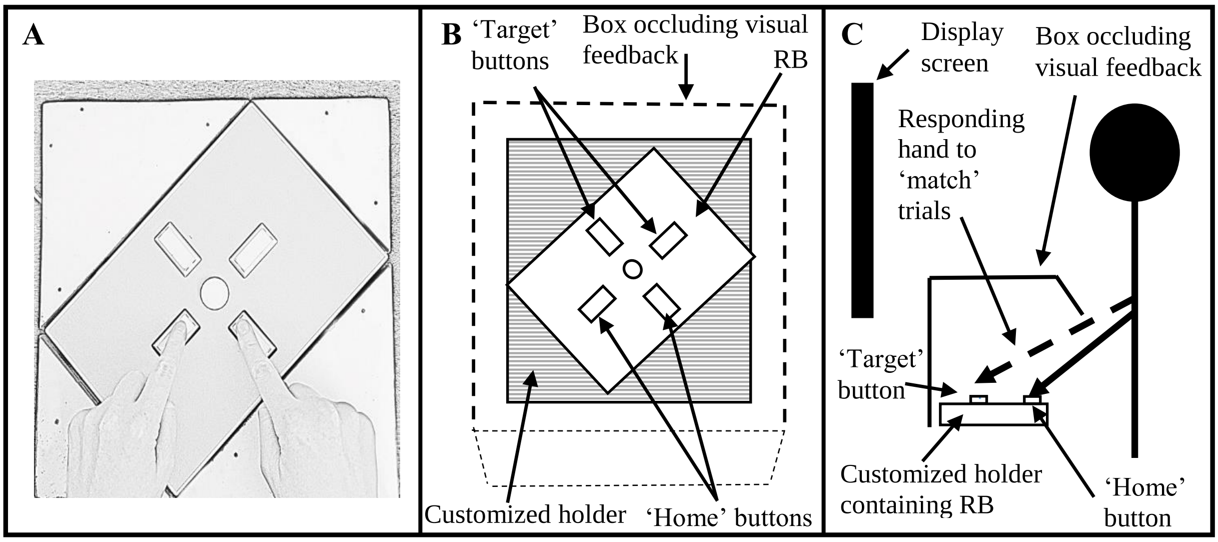

Figure 5.1 Schematic of Study C5.1 task apparatus and setup. RB = response box. **A.** Aerial view of the RB and customized holder with participant holding down the ‘home’ buttons. The participant’s right hand moves to the top right (target) button, their left-hand to the top-left (target) button (box occluding visual feedback not shown). **B.** Aerial view with box occluding visual feedback shown. **C.** Cross-sectional view. (Adapted from: Desebrock & Spence, 2021, *Attention, Perception, and Psychophysics,* **83(6)**, 2656–2674, Springer Nature.)

5.3.1.3. Procedure

The participants were instructed (via on-screen text) to associate one geometric shape with ‘self’ (specifically, as ‘yours’; e.g., ‘the square is yours’) and a second shape with ‘a stranger’ (as ‘theirs’; e.g., ‘the circle is theirs’) and to memorize these pairings. Following this, the participants completed the ‘matching’ task. The participants held two response-box buttons down with their index fingers before the first trial, and did so continuously throughout the task, except when making a response. To make a response, the participants released a response-box button by lifting an index finger and moving the hand forward to depress a target key with that index finger. The participants were instructed to make their response to the stimuli as rapidly and accurately as possible. Right-hand (i.e., dominant-hand) responses were made for those shape–label pairs participants judged as matching, and left-hand responses for those pairs judged to be mismatching.

In Chapter 3 (Desebrock et al., 2018), trial type (matching, mismatching) and assigned response options (using the dominant or non-dominant hand) were counterbalanced across two testing sessions per participant. No interaction between hand (left, right) and association (self, stranger) in RT or MT was documented. However, movements in the non-dominant hand were slower, and there was an interaction across hands in sensitivity (*d'*). These findings are consistent with established differences in preparatory and motor control mechanisms and associated brain activation across dominant/non-dominant hand-motor networks (Babiloni et al., 2003; Dirnberger et al., 2011; Olex-Zarychta & Raczek, 2008; Poole et al., 2018; Sainburg, 2016). Furthermore, in the present chapter, only the match-trial data was analysed because only match-trial responses index self-associated and stranger-associated processing (see Data Analysis section). Mismatch trials are essentially fillers Schäfer, Wesslein et al., 2020, and match and mismatch trials are typically analysed separately (e.g., Janczyk et al., 2019; Sui & Humphreys, 2017c; Woźniak et al., 2018). Therefore, participants in the present chapter made matching-trial responses with their dominant hand so that effects of self-related versus stranger-related responses could be compared without having to pool dominant and non-dominant hand responses, consistent with previous studies using the dominant hand to make match-trial responses (e.g., Sui et al., 2012). Figure 5.2 provides a schematic representation of the matching task. Preceding the main task, there was a practice block of 24 trials with the performance-accuracy threshold set at 60%. Participants repeated the practice block until this threshold was achieved. The main task consisted of four blocks of 80 trials separated by 8000 ms breaks, with each condition randomly generated with an equal number of presentations (80 trials per condition). The participants were informed of their overall accuracy at the end of each block of trials.

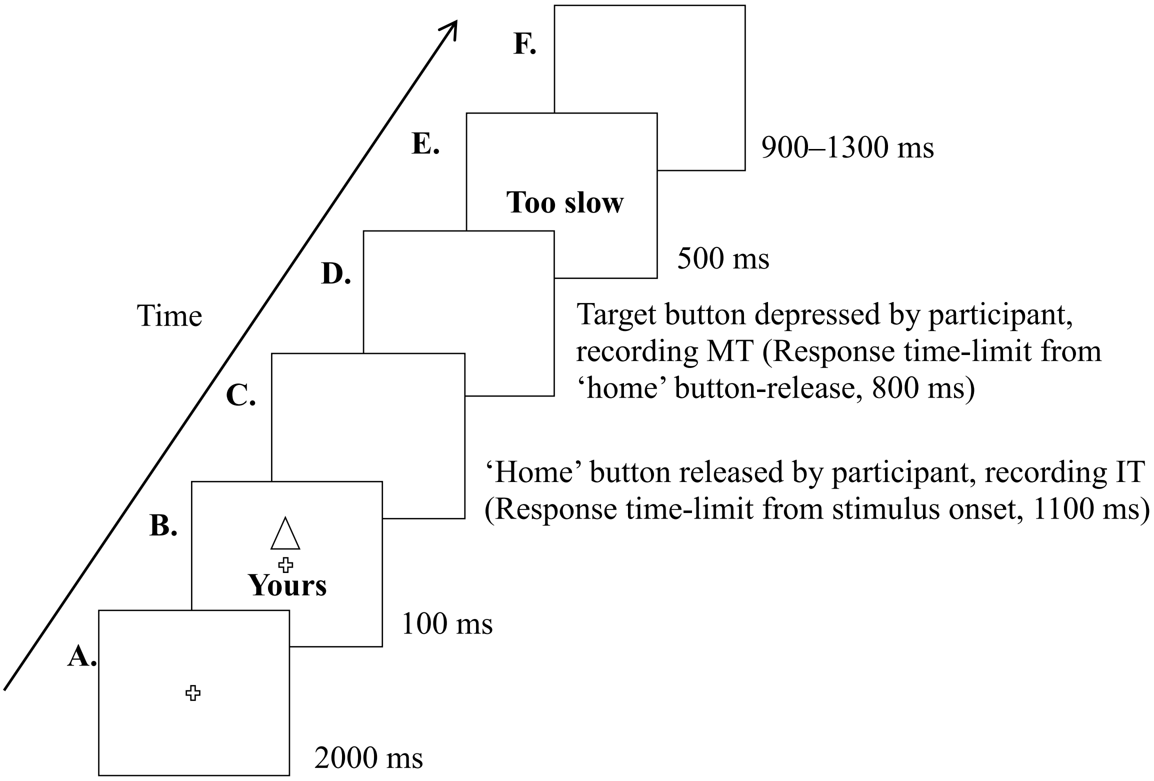

Figure 5.2. Schematic overview of an experimental trial sequence in Study C5.1 (displayed elements not to scale). **A**. Fixation cross. **B.** Stimulus onset (example shape-label pair shown). **C.** Blank screen. IT = movement initiation time. **D**. Blank screen. **E**. Onscreen feedback – "Correct" / "Incorrect" / "Too slow". **F**. Inter-trial intervals generated at random. IT response time-limit = the time limit measured from stimulus onset within which a participant had to select their response and initiate the onset of the movement by releasing the 'home' button. MT response time-limit = the time limit measured from the release of the 'home' button within which a participant had to complete their movement response by depressing the 'target' button.

5.3.1.4. Data analysis

There were two within-participants factors, each having two levels: Association (self, stranger) and Matching condition (matched, mismatched). Following Chapter 3, there were four main output measures in the two-stage response: movement initiation time (IT; measured from stimulus onset to the release of the response-box home button) for correctly-initiated movements, and movement execution time (MT; measured from the release of the response-box home-button to the depression of the target key on the PC keyboard) for correctly-initiated and completed arm-movement responses; movement initiation accuracy (*movement initiation PC-1*; the percentage of correctly-initiated movements), and movement execution correct-completion (*movement execution PC-2*; the correctly-completed movement executions, following correct movement initiation, as a percentage of the total number of trials).

Following Study C3 (see *Data analysis*, Chapter 3), an error in a valid movement response consisted in not depressing the target key (missing the target key) or hitting the incorrect target key, following a correct initiation response. Movement execution errors consisting of hitting the incorrect target key were negligible in the stranger-match (< 0.5% / ~0.3%) and self-match (< 0.1% / ~0.04%) conditions, thus suggesting a floor effect and were not analysed further. All remaining errors consisted of a failure to correctly complete the movement response and hit the target key. The predominance of such errors was due to the speeded nature of the task and the fact that the participants' hands and the response box were occluded from the participant's view. This set-up increased task difficulty and required the participants to plan and execute ballistic arm-movement responses in the absence of any visual feedback (see Figure 5.1).

Following Chapter 3 (Desebrock et al., 2018) and previous work (Sui et al., 2012; Sui & Humphreys, 2017c), a signal detection approach was used to calculate an index of sensitivity (D-prime; *d'*; Green & Swets, 1996). Hits were coded as yes responses to match trials, and false alarms were coded as yes responses to mismatch trials with the same shape; thus, sensitivity scores were derived from right (match)-hand responses only (namely, the same effector). Mismatch conditions were defined as shape-based (i.e., a self-mismatch trial consisted of the self-associated shape and the stranger-associated label, a stranger-mismatch trial consisted of the stranger-associated shape and the self-associated label).

ITs were based on correct responses, and ITs above or below 2.5 SDs from individual means were trimmed (< 2% (130) of ITs in the matching- and mismatching-trial data were excluded). Similarly, MTs were based on correct movement executions following a correct initiation-response. MTs greater than 2.5 standard deviations above individual means were excluded, eliminating < 1% of the trials in the matching-trial MT data, and < 1% in the mismatching-trial data. MTs faster than 2.5 SDs below individual means were retained since correct MTs could not be executed erroneously too fast.

As in Chapter 3, normalised differential scores—self-bias index scores (e.g., Constable et al., 2021; Schäfer, Wesslein, et al. (2016); Sui & Humphreys, 2017c)—were analysed to examine the extent of the self-advantage across the initiation and execution response stages. These scores provide an index of the relative magnitude of the difference in performance between self- and stranger-related responses. Different types of responses are made to the matching versus mismatching stimuli (Janczyk et al., 2019; Sui & Humphreys, 2017c; Woźniak et al., 2018; Yankouskaya et al., 2020). Match-trial stimuli (e.g., a self-associated shape and self-associated label) involve one association, thus in behavioural paradigms where effects in mismatch trials cannot be disentangled, matching-trial responses index self- and stranger-related processing (Sui et al., 2012). Researchers in this area typically treat mismatch trials as fillers (Schäfer, Wesslein et al., 2020). Therefore, in accordance with the aims of the present chapter, and following the rationale of previous research, the focus of the analysis reported here was on the match-trial data. The self-bias index scores were calculated using matching-trial ITs, MTs, and the percentage of correctly-initiated and -executed responses (following Sui & Humphreys, 2017), and are given by the formula: self-bias = "(stranger − self) / (stranger + self)" for the IT and MT metrics, and "(self − stranger) / (self + stranger)" for the percentage of correct scores. Positive values indicate an advantage for self over stranger. Positive values indicate an advantage for self.

Effect sizes were calculated using Cohen's *dz* for t-tests and partial eta-squared (η_p^2) for Analysis of Variance (ANOVAs; Cohen, 1988; Lakens, 2013). To adjust for multiple comparisons, Holm-Bonferroni corrections at an α value of .05 were applied (Holm, 1979).

A supplementary analysis (ANOVA) comparing the self-bias in IT, MT, and movement execution accuracy (PC-2) across Study C3, C5.1, and C5.2 was conducted to assess whether the self-advantage was reduced in C5.1 and C5.2 (see between-experiment supplementary analysis, Section *5.5*). If a self-advantage arose in C5.1 and C5.2, this would suggest that the self-advantage was not solely contingent on an explicit decisional response bias (acting through online control using visual feedback) or approach motivation through affective evaluation processes. However, if the self-advantage in C5.1 and C5.2 was reduced as compared with C3, this would suggest that the self-advantage might be moderated by these processes.

5.3.2. Results

One participant was excluded due to equipment failure, one for not completing the session, four for scoring < 55% accuracy in two or more of the conditions (*M* < 55% accuracy), and one constituted a multivariate outlier (Mahalanobis distance test, $p < .01$; Mahalanobis, 1930). The data from the remaining 27 participants (13 males, ages 18–37 years, mean age 23.56 ± 4.97 years) were included in the final analysis. The effect size detectable with 27 participants, an alpha value of .05, and a probability of $1 - \beta = .80$, was $dz = 0.57$ (G*Power 3.1 program; Faul et al., 2009).

For absolute measures in *d′* and (match-trial data) in IT, MT, movement initiation percent correct (PC-1), and movement execution percent correctly-completed (PC-2), see Figure 5.3. (See Appendix B, Table B1, for absolute measures for the Mismatch-data in Study C5.1.)

5.3.2.1. Movement initiation

Movement initiation times (ITs) were assessed using a paired-samples *t*-test which revealed a significant difference between the ITs for self-associated versus stranger-associated matching trials, *t*(26) = 10.57, *p* < .001, *dz* = 2.03. ITs for self-related responses were shorter than for stranger-related responses (see Figure 5.3A).

Movement initiation accuracy (percent correct; PC-1) was assessed using a paired-samples *t*-test which revealed a significant difference between the self-associated versus stranger-associated matching trials, *t*(26) = 9.77, *p* < .001, *dz* = 1.88, with greater accuracy in the self-related responses as compared with the stranger-related responses. Difference scores (Stranger – Self) were normally distributed, but there was one difference score with a median value > Q3 + 1.5*IQR. A Wilcoxon signed-rank test also revealed that the median difference (*Mdn* = 25, SD = 12.37) between the self-match (*Mdn* = 94, *SD* = 4.42) as compared with the stranger-match condition (*Mdn* = 69, SD = 10.93) was statistically significant, *z* = 4.51, *p* < .001, with an advantage for self, and thus supporting the findings of the parametric test (see Figure 5.3B).

Sensitivity index scores (D-prime; *d′*) for movement initiation were analysed using a paired-samples *t*-test which revealed a significant difference between self- and stranger-

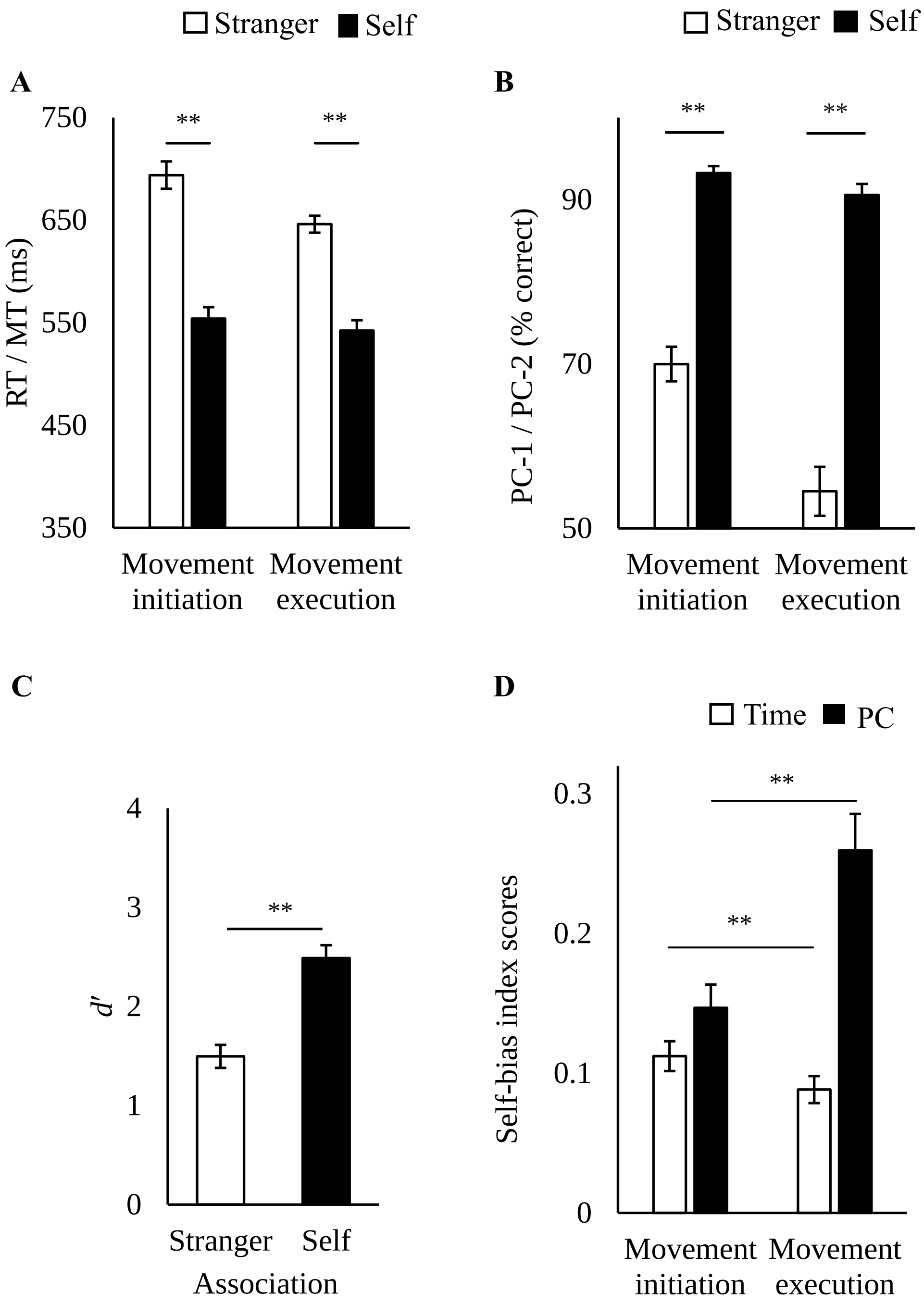

Figure 5.3. A. Movement initiation times (IT) and movement execution times (MT) as a function of Association (self vs. stranger) in the shape-label matching trials. **B.** Percentage of correctly-initiated movements (PC-1) and percentage of correct movement executions (PC-2) as a function of Association (self vs. stranger) across the two response stages (movement initiation vs. movement execution). **C.** D-prime (sensitivity) index scores (*d′*) as a function of Association (self vs. stranger). **D.** Extent of the self-advantage (self-bias index scores) in movement initiation time (IT), movement execution time (MT), percentage of correctly-initiated movements (PC-1), and percentage of correct movement executions (PC-2) as a function of response stage (movement initiation vs. movement execution), in Study C5.1. Time = IT/MT in ms, PC = percent correct. Error bars represent standard error. $^{**}p < .001$. (Adapted from: Desebrock & Spence, 2021, *Attention, Perception, and Psychophysics*, **83(6)**, 2656–2674, Springer Nature).

related, responses, $t(26) = 7.62$, $p = .001$, $dz = 1.47$. Difference scores (Self – Stranger) were normally distributed, but there were two difference scores with median values < Q1 – 1.5*IQR & > Q3 + 1.5*IQR. A Wilcoxon signed-rank test revealed that the median difference (0.98) between *d′* in the self-match (*Mdn* = 2.72) as compared with stranger-match condition (*Mdn* = 1.42) was statistically significant, $z = 4.30$, $p < .001$, supporting the findings of the parametric test (see Figure 5.3C).

5.3.2.2. Movement execution

Movement times (MTs) were assessed using a paired-samples *t*-test which revealed a significant difference between the MTs for self-related as compared with stranger-related matching trials, $t(26) = 9.53$, $p < .001$, $dz = 1.83$. MTs were shorter for self-related than stranger-related responses. Difference scores (Stranger – Self) were normally distributed, but there were four difference scores with median values < Q1 – 1.5*IQR & > Q3 + 1.5*IQR. A Wilcoxon signed-rank test also revealed that the median difference (93 ms) between MTs in the self-match (*Mdn* = 566 ms, *SD* = 52.73) as compared with stranger-match condition (*Mdn* = 657 ms, *SD* = 42.91) was statistically significant, $z = 4.52$, $p < .001$. The non-parametric test supported the findings of the parametric test (see Figure 5.3A).

Movement execution PC-2 data (correctly-completed movement executions; see Section *5.3.1.4 Data analysis*) were assessed using a paired-samples *t*-test which revealed a significant difference between the self-related as compared with stranger-related movement executions, $t(26) = 10.62$, $p < .001$, $dz = 2.04$ (see Figure 5.3B). Non-parametric tests validated the results of the parametric analysis.

5.3.2.3. Comparing the relative advantage for self in initiation and execution response stages

To assess whether the extent of the self-advantage was moderated across the two-stage response, the self-advantage in ITs and MTs, and in the percentage of correctly-initiated and correctly-executed movement responses, were compared using normalized self-bias index scores (see Section *5.3.1.4 Data analysis*). A paired-samples *t*-test revealed a significant difference between the self-bias in IT and MT, $t(26) = 5.64$, $p < .001$, $dz = 1.09$. Self-bias in ITs was significantly greater than in MTs. A paired-samples t-test was also used to assess the change in the extent of self-bias in percent correct across movement initiation (PC-1) and movement execution (PC-2; see Section *5.3.1.4 Data analysis*). A significant difference in self-bias was revealed between movement initiation accuracy and the percentage of correctly-completed movement executions, with a larger magnitude of self-bias in movement execution, $t(26) = 5.58$, $p < .001$, $dz = 1.07$ (see Figure 5.3D). However, the distribution of the difference scores was only approximately normally distributed and not symmetrical. A sign test with continuity correction confirmed the parametric test, and revealed a statistically significant median difference (*Mdn* = .09, *SD* = .11) in self-bias between movement initiation accuracy (PC-1; *Mdn* = .15, *SD* = .09) and the percentage of correctly-completed movement executions (PC-2; *Mdn* = .28, *SD* = .14), $z = 4.62$, $p < .001$. Self-bias in the percentage of correct responses was greater in movement execution than in movement initiation (see Figure 5.3D).

5.3.3. Discussion

In Study C5.1, participants carried out a movement adaptation of the matching task (Sui et al., 2012) making ballistic arm-movement responses to a target. Visual feedback pertaining to hand and target position was occluded and not available in the planning or guidance of movement execution. An advantage in both the initiation and execution of arm-movement responses to the self-associated stimuli was observed, consistent with the findings of Chapter 3 (Desebrock et al., 2018). The self-advantage in movement is therefore not specific to the task response used in Chapter 3. Specifically, the findings of Study C5.1 indicate that self-bias in arm-movement responses does not reflect an explicit decisional response bias available to non-ballistic action. The self-advantage is also not contingent on the modulation of visual-specific processing of hand or target position (Gallivan et al., 2018; Krüger & Hermsdörfer, 2019) or integrated visual and proprioceptive information to estimate hand position (Scott, 2016). Furthermore, these findings demonstrate that self-relevance in the matching task can modulate movement responses (predominantly) driven by proprioceptive, kinaesthetic, and tactile information. These findings are consistent with a previous study using discrete button-presses that documented that novel self-associations in an identification task modulated non-decisional processes (i.e., which can include response execution; Macrae et al., 2017). Consistent with the findings of Chapter 3, the *extent* of the self-bias was also significantly different across the response stages. Self-bias in IT was greater than in MT, and self-bias in the percentage of correct responses was greater in movement execution than movement initiation. The implications of these findings, when taken in conjunction with the findings of Chapter 3 and Study C5.2, are discussed in Section *5.6 Chapter Discussion*.

One potential limitation of the findings discussed in Chapter 3 was that differences in online control may account for the self-advantage in movement execution. The slower stranger-associated responses may be top-down controlled at movement onset. In contrast, faster self-associated responses may be bottom-up driven at movement onset, with explicit top-down control only taking over mid-flight (see Chapter 3; Schmidt et al., 2011; Schmidt & Seydell, 2008). Indeed, a recent study (Orban de Xivry et al., 2017) documented that accuracy demands of the movement plan can be processed either before or after movement onset. If accuracy demands are processed after movement onset, IT is reduced, and an initial transport phase carries the movement while the plan is finalised. Processing the movement plan during movement execution could underpin the shorter ITs in the self-associated condition. However, as argued in Chapter 3, the button being released (the choice) indicated the motor decision (effector and target); a button could not be released and then a target selected in a correct response. Furthermore, such differences in online control do not account for the significantly higher percentage of correctly-completed movement executions in the self-related condition. Increased online control would be expected to enhance endpoint accuracy in stranger- relative to self-related movements should their motor preparatory processes be equivalent. Crucially, the findings of Study C5.1 are not consistent with this account. In the ballistic movement responses of Study C5.1, such a transport phase would not be possible.

If self-relevance in the matching task can modulate ballistic movement without visual feedback, this raises the question of what mechanism can account for this finding. Although ballistic movements can be subject to a form of online regulation (Elliott et al., 2010), when visual feedback is not available, ballistic movements rely heavily on pre-planning of the movement. Movement planning includes the formation of an internal model of the expected sensory consequences of the movement, and this occurs prior to movement onset (Elliott et al., 2010). Sensory consequences of the movement may include their associated social sensory consequences—the anticipation of associated real-world consequences for self-associated versus stranger-associated movements. Thus, self-relevance may interact in this way with movement planning. Such a notion is in line with feedforward models of sensorimotor control (Yeo et al., 2016) and a growing recognition in the sensorimotor control literature that cognitive factors can influence movement selection, planning, and control at multiple levels of human information processing (Gallivan et al., 2018; explored further in Section *5.6 Chapter Discussion*).

A limitation of Study C5.1 was that the movement response was still effectively directed ‘toward’ the stimuli. Although the distance between the participant’s hand and the stimuli was not *visibly* decreased, simply ‘labelling’ a response as ‘toward’ has been argued to automatically assign the response a positive valence. An affective S–R congruency between valence of the motor response and the stimulus can also facilitate movements. According to the evaluative coding hypothesis (Eder & Hommel, 2013; Eder & Rothermund, 2008), the *intentional* affective evaluation of stimuli automatically activates a behavioural goal that, in turn, facilitates a correspondingly-valenced motor response. This mechanism can arise irrespective of the distance from a self-representation (Phaf et al., 2014). Therefore, Study C5.2 further tested whether the approach–avoidance context impacted the self- and stranger-associated movement responses by instructing participants to make sideways motion movement responses which were framed as both ‘away’ from the participant’s body and the stimuli. As such, the task responses were labelled as ‘away’ (negative) as opposed to ‘toward’ (positive), thus contrasting with Studies C5.2 and C3. Therefore, if approach motivation operating through an automatic or intentional affective evaluation S–R mechanism does not solely account for self-advantage in stimulus-directed movement responses, a self-advantage in movement execution should be observed in Study C5.2.

5.4. Study C5.2

5.4.1. Methods

5.4.1.1. Participants

The effect sizes for the self-advantage in MT in Study C5.1 and C3 were *dz* = 1.83 and *dz* = 2.46, respectively. However, if motivational orientation processes moderated (boosted) the advantage for self in response execution, then, once again, the effect size may be diminished. Therefore, in order to detect an effect size of *dz* = 0.80 (Sui et al., 2012), with a probability of $1 - \beta = .80$, and an alpha value of .05, a minimum sample size of 15 participants was required. (G*Power 3.1 program; Faul et al., 2009). Twenty participants (five males, ages 18–40 years, mean age 22.20 ± 6.31 years) took part in Study C5.2.

5.4.1.2. Apparatus and procedure

Following Study C5.1 and Study C3, the participants held down two ‘home’ response-box buttons with their index fingers until a response was required. However, in contrast to the previous experiments, the participants were instructed to execute a sideways motion task response, ‘away’ from themselves and the stimuli. As such, this movement was framed by the participant as ‘away’ from their body and the stimuli, and the distance between the participant’s hand and the stimuli did not decrease. (NB an arm-movement response directed away from the stimuli but towards the participant’s body can be associated with bringing an object toward the self. Such task responses to positively-evaluated stimuli can thus also be facilitated by ‘approach’ motivation, which introduces a potential confound (Elliot et al., 2013; Phaf et al., 2014; Seibt et al., 2008).) The response box was positioned in between two PC QWERTY keyboards, and a response consisted of releasing the relevant response-box button and moving the arm on the ipsilateral side out sideways along the horizontal, sagittal plane to press the relevant keyboard target key on the same side. The keyboard positioned to the right of the response box recorded MTs of ‘matching’ trial responses (executed using the right-hand to depress the key ‘z’), and the keyboard to the left of the response box recorded MTs of ‘mismatching’ trial responses (executed using the left hand to depress the ‘5’ key). The response box and keyboard target keys were aligned such that the right-hand RB key and target key and the left-hand RB key and target key were 13 cm apart, respectively. Following Study C3, in which participants executed movement responses over the same travel distance, a movement response time limit of 1250 ms was set. For more information, see Section: *5.5 Comparing the extent of the self-advantage across experiments (Studies C3 and C5*).

5.4.1.3. Data analysis

Data analysis procedures followed Study C5.1. As before, ITs were based on correct responses, and ITs above or below 2.5 SDs from individual means were trimmed (< 2% of ITs in the matching- and mismatching-trial data were excluded). Similarly, MTs were based on correct movement executions following a correct initiation-response. MTs greater than 2.5 standard deviations above individual means were trimmed (< 1% of MTs in the matching- and mismatching-trial data were excluded). MTs faster than 2.5 SDs below individual means were retained since correct MTs could not be executed erroneously too fast.

5.4.2. Results

The data from five participants were excluded (two due to a technical issue, one for not following instructions, and two for scoring < 55% accuracy in two or more conditions (*M* < 55% accuracy). The data from 15 participants (5 male, ages 18–35 years, mean age 21.73 ± 5.39 years) were included in the final analysis.

For absolute measures in *d′* and (match-trial data) in IT, MT, movement initiation percent correct (PC-1), and movement execution correct-completion (PC-2), see Figure 5.4. (See Appendix B, Table B2, for absolute measures for the Mismatch-data in Study C5.2.)

5.4.2.1. Movement initiation

Movement initiation times (ITs) were assessed using a paired-samples *t*-test which revealed a significant difference between the ITs for self-associated versus stranger-associated matching trials, $t(14) = 8.98$, $p < .001$, $dz = 2.32$. ITs for self-related responses were shorter than for stranger-related responses (see Figure 5.4A). Movement initiation accuracy (percent correct) was assessed using a paired-samples *t*-test which revealed a significant difference between the self-associated versus stranger-associated matching trials, $t(14) = 5.48$, $p < .001$, $dz = 1.88$, with greater accuracy in the self-related responses as compared with the stranger-related responses. Difference scores (Stranger – Self) were normally distributed, but there was one difference score with a median value > Q3 + 3*IQR. An exact sign test also revealed that the median difference (*Mdn* = 16, *SD* = 12.43) between the self-match (*Mdn* = 96, *SD* = 2.73) as compared with the stranger-match condition (*Mdn* = 76, *SD* = 11.99) was statistically significant, $z = 3.62$, $p < .001$. All participants were more accurate in self-related as compared with stranger-related matching trials; thus, supporting the findings of the parametric test. (See Figure 5.4B.)

Sensitivity index scores (D-prime; *d′*) for movement initiation were analysed using a paired-samples *t*-test which revealed a significant difference between self-related and stranger-related, responses, $t(14) = 4.10$, $p = .001$, $dz = 1.06$. (See Figure 5.4C.)

5.4.2.2. Movement execution

Movement times (MTs) were assessed using a paired-samples *t*-test which revealed a significant difference between the MTs for self-related as compared with stranger-related matching trials, $t(14) = 9.31$, $p < .001$, $dz = 2.40$. MTs were shorter for self-related than stranger-related responses (see Figure 5.4A).

Movement execution PC-2 data (correctly-completed movement executions; see Section *5.3.1.4 Data analysis*) were assessed using a paired-samples *t*-test which revealed a significant difference between the self-related as compared with stranger-related movement executions, $t(14) = 5.64$, $p < .001$, $dz = 1.46$. (See Figure 5.4B.)

5.4.2.3. Comparing the relative advantage for self in initiation and execution response stages

Following Study C3 and C5.1, the extent of the self-advantage was examined across the two-stage response. The self-advantage in ITs and MTs, and in the percentage of correctly-initiated and correctly-executed movement responses, were compared using normalized

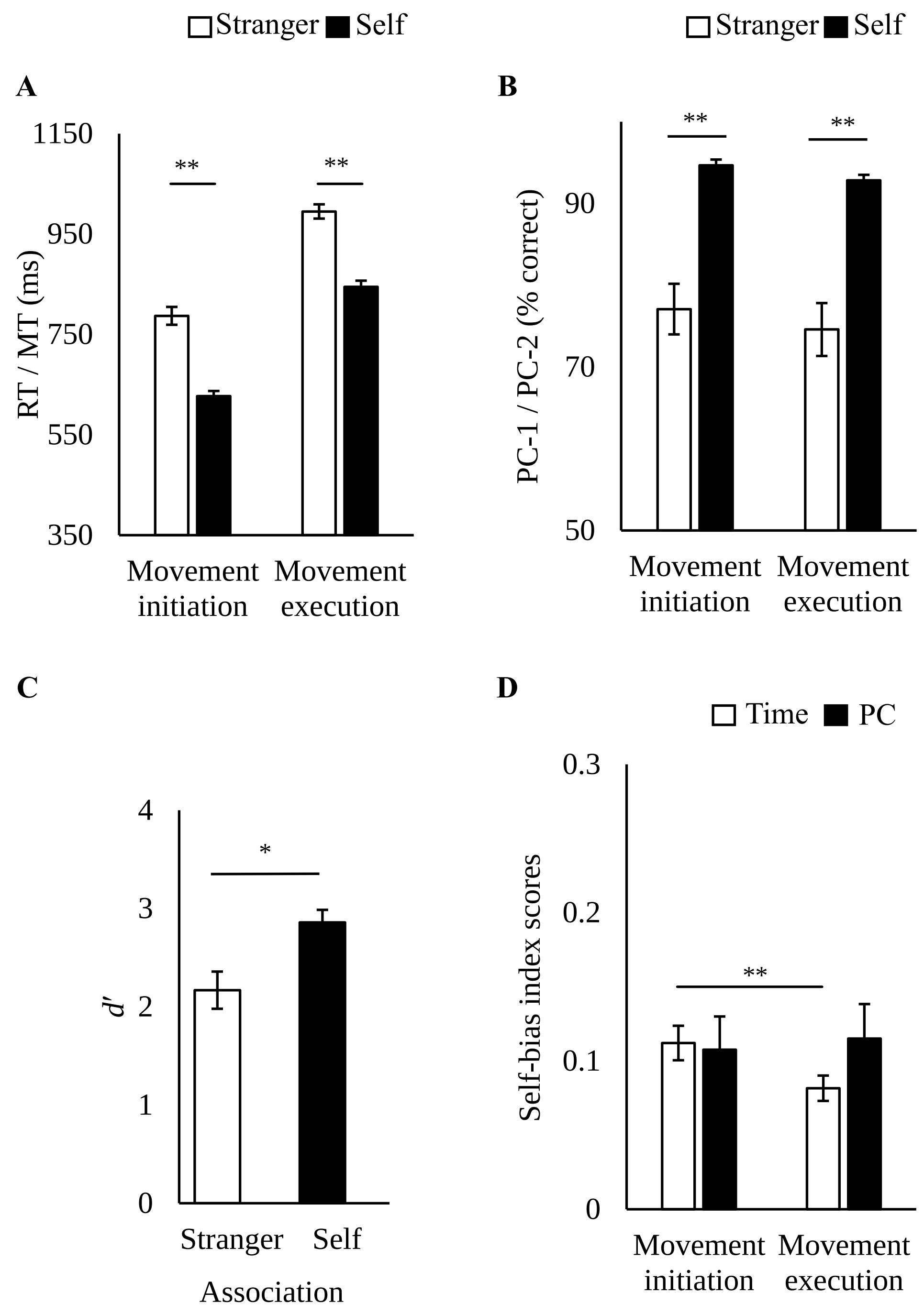

Figure 5.4. Study C5.2. A. Movement initiation times (IT) and movement execution times (MT) as a function of Association (self vs. stranger) in the shape-label matching trials. **B.** Percentage of correctly-initiated movements (PC-1) and percentage of correct movement executions (PC-2) as a function of Association (self, stranger) across the two response stages (movement initiation, movement execution). **C.** D-prime (sensitivity) index scores (*d′*) as a function of Association (stranger, self). **D.** Extent of the self-advantage (self-bias index scores) in movement initiation time (IT), movement execution time (MT), percentage of correctly-initiated movements (PC-1), and percentage of correct movement executions (PC-2) as a function of response stage (movement initiation, movement execution). Time = IT/MT in ms, PC = percent correct. Error bars represent standard error. $^*p < .01$. $^{**}p < .001$. (Adapted from: Desebrock & Spence, 2021, *Attention, Perception, and Psychophysics*, **83(6)**, 2656–2674, Springer Nature).

self-bias index scores (see Data analysis). A paired-samples *t*-test revealed a significant difference between the self-bias in IT and MT, *t*(14) = 7.85, *p* < .001, *dz* = 2.03. Self-bias in ITs was significantly greater than in MTs (see Figure 5.4D). A paired-samples t-test was also used to assess the change in the extent of self-bias in percent correct across movement initiation (PC-1) and movement execution (PC-2; see Section *5.3.1.4. Data analysis*). No significant difference in self-bias was revealed between movement initiation accuracy and the percentage of correctly-completed movement executions, *t*(14) = 1.67, *p* = .12 (see Figure 5.4D).

However, the distribution of the difference scores was only approximately normally distributed and not symmetrical. An exact sign test confirmed the parametric test, and revealed no statistically significant median difference (*Mdn* = .01, *SD* = .02) in self-bias between movement initiation accuracy (PC-1; *Mdn* = .09, *SD* = .09) and the percentage of correctly-completed movement executions (PC-2; *Mdn* = .09, *SD* = .09), *z* = 1.03, *p* = .30. Self-bias in the percentage of correct responses was greater in movement execution than in movement initiation. A Bayesian Wilcoxon signed-rank test, however, indicated that evidence for the null model was inconclusive. Bayes factors were calculated using the Bayesian-T-tests/Wilcoxon signed-rank module of JASP (Version 0.12.2; JASP Team, 2020) and the JASP default prior. The Bayes factor in favour of the null model was BF01 = 0.94, indicating that there was ‘weak’ or ‘anecdotal’ evidence for the null model (Jeffreys, 1998; Raftery, 1995).

5.4.3. Discussion

In Study C5.2, participants made fast-aiming, but non-ballistic, visual-feedback-driven arm-movement responses to a target. The experimental set-up was identical to Chapter 3 except that the movement responses were executed sideways, framed as ‘away’ from the participant’s body and the stimuli. An advantage in both the initiation and execution of arm-movement responses to the self-associated stimuli was observed, consistent with the findings of Study C5.1 and Chapter 3 (Desebrock et al., 2018). These findings provide further evidence that the advantage for self in arm movements is robust in multiple task response types. Specifically, they demonstrate that the self-advantage in movement is not contingent on a forward-motion movement response directed toward the stimuli.

In Study C5.2, arm-movement responses were executed ‘away’ from the participant’s body without decreasing the distance between their hand and the stimuli (potentially incongruent for self-associated responses and congruent for stranger-associated responses). If self-associated stimuli in the matching task are positively-evaluated relative to stranger-associated stimuli then according to both a distance-regulation and evaluative coding account of approach–avoidance action tendencies, self-associated responses in Study C5.2 should have been relatively disadvantaged. Conversely, stranger-associated responses should have been potentially advantaged. If automatic or intentional affective S–R compatibility *solely* underpinned the advantage for self in movement responses in Chapter 3, the advantage for self should have been extinguished, or the sign perhaps even reversed in Study C5.2, which was not the case. The possibility that the self-advantage may be reduced (i.e., that affective S–R compatibility may moderate the self-advantage) is explored further in Section *5.5*.

Consistent with Chapter 3 and Study C5.1, there was a significantly larger self-advantage in movement initiation than movement execution. However, in contrast to the previous experiments, there was no significant difference between the percentage of correct responses in movement initiation and execution. In other words, the extent of self-bias in correctly-selected and correctly-completed movement responses was unaltered across the two stages. Implications of this finding are explored in Section *5.6 Chapter Discussion*.

5.5. Comparing the extent of self-bias Studies C3 and C5

Taken together, the findings of Studies C5.1 and C5.2 indicated that the advantage for self in movement responses is not solely contingent on an explicit or automatic modulation of visual-feedback driven processes and approach motivation. To assess whether the self-advantage may be part-dependent on a modulation of these processes, a supplementary analysis was conducted. The extent of the self-advantage in IT, MT, and the percentage of correctly-initiated movements (PC-1) and correctly-completed movement executions (PC-2) was examined across Study C5.1, C5.2, and C3. It was hypothesized that if the advantage for self was reduced in Studies C5.1 and C5.2, as compared with Study A1, this would suggest a the movement self-advantage was partly-dependent on features of the movement response used in Chapter 3. In other words, the self-advantage would be partly-dependent on processes exclusive to the visual-feedback-driven non-ballistic movements directed towards the stimuli in Chapter 3.

5.5.1. Methods

In contrast to the two experiments reported in the present chapter, Chapter 3 used a two-session experimental design across which the allocations of the dominant/non-dominant-hand to matching/mismatching-trial responses were counterbalanced. Therefore, in order to compare the findings of Chapter 3 with the experiments of the present chapter, data from a sub-sample of participants from Chapter 3 were used in the analysis. This sub-sample of participants comprised the participants in Chapter 3 who made matching-trial responses with their right-hand in the first session (N = 17). In other words, the participants who carried out the matching task under the same task conditions as those in the present chapter. This sub-sample and subsequent analyses of this data will hereafter be referred to as Study A1.

5.5.2. Results

For absolute measures in matching-trial data being compared across Study A1 (Study C3 sub-sample), Study C5.1, and C5.2, in IT, MT, movement initiation accuracy (percent correct; PC-1), and movement execution correct-completion (PC-2), see Table 5.

Table 5
Mean movement initiation times (IT) and movement execution times (MT) in ms, and percentage of correctly-initiated movements (PC-1) and correctly-completed movement executions (PC-2), with standard deviations, as a function of Association (Self vs. Stranger) in the Matching condition for Study A1, Study C5.1, and Study C5.2.

	Study A1 (Visual feedback, approach motion)		Study C5.1 (Visual feedback occluded, approach motion)		Study C5.2 (Visual feedback, avoidance motion)	
Association	Self	Stranger	Self	Stranger	Self	Stranger
IT	635 (62)	782 (66)	554 (59)	694 (69)	627 (40)	787 (69)
MT	797 (60)	931 (70)	542 (53)	646 (43)	845 (47)	996 (55)
PC-1	96 (4)	89 (9)	93 (4)	70 (11)	95 (3)	77 (12)
PC-2	96 (3)	79 (11)	91 (7)	55 (15)	93 (3)	75 (13)

Note. Study A1 = A sub-sample of participants from Study C3. In order to match key task parameters across experiments, the data of a sub-set of participants from Study C3 that made matching responses with their right (dominant) hand in the first session were used in Study A1. See main text. (Adapted from: Desebrock & Spence, 2021, *Attention, Perception, and Psychophysics*, **83(6)**, 2656–2674, Springer Nature.)

A one-way ANOVA on self-bias index scores in IT revealed no significant difference across Study A1 ($N = 17$; $M = 0.10$, $SD = 0.04$), Study C5.1 ($N = 27$; $M = 0.11$, $SD = 0.05$), and Study C5.2 ($N = 15$; $M = 0.11$, $SD = 0.04$), $p = .86$. Similarly, ANOVA on the MT self-bias scores across Study A1 ($N = 17$; $M = 0.08$, $SD = 0.03$), Study C5.1 ($N = 27$; $M = 0.09$, $SD = 0.05$), and Study C5.2 ($N = 15$; $M = 0.08$, $SD = 0.03$), $p = .70$ revealed no significant difference in the extent of self-bias. In contrast, the magnitude of self-bias in the percentage of correctly-completed movement executions (PC-2) was significantly different across Study A1, Study C5.1, and Study C5.2, Welch's $F(2, 34.95) = 13.08$, $p < .001$. Games-Howell post hoc analysis revealed a statistically-significant difference between Experiments A1 and Study C5.1, $p < .001$, and Studies C5.1 and C5.2, $p = .001$, and no significant difference between

Experiments A1 and Study C5.2, *p* = .92 (see Figure 5.5). Self-bias in PC-2 was significantly greater in Study C5.1 than in the other experiments.

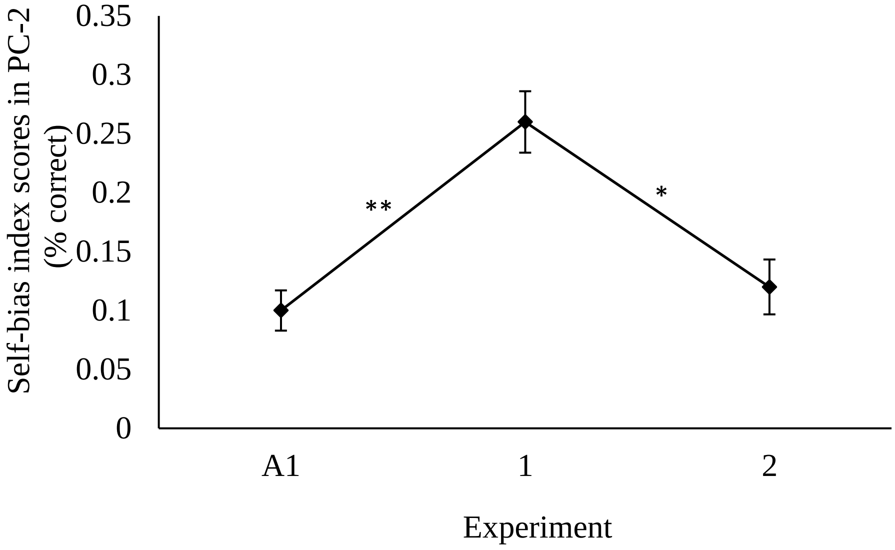

Figure 5.5.
Mean self-bias index scores (extent of the self-advantage) in the percentage of correctly-completed movement executions (PC-2) as a function of Experiment (A1, Study C5.1, Study C5.2). Error bars represent standard error. **p* =.001, ***p* <.001. (Study A1 was based on a subset of participants from Chapter 3, see main text for details.)(Adapted from: Desebrock & Spence, 2021, *Attention, Perception, and Psychophysics,* **83(6)**, 2656–2674, Springer Nature.)

Further supporting the null models for the comparisons of self-bias in IT and MT across experiments, Bayesian analyses indicated ‘positive’ or ‘substantial’ evidence for the null effects (Jeffreys, 1998; Raftery, 1995). Specifically, Bayes factors were calculated using the Bayesian-ANOVA module of JASP version 0.12.2 (JASP Team, 2020). The Bayes factor in favour of the null model for self-bias index scores in IT across experiments was BF_{01} = 6.34, and for self-bias index scores in MT across experiments was BF_{01} = 5.42.

5.5.3. Discussion

In Study A1 (a sub-sample of participants from Study C3), participants made forward-motion arm-movements towards the stimuli, and visual feedback was available. In Study C5.1, participants made forward-motion arm-movements toward the stimuli, and visual feedback was not available. In Study C5.2, participants made sideways-motion arm-movements which were framed as ‘away’ from their body and the stimuli, and visual feedback was available. A comparison of the self-advantage across these experiments indicated that the extent of self-bias was not reduced by the manipulation of the task response. These preliminary findings therefore suggest that the advantage for self in movement execution was not partly-dependent on visual-feedback-driven processes nor approach motivation processes in affective S–R compatibility.

The between-experiment analysis was aimed at assessing whether the self-advantage would be reduced by the visual feedback- and motivational orientation-related manipulations. However, the findings also revealed that the magnitude of the self-advantage in PC-2 was significantly greater in Study C5.1, than in either Study C5.2 or Study A1. There was a substantial drop in the percentage of correctly-completed movement executions in the stranger-associated condition. At first glance these findings may seem counterintuitive. Making a short ballistic arm-movement response to a target over a 6cm travel distance ought to be an easy task (with which participants indeed did not have difficulty when making movement responses in self-associated trials). Imagining everyday examples, it is easy to intuit that performance should be near ceiling in such a task (although, in everyday examples, visual information is almost always involved). We may then claim that whether or not visual feedback was available should make no difference to responses (in contrast, removing visual feedback from the tasks of Study C5.2 and Study C3 produced a floor effect). The short travel distance of the task response of Study C5.1 did not require visual feedback for successful completion. However, if the removal of visual feedback made no difference, then one would have expected the task to be ‘easy’ for stranger-related responses as well as for self-related responses. Stranger-related responses in Study C5.1 should have somewhat closed the gap and reduced the self-advantage in movement-completion accuracy, or perhaps even extinguished it due to a ceiling effect. In ballistic movement responses where visual feedback *is* available, movements can be planned and re-calibrated throughout the task using visual information. Visual information about the participant's hand and the target can be gained through peripheral vision, or through direct-line vision at intervals during and between trials/blocks. In Study C5.1, this was not available. One speculative interpretation is that the increase in self-bias in PC-2 in Study C5.1 may reflect an interaction between self-relevance and the availability of visual information, specifically in feedforward movement planning. This notion is explored further in Section *5.6 Chapter Discussion*.

One caveat regarding the between-experiment analysis is that although the IT response time-limit was the same across all experiments, a shorter MT response time-limit was used in Study C5.1. The shorter time limit was necessary to accommodate the much-reduced travel distance in Study C5.1, to 'push the system' equivalently across tasks. Furthermore, the reduced time-limit prevented participants from using a non-ballistic or non-aiming response (e.g. where participants could feel around for the target button)—in this case, movement completion performance would have been at ceiling. Hence the between-experiment analysis should be considered preliminary in nature. However, the findings provide preliminary evidence that the self-advantage may interact with the type of motor response used in the matching task.

5.6. Chapter Discussion

Using a movement adaptation of Sui et al.'s (2012) matching task, Chapter 3 documented a self-advantage in the duration and accurate completion of non-ballistic visual-feedback-driven arm-movement responses directed towards the stimuli. The present chapter examined whether the movement self-advantage would be robust in ballistic responses without visual feedback (Study C5.1), and in non-ballistic responses framed as being directed away from the participant’s body and the stimuli, without decreasing the distance between the participant’s hand and the stimuli (Study C5.2). A self-advantage in the execution as well as initiation of the arm-movement responses was observed in both Studies C5.1 and C5.2. These findings suggest that the self-advantage in movement does not depend on approach motivation through affective S–R compatibility processes (Studies C5.1 and C5.2), nor an explicit response bias using visual-feedback (or an automatic modulation of execution processes involving visual feedback; Study C5.1). They further indicate that self-relevance can modulate movement responses in the absence of relevant exogenous visual input; in other words, movements that are planned and executed using a combination of proprioceptive, kinaesthetic, and tactile information, and potentially, self-generated visual imagery (see below). A preliminary analysis across experiments indicated that the self-advantage in IT and MT was not reduced in Study C5.1 and C5.2 as compared with Chapter 3. Thus, the self-advantage does not appear to be partly dependent on a modulation of visual-feedback-driven and affective evaluation processes in approach-avoidance tendencies. The present chapter therefore supports and extends the finding of Chapter 3 that self-relevance in the matching task can modulate both the initiation and execution of movement responses, consistent with a multiple-stage influence (Desebrock & Spence, 2021; Scheller & Sui, 2022a; Sui & Humphreys, 2015a)

As discussed in Chapters 3 and 4, Janczyk et al. (2019) documented in their fourth experiment that the duration of the motor-stage of button-presses was not influenced by self-relevance in the matching task. The authors note that while their null findings relate to discrete keypress responses, they did not test effects in (e.g.) continuous mouse movements. Continuous mouse movements are typically non-ballistic target-aiming motor responses guided by visual feedback. Study C5.1 of the present chapter suggests however that the self-advantage does not depend on visual feedback or a non-ballistic response. Whether a self-advantage arises in the motor-stage of button-presses thus remains unclear (see also Chapter 4). If the self-advantage in arm-movement execution does not reflect explicit online control processes, or a modulation of automatic visual-feedback-driven processes, and can arise in ballistic motor responses without visual feedback, this raises the question of what mechanism can best explain the modulation of movement in the matching task.

5.6.1. Distinguishing between potential accounts of the self-advantage in movement

Ostensibly, there are three potential accounts of the self-advantage in movement: (1) the advantage for self in perceptual processes or central-stage processes (i.e. premotor processes) directly drives the self-advantage in movement execution processes; (2) the self-advantage in premotor processes and the self-advantage in movement execution are independent, but coordinated by a third factor; (3) the advantage for self in premotor processes and the advantage for self in movement execution are independent, influenced by distinct factors.

Some researchers have suggested that enhanced attention to self-associated stimuli increases certainty in decision-making processes pertaining to those stimuli, coupling the perceptual- and central-stage self-advantages (Liu et al., 2016; Sui & Humphreys, 2015a; see also Macrae et al., 2018). The self-advantage in movement may similarly be coupled to the premotor self-advantage—the latter may drive the former. During decision-making, an urgency signal speeds-up ITs (Reddi & Carpenter, 2000; Reynaud et al., 2020; Thura et al., 2014), and decisional urgency has been associated with faster motor-specific preparation (reflected in a faster build-up of EMG activity; e.g., Speiser et al., 2017). However, in such cases, responses are also less accurate (Speiser et al., 2017). In Studies C5.1, C5.2, and Chapter 3, a higher-percentage of correctly-selected and -completed movements were observed. Furthermore, from a theoretical perspective, decision urgency cannot account for the self-advantage in movement. As outlined in Chapter 3, movement dynamics (i.e. speed, amplitude, duration; Berret et al., 2018) are driven by an independent ‘movement vigour’ signal which influences MT but not IT (Reynaud et al., 2020). Indeed, consistent with the independence of IT and MT, effects of ownership have been documented to influence ITs but not MTs when movements were directed away from the stimuli, towards the participants’ body (Barton et al., 2020).

From an evidence-based perspective, if the speed of premotor processing is directly reflected in MTs, one would have expected to observe an equivalent magnitude of self-bias in the normalised differential scores in IT and MT across stages, particularly in a ballistic movement. In Studies C5.1, C5.2, and C3, the self-advantage in IT was consistently greater than in MT. It might be argued however that the self-advantage simply develops before movement onset and is subsequently reduced in amplitude due to movement dynamics. As such, the self-advantage in movement execution would be an artefact of a single decisional-urgency signal which interacts with the mechanics of the motor response. Again, this contention does not take into account that the movement vigour signal is a separate process (Reynaud et al., 2020). Furthermore, the between-experiment analysis (section *5.5*), revealed that the extent of self-bias in MT was not moderated across Studies C5.1, C5.2, and C3. If self-bias in IT interacts with the mechanics of the motor response, it should be expected to change across different types of motor response.

The notion that the self-advantage in perception or decision-making is simply reflected in movement execution also does not fit with the accuracy findings. As noted, faster EMG activity is associated with increased overt errors (Speiser et al., 2017) which were not observed in self-associated movement executions. Movement vigour is also not associated with endpoint accuracy (Reppert et al., 2018). As discussed in Chapter 3, if accurate target selection is simply reflected in the correct-completion of the movement responses, then one would expect to observe that correctly-selected responses should go on to be correctly-completed at an equivalent rate across self- and stranger-match conditions. In Study C5.1 and Chapter 3, the self-advantage in correctly-executed movements was greater than in correctly-initiated movements.

Notably, in Study C5.2, the self-advantage in percent correct across the initiation and execution of the movements was not significantly different. It might be argued that this difference across experiments points to a central-stage effect. There may be a relative lack of confidence in associating a 'positive' response (i.e., a stimulus-directed arm-movement) with the stranger. In Study C5.1 and Chapter 3, the responses were directed toward the stimuli, whereas in Study C5.2 they were framed as 'away' from both the stimuli and the participant's body, and directed away from the participant's body without decreasing the distance between the participant's hand and the stimuli. If this were the case, however, one would expect to see 'lower confidence' in the stranger-response association reflected in the selection as well as execution of the movements. Notably, movement initiation accuracy (PC-1) in the stranger-associated condition was not greater in Study C5.2 than Chapter 3 (Study A1). Self-associated PC-1 was also consistent across Study C5.1, Study C5.2, and Study A1. Furthermore, lower confidence or certainty when responding to stranger-associated stimuli with a stimulus-directed arm-movement would potentially produce slower less vigorous movements. However, if reduced movement vigour impacted the correct-completion of the movements, this would implicate 'insufficient force to depress the target button' as the explanatory factor (since movement vigour is not related to endpoint accuracy; Reppert et al., 2018). However, the target buttons required very little force to depress them. In addition, the preliminary between-experiment analysis (Section *5.5*) suggested that self-bias in the accurate completion of the movement responses was modulated across the types of motor response, with a significantly larger magnitude self-advantage in Study C5.1 than in Study

C5.2 and Chapter 3. Modulation of the self-advantage in accuracy (percent correct) across stages cannot simply be related then to a stimulus-directed response.

Another possibility is that the self-advantage in movement may be supported by a modulation of central-stage processes that pertain specifically to aiming arm-movements. As discussed, in Chapter 3, representations of arm-movement responses may be accessed more efficiently in self-associated trials (Frings & Wentura, 2014). As such, more efficient selection of action representations in line with the movement goal could thus contribute to the self-advantage in IT and decisional accuracy (PC-1). Previous research has suggested that self-associations established in the matching task can modulate working memory (Yin et al., 2019). These authors suggested that self-representations may be afforded superior maintenance in working memory through internal attentional processes. Such a mechanism however does not account for the self-advantage in movement execution since the self- and stranger-associated conditions used the same effector and target. Yin et al. (2019) suggest in their study that: “prioritization of information in [working memory]…allows us to temporarily keep information in mind for additional cognitive processing and the guidance of actions” (Yin et al., 2019; p. 3). Indeed, visual imagery maintained by working memory can guide action (Ede et al., 2019). A visual image of the target and its location may be more efficiently formed, accessed, or held in mind in self-associated trials to plan and guide the movement while attention is diverted to onscreen stimuli. Such a mechanism could fit with the findings in Study C5.2 and Study C3. However, this mechanism could not explain the self-advantage in movement in Study C5.1, where no visual feedback was available pertaining to the target or participant’s hands.

Although movement planning in the motor responses of Study C5.1 must rely (predominantly) on proprioceptive, kinaesthetic, and tactile information, another possibility is that visual imagery generated in the absence of relevant visual input could play a role in generating such movements. One study has documented that self-generated movements that typically have reliable visual consequences can generate visual imagery in the absence of exogenous visual input (Dieter et al., 2014). Such imagery may then arise in the case that visual feedback pertaining to the participant's hand and the target are occluded throughout the matching task. Alternatively, *non-visual imagery* may support the self-advantage in movement. It remains for future studies to test these possibilities. How such imagery and movement execution processes are related lies outside of the scope and aims of this thesis to discuss further.

As discussed, the movement vigour signal cannot (solely) account for the self-advantage in movement responses. The increase in self-bias in PC-2 in Study C5.1 may then reflect an interaction between social-relevance and movement planning and online control. Notably, ballistic movements (the initial impulse) can be subject to a form of online regulation which compares perceived velocity and limb direction to an internal model of expected sensory consequences of the movement (Elliott et al., 2010).[18] However, movement planning in relation to an internal model of the sensory expectations occurs prior to movement onset. As such, ballistic movement is highly-dependent on expectations about feedback. In the absence of visual feedback, ballistic movements rely heavily on pre-planning of the movement. One might speculate then that despite grossly planning the same goal-directed movement in the self-associated and stranger-associated conditions (i.e., the goal to hit the same target key in the matching condition), a distinct sensorimotor control policy may be engaged across these conditions.

In feedforward models[19] of sensorimotor control (Yeo et al., 2016), movements are thought to be planned in terms of the consequences of the movement on sensory feedback.

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[18] *Impulse control* is distinguished from *limb-target control.* Limb-target control arises later in the movement and integrates target information (Elliott et al., 2010; Tremblay et al., 2013).

[19] Traditional optimal feedback control (OFC) models in the sensorimotor control literature hold that a control policy that minimizes the cost of the movement in terms of effort, inaccuracy, and regularization determines

This necessarily implicates a feedforward component (Yeo et al., 2016).[20] This component may therefore be susceptible to influence by self-relevance through anticipation of differential real-world consequences for self-associated versus other-associated movements (such associations may be rooted in our development; discussed further in Chapter 6). As such, sensorimotor control policies associated with stranger-related responding may be less compatible with the type of movement required by Study C5.1 than Study C5.2 or Chapter 3. In Study C5.1, movements could not be planned, guided, or recalibrated using exogenous visual information. It may be that stranger-associated responses may rely more on the use of visual feedback. As suggested earlier, it may be that distinct neural circuitry underpins self- as compared with stranger-associated movements in the matching task, as has been documented in premotor processes (Sui, Rotshtein, et al., 2013). Such a notion is in line with a growing recognition in the sensorimotor control literature that cognitive factors can influence movement selection, planning, and control at multiple levels of human information processing (Gallivan et al., 2018).

From both a theoretical and evidence-based perspective, the most likely account of the self-advantage in movement from the three potential accounts suggested above (section 5.6.1) is (2): the self-advantage in premotor processes and the self-advantage in movement execution are somewhat independent, but coordinated by a third factor. Indeed, decisional urgency and movement vigour signals may be independent, but they also interact (Reynaud et al., 2020). Efficient coordination (as well as separation) of the processes involved in movement initiation and execution are clearly crucial in the service of flexible, optimal, and

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movement planning and execution, highlighting an emphasis on feed*back* rather than feed*forward* processing (see Gallivan et al., 2018).

[20] Yeo et al. (2016) argue that sensorimotor control involves a feedforward component. Visual and proprioceptive noise on the sensory input associated with limb position varies with the state of the body. Therefore, costs not only include accuracy and energy expenditure, but also the sensory consequences of the movement. "[Planning] has to take into account the consequences of the movement in shaping the upcoming sensory afferents, which will be used to guide the movement" (p. 2). This necessarily implicates a feedforward component.

functional responding. Indeed, there were strong correlations between the self-advantage in IT and MT in both Studies C5.1 ($r(25) = .92$, $p < .001$) and C5.2 ($r(13) = .97$, $p < .001$), indicating that participants with a greater self-over-stranger advantage in IT tended to have a greater self-over-stranger advantage in MT. These findings support that the separate processes of the two stages must be coordinated by a third factor. Reynaud et al. (2020) suggest that the urgency and vigour signals are coordinated in the basal ganglia. Another third factor candidate might be found in the vmPFC. Functional coupling between the vmPFC and pSTS (Sui, Rotshtein, et al., 2013; Yankouskaya et al., 2017), and between the vmPFC and a classic working memory region (fronto-parietal cortex; Yin et al., 2021) have all been documented to underpin the self-advantage in the matching task and a spatial working memory task, respectively. Such a coupling may also extend to motor-linked regions and modulate the self-advantage across the initiation and execution of movement.

5.6.2. Limitations and conclusions

Taken together, the findings of the present chapter and of Chapter 3 demonstrate that self-relevance in the matching task can influence the initiation and execution of multiple types of arm-movement response. The findings reported in this present chapter further indicate that the self-advantage in movement execution does not depend on an explicit decisional response bias, a modulation of automatic visual-feedback-driven processes, or approach motivation through affective S–R compatibility. These findings thus support and extend those of Chapter 3, highlighting a multiple-stage influence (Scheller & Sui, 2022a; Sui & Humphreys, 2015a), and increasing understanding of the effects of self-relevance at the motor-stage (Frings & Wentura, 2014; Huang et al., 2022; Janczyk et al., 2019; Macrae et al., 2017).

Study C5.1 of the present chapter also demonstrates that self-relevance in the matching task can modulate ballistic movement responses using predominantly proprioceptive, kinaesthetic, and tactile information (and potentially self-generated visual imagery). As such the self-advantage in movement may reflect a modulation of movement planning and automatic top-down control (Elliott et al., 2010; Gaspelin & Luck, 2018; Scott, 2016; Tremblay et al., 2013). Following Chapter 3, the aim of this chapter was to further examine *whether* and not *how* self-relevance in the matching task could modulate movement execution. Suggestions relating to *how* self-relevance modulates movement execution are therefore necessarily speculative. However these speculative accounts highlight plausible underlying mechanisms for a modulation of movement execution by self-relevance. Future investigations could systematically examine how self-relevance modulates movement execution using, for example, techniques such as kinematic analysis (Khan et al., 2006; see also Chapter 7).

In the present thesis the self-advantage is accordingly further examined in ballistic movement without visual feedback using the task set-up of Study C5.1. The final experimental chapter of this thesis (Chapter 6) examines the relationship between the self-advantage and underlying self–other representations. Notably, across the experiments in Chapters 3 and 5, the type of movement response was varied, but the stimuli were not. It is therefore not known whether the self-advantage in movement may be dependent on dichotomous self- versus stranger-associations in the matching task. Hierarchical relations between associations in the matching task can be altered across contexts (Stolte et al., 2021), including by the combination of identities (Verma et al., 2021). Therefore, in the following chapter (Chapters 6) the friend association is introduced (e.g. Sui et al., 2012). The addition of the friend variable also permits measurement of the Friend-stranger bias (the advantage for friend-over-stranger-associated responses) alongside self-bias. As such, responses underpinned by allocentric (other-other) representations as well as egocentric (self–other) representations are examined in relation to the self-advantage in arm-movements.

Chapter 6—The influence of empathy and perceived closeness on self- and friend-bias in arm-movements (Study C6)

6.1. Chapter overview

Chapter 5 demonstrated that the self-advantage in movements is supported by processes that do not depend on visual information pertaining to the hand or target position, nor do they depend on a non-ballistic or stimulus-directed response. Specifically, Study C5.1 demonstrated that the self-advantage emerges in ballistic movements using predominantly proprioceptive, kinaesthetic, and tactile information (and potentially visual imagery formed in the absence of relevant visual sensory information; Dieter et al., 2014) in planning and execution. In the present chapter, the self-advantage was further examined using the task set-up of Study C5.1. The Friend variable was also introduced permitting assessment of Self-friend and Friend-stranger bias as well as Self-stranger bias. Chapter 2 documented that a significant self-advantage did not arise in simple detection motor responses. If self-bias reflects the operation of the minimal self, however, one might expect that the influence of these self-associations would arise more automatically and therefore emerge in these motor responses. It may be that rather than reflecting operation of the minimal self, self-bias reflects the operation of a higher-level subcomponent of self. The aim of the present study was therefore to better understand the processes supporting self-bias in the matching task motor responses by investigating representations of the self and others underpinning these responses.

To date, little is known about the representations underlying self-bias in the matching task. An emerging theoretical view is that self-bias is not influenced by consciously-accessible constructs related to the self, such as explicit self-esteem (Schäfer & Frings, 2019b) and instead reflects implicit (automatic and preconscious) self-related processing (Northoff, 2016; Schäfer & Frings, 2019b; Schäfer, Wesslein, et al., 2020). An alternative view is that self-bias *is* influenced by explicit self-representations and self-reflective processing. To decide between these two accounts, this chapter (Desebrock, Barutchu, et al., 2022) examined for the first time the relationship between Self-bias and Friend-stranger bias and subjective measures of empathy and personal distance (the perceived closeness between others and the self).

A self-advantage in arm-movement responses was documented, indicating that the movement self-bias reported in Chapters 3 and 5 (Desebrock et al., 2018; Desebrock & Spence, 2021) was robust to the addition of the Friend variable. Associations were revealed between the subjective measures and the biases in the arm-movement responses. Regression analyses revealed that empathy was a significant predictor of Self-bias, and personal distance was a significant predictor of Friend-stranger bias.

This chapter (Desebrock, Barutchu, et al., 2022) thus presents a novel demonstration that biases in matching task motor responses may be (directly or indirectly) influenced by explicit representations of the interrelations between others and the self. These biases may therefore not operate independently of higher-level self-related constructs as has been suggested previously. The wider implications of these findings for understanding the operation of different aspects of the self in cognition and action, and across divergent populations, for example, in autistic individuals, are discussed.

6.2. Introduction

As outlined in Chapter 1, neuroimaging studies have revealed that distinct neural circuitry underpins self-bias in the matching task motor responses (Sui et al., 2013; Yankouskaya et al., 2017), and the self-advantage is not simply driven, for example, by stimulus reward value

(Stolte et al., 2021; Sui & Humphreys, 2015b,c), or emotional valence (Schäfer, Wentura, et al., 2020; Stolte et al., 2017). Chapter 2, along with other studies using multimodal adaptations of the matching task, documented that the self-advantage arises in auditory and multisensory as well as visual processes in the manual motor responses (Desebrock, Spence, et al., 2022; Schäfer, Wesslein, et al., 2016; Scheller & Sui, 2022a; Stolte et al., 2021). Chapters 3 and 5 of this thesis further demonstrated that the self-advantage emerges in the execution as well as initiation of manual motor responses (Desebrock & Spence, 2021; Desebrock et al., 2018), in line with a multiple-stage modulation (Scheller & Sui, 2022a; Sui & Humphreys, 2015a). Little is known, however, about the self and other representations underlying self-bias in the matching task motor responses (Schäfer & Frings, 2019b; Woźniak et al., 2022).

6.2.1. Self-bias and lower- and higher-level representations of self

Self-representation is widely held to guide our cognition and action (Golubickis et al., 2018; James, 1890/2007; Neisser, 1988; Turk et al., 2008), and is commonly conceptualised as operating at multiple levels of information processing. For example, as outlined in Chapter 1, Gallagher (2000) makes a widely-accepted distinction between two conceptions of self—the *minimal* and *narrative* self. Minimal self typically pertains to a person's phenomenal experience as a conscious embodied subject, emerging on a moment-by-moment basis from multisensory input, and lacking temporal extension. The narrative self pertains to higher-level representations of self, one's personal identity, comprising personality traits, beliefs, attitudes, preferences, and is extended in time, drawing on autobiographical memories and explicit reflections about ourselves (Gallagher, 2000; Hommel, 2019; Noel, Blanke, et al., 2017; Noel, Cascio, et al., 2017; Schäfer & Frings, 2019b). The distinction between the minimal and narrative self is not without its shortcomings (Bortolan, 2020; Hommel, 2019). However, this basic dichotomy serves as a useful framework when conceptualising 'lower-level' and 'higher-level' constructs of self and self-referential processing. For example, those tasks in which participants explicitly evaluate traits and attributes in relation to themselves and other people are considered to be 'higher-level' or 'second order' self-referential tasks (e.g. Moseley et al., 2021; Williams et al., 2018). Superior recall is documented for the self-related items (known as the Self-Reference Effect; SRE; Rogers et al., 1977), with the underlying processes thought to draw on explicit representations of the narrative self.

In contrast, some researchers have postulated that self-bias in the matching task may constitute a measure of the minimal self (Schäfer & Frings, 2019b). Indeed, these researchers documented no relationship between self-bias in the manual motor responses and a self-report measure of self-esteem (a higher-level self-construct). In contrast, a relationship between the SRE and self-esteem has been documented (Nowicka et al., 2018). Furthermore, while autistic people have been documented to show a reduced or absent SRE (Dawson & McKissick, 1984; Henderson et al., 2009; Lombardo et al., 2007; Toichi et al., 2002; cf. Amodeo et al., 2021; Lind et al., 2020), an intact attentional self-bias (Nijhof et al., 2021) and also an intact SPE has been demonstrated in this population (Moseley et al., 2021; Williams et al., 2018). Indeed, the social deficits in autism are not thought to relate to a lack of basic differentiation between the self and others (Dawson & McKissick, 1984). On the basis of such findings, it has been suggested that self-bias may relate to the function of making a basic distinction between self and other, and reflect lower-level or 'first order' self-related processing; that is, implicit (automatic and preconscious) processing that is (somewhat) independent of explicit higher-level self-referential or self-reflective processing (Northoff, 2016; Schäfer, Wesslein, et al., 2020; Schäfer & Frings, 2019b).

6.2.2. Self-bias and self–other relations

Explicit representations of *self–other relations* also exert a potent influence on our behaviour, however. Indeed, "…the self exists only in the context of the other" (Fonagy & Target, 1997;

p 684). As such, representations of the self and others are necessarily formed in relation to one another. During development, a pre-reflective core self-representation is thought to emerge through sensorimotor exploration of the physical and social environment, which gives rise to a sense of agency and ownership over the body and its movements (Cunningham et al., 2008; Fotopoulou & Tsakiris, 2017; Hommel, 2019; Noel, Blanke, et al., 2017). Concomitantly, representations of self–other relations emerge which guide automatic responding in interpersonal contexts (Luyten et al., 2021; Zahavi, 2014). Explicit self-representations are thought to develop later on these foundations through semantic and autobiographical memory processes (Blanke & Metzinger, 2009; Cermolacce et al., 2007; Hommel, 2019; Noel, Blanke, et al., 2017). The explicit representations that we use to report on ‘the individual self’ and those we use to report on ‘the self-in-relation-to-close-others’ (or relational self), however, are thought to be distinct (Gaertner et al., 2012; Sedikides & Brewer, 2001). It may be the latter that are reflected in manual motor responses to self- and other-associated stimuli in the matching task. Indeed, there is some evidence to support this notion.

6.2.3. Self-bias and personal distance

A handful of studies have documented an association between self-bias and ‘personal distance’ using the personal distance scale (PDS; Sui & Humphreys, 2015b)—an explicit self-report measure of the perceived closeness between pairs of individuals; e.g., self–friend, self–stranger, friend–stranger (Enock et al., 2018; Sui & Humphreys, 2017c; Yankouskaya et al., 2020). For example, in one study, a close personal distance to strangers was associated with a reduced self-advantage in the matching task (Sui & Humphreys, 2015b). In another study, self-partner and self-mother personal distance predicted the respective biases in the matching task (Yankouskaya et al., 2020). Self-bias in the matching task motor responses may reflect the operation of the relational rather than individual self.

The pattern of findings across studies has, however, been inconsistent. For example, in one study, the self–stranger personal distance was associated with the SPE in RT (Sui & Humphreys, 2015b), while in another study only the friend–stranger personal distance and friend–stranger bias in sensitivity (D-prime; *d′*) were associated (and in an elderly but not a young sample of participants; Sui & Humphreys, 2017c). In addition, Yankouskaya et al. (2020) documented that self–partner and self–mother personal distance predicted the respective biases in the matching task, but self–friend personal distance did not predict self–friend bias. Further research is therefore needed to determine whether there is a relationship between explicit representations of self–other relations and self-bias.

6.2.4. Arm-movements and representations of self–other relations

To date, studies investigating the self and other representations underpinning self-bias in the matching task have used keypress motor responses (Schäfer & Frings, 2019b; Woźniak et al., 2022). Chapters 3 and 5 of the present thesis demonstrated a robust self-advantage in arm-movement motor responses. However, the biases may not be identical across the two types of motor response. For example, a self-advantage has been documented in the initiation and execution of arm-movement responses (Desebrock & Spence, 2021; Desebrock et al., 2018), but only in the initiation and not in the execution of keypress responses (Janczyk et al., 2019—Experiment 4; although cf. Chapter 4). Effect sizes of the self-advantage are also typically larger in the initiation of arm-movements ($\eta^2 = .67$; Chapter 5) than in keypress responses (e.g., $\eta^2 = .25$; Sui et al., 2012), and the initiation and execution stages of responses also exhibit differential magnitudes of self-bias (Chapters 3 and 5). Self–other biases may manifest more strongly in arm-movement responses than in keypress responses to the same stimuli, with greater scope to reveal the operation of underlying self–other representations. Indeed, arm-movement responses have primacy over keypresses in development, and pre-conceptual intentionality is evidenced even in neonatal arm-movements which are organized according to their anticipated effects (Delafield-Butt et al., 2018). Social effects can shape movements throughout development (Silver et al., 2021), and, as outlined earlier, the social self is thought to develop through sensorimotor exploration of the social environment. Thus, arm-movement responses (particularly those that are fast and ballistic) are likely to reflect the automatic operation of self–other relations more reliably than keypress responses owing to deeply-ingrained links. Therefore, in the present chapter, the relationship between personal distance and self-bias in the matching task using ballistic arm-movement responses is examined for the first time.

6.2.5. Self-bias and empathy

Another candidate measure with which to examine the relationship between self-bias in arm-movement responses and explicit representations of self–other relations is self-reported empathy. Empathy is a fundamental socio-cognitive ability and central to effective social interaction (Baron-Cohen & Wheelwright, 2004). Empathy has been defined, for example, as a responsivity to the experiences of another (Davis, 1980). The neuroscientific literature suggests that there are two main components to empathy: emotional representations that are shared across self and other, and in self–other distinction (Lamm et al., 2016). The self–other distinction involves discriminating between self- and other-person generated perceptions, cognitions, and actions (Jeannerod, 2003). Awareness of the distinction between self and other, for example, can increase higher-level aspects of empathy (Saito et al., 2016). Since empathy is linked to self–other relations, if self-bias in the matching task motor responses is influenced by explicit self–other representations, then one would expect self-bias to be influenced by explicit empathy.

Empathy-related processes are also thought to be integral to the interpersonal self which is conceptualised to operate as a bridge between the automatic processes of the minimal self and reflective processes of the narrative self (Kyselo, 2016; Zahavi, 2014). If self-bias is related not just to the function of making a basic distinction between self and other at the implicit level but to the operation of the interpersonal self, and implicit and explicit representations of self–other relations are (somewhat) linked, then explicit perceptions of empathy-related behaviour may be reflected in self-bias.

6.2.6. Friend-stranger bias

Representations of allocentric (indirect other–other) relations, as well as egocentric (direct self–other) relations, are also thought to exert a potent influence on our behaviour; for example, in orienting the self within social networks (Arzy & Schacter, 2019; Huang et al., 2022; Lin et al., 2022; Parkinson & Du, 2020; Weaverdyck & Parkinson, 2018). A related measure yielded by both the PDS (Sui & Humphreys, 2015b) and the matching task is Friend-stranger bias. In the PDS, this constitutes the perceived closeness between friends and strangers; in the matching task, the difference between responses to friend- versus stranger-associated stimuli. A friend-over-stranger advantage in the matching task has been observed in both RT and accuracy in certain studies (e.g. Sui et al., 2013), or in just RT (Enock et al., 2018; Stolte et al., 2017; Sui et al., 2012), but other studies have reported no friend-bias (Lee et al., 2021; Moseley et al., 2021; Reuther & Chakravarthi, 2017; Sui & Humphreys, 2015a).

Friend–stranger relations are conceptualised *relative* to self–other relations, and during development friend–stranger representations would be formed in reference to self–other representations. As Moseley et al. (2021, p. 9) note: “perturbations in the FPE [friend-prioritization effect] are also reflective of self-prioritization”. Indeed, these authors documented that friend–stranger distance in the PDS and friend–stranger bias in the matching task were both reduced in autistic as compared with non-autistic participants. If a relationship was observed between friend–stranger bias in the matching task arm-movement responses and personal distance this would support the notion that the biases in the matching task reflect representations of the relations between others and the self.

Notably, the movement adaptations of the matching task used in Chapters 3 and 5 used dichotomous Self and Stranger associations, and Friend-stranger bias was not assessed. It is therefore not known whether the movement self-advantage documented in the previous chapters was dependent on dichotomous associations, and whether Self-friend bias and Friend-stranger bias would alter, or influence self-stranger bias, in arm-movement responses. The Friend variable was therefore introduced to the movement adaptation of the matching task in this chapter permitting assessment of the robustness of the movement self-advantage, and also the measurement of Self-friend and Friend-stranger biases.

6.2.7. The present study

In summary, an emerging theoretical view in the literature on self-bias is that self-bias in the matching task motor responses is not associated with higher-level explicit self-related representations. Instead, self-bias is thought to reflect implicit (automatic and preconscious) self-related processing that is independent of explicit higher-level self-reflective processing (Northoff, 2016; Schäfer & Frings, 2019b; Schäfer, Wesslein, et al., 2020). An alternative view is that self-bias in the matching task motor responses *is* influenced by higher-level explicit self-related representations. The present chapter therefore aimed to discriminate between these two accounts. The Friend variable was introduced to the movement adaptation of the matching task used in Study C5.1 in order to measure both Self-bias and Friend-stranger bias in IT, MT, percentage of correct scores, and *d′*. This chapter then examined the relationship between composite scores of these biases and explicit representations of the relations between others and the self—indexed by explicit measures of personal distance (Sui & Humphreys, 2015b) and empathy (Davis, 1983). Following Chapter 2, the matching task motor responses were treated holistically (in their entirety) to examine the relationship between the subjective and bias measures in the motor responses; thus, composite bias scores combining both response stages were used[21].

No previous studies have examined the relationship between empathy and self-biases in the motor responses of the matching task (cf. Bukowski et al., 2021; Mattan et al., 2016), or between the biases in arm-movement responses and personal distance. Examining the relationship between self–other biases in motor responses and their underlying self–other representations will likely increase our understanding of the operation of the self in our cognition and action. It was hypothesized that if biases in the matching task arm-movement responses are related to explicit representations of self–other relations, empathy would be related to, and could potentially predict, self-bias, and personal distance would be related to and could potentially predict one or both of self-bias and friend-stranger bias.

6.3. Methods

6.3.1. Participants

The effect size for the self-advantage in IT and MT in Study C5.1 (Desebrock & Spence, 2021), which used the same task set-up and movement response, was $\eta^2 = .67$ and $\eta^2 = .46$, respectively (paired-samples t-test). However, in contrast to this previous study and the movement studies reported so far in this thesis, the present chapter used the Friend as well as Self and Stranger associations in the matching task. In previous studies using the matching task that have used the Friend association, the effect size for the self-advantage was relatively smaller, e.g., $\eta^2 > .25$ (Sui et al., 2012; although keypress responses rather than arm-movement responses were used). Therefore, in order to allow for the detection of an effect

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[21] In this chapter, *arm-movement response* refers to the entirety of the arm-movement response; namely, including both the initiation and execution of the arm-movement response; and is distinguished from *movement initiation* (the information processing that occurs between stimulus onset and the onset of the overt movement response) and *movement execution* (the overt movement response).

size of $\eta^2 = .25$, with a probability of $1 - \beta = .80$, and an alpha value of .05, a minimum sample size of 26 participants was required (MorePower 6.0.4 program; Campbell & Thompson, 2012). In previous studies that have documented a significant relationship between self-bias and personal distance measures using young control samples (Sui & Humphreys, 2015b; Yankouskaya et al., 2020; cf. Enock et al., 2018; Moseley et al., 2021; Sui & Humphreys, 2017c), effects were documented for self-bias in RT with sizes ranging from $\eta^2 = .31$ to .37. For the correlational and multiple regression analyses, a minimum sample size of 22 participants was required to detect an effect size of $\eta^2 = .31$ with a probability of $1 - \beta = .80$, and an alpha value of .05 (MorePower 6.0.4 program; Campbell & Thompson, 2012). No previous studies have examined the relationship between empathy measures and self-bias in the matching task: a sample size of 43 participants allowed for the detection of an effect size of $\eta^2 = .17$ with a probability of $1 - \beta = .80$, and an alpha value of .05 (MorePower 6.0.4 program; Campbell & Thompson, 2012).

Forty-three right-handed participants (14 male, ages 18-37 years, mean age 21.51 ± 5.03) with normal or corrected-to-normal vision took part in the study. They were recruited via the national callforparticipants.com website, the Bath University Research Participation Scheme, and Bath University electronic noticeboard. They received monetary reimbursement (£10) or course credits for their time and effort. All participants completed a written consent form approved by the Oxford Research Ethics Committee (R55087/RE001/RE002) and the University of Bath Psychology Research Ethics Committee (17-230).

6.3.2. Apparatus and stimuli

The study was conducted on a PC with a 23-in. LCD monitor (1920 x 1080 pixels at 60 Hz refresh rate) using E-Prime software (version 2.0). Following Study C5.1 (Desebrock & Spence, 2021), a Cedrus RB-530 response-box, positioned in front of the PC monitor, recorded home-button-releases (measuring IT from stimulus onset) and also target-key presses (measuring MT from release of the home-button). The response-box was placed inside a custom-built wooden holder such that the ‘home’ and ‘target’ buttons were separated by 6cm. A cardboard box was placed over the response box occluding the participant’s hands from direct sight. (See Figure 5.1, Chapter 5.)

The stimuli consisted of three geometric shapes from the following set (circle, square, triangle, hexagon, pentagon, or octagon, each subtending 3.2 × 3.2 deg. of visual angle), and three written-text self- and other-related word-labels (i.e., ‘yourself’, ‘stranger’, ‘friend’). The shape was positioned above (and the label below) a central fixation cross. The associations between the three shapes allocated to each participant and the written labels that they were paired with were counterbalanced across participants. The shapes and labels were presented in the centre of the PC-screen against a black background.

6.3.3. Personal distance and empathy measures

Measures of empathy and perceived closeness between the self and other people were obtained using the *Interpersonal Reactivity Index* (IRI; Davis, 1980; Keaton, 2017), and the *personal distance scale* (PDS; Sui & Humphreys, 2015b; see also Moseley et al., 2021) , respectively. The IRI consists of 28 items, with responses given on a 5-point Likert scale (from “does not describe me well” to “describes me very well”). Aligned with the view of empathy as a multidimensional construct, the IRI taps aspects of empathy across four subscales—*Empathic Concern* (EC), *Fantasy* (FS), *Personal Distress* (PD), and *Perspective Taking* (PT). EC measures other-person-directed feelings of concern and compassion, FS assesses the tendency to identify with fictional characters, PD assesses self-focused feelings of unease and anxiety when encountering other people’s negative experiences, and PT assesses the tendency to spontaneously adopt other people’s points of view (Davis, 1980; Keaton, 2017). The measure yields a total score (ranging from 0 to 112) and scores for the four subscales. The correlational analyses of the present study focused on empathy (total scores). (See Appendix C1.1.)

The ‘Personal Distance’ scale developed by Sui and colleagues has been used in a number of studies examining self-prioritization (e.g., Enock et al., 2018; Sui & Humphreys, 2015b, 2017c). Participants are asked to make two marks on a straight line which indicate the relative distance in terms of closeness that they perceive lies between two individuals (i.e., the participant, their best friend, or a named unfamiliar other). In each of the three category-pairs (self-stranger, self-friend, friend-stranger) there are 10 measurements with the order of first and second person in the pair counterbalanced. For example, there are five sub-category measures of self-stranger, and five sub-category measures of stranger-self. Overall, thirty measurements are taken per participant. A larger score indicates a larger perceived distance between the two individuals. (See Appendix C1.2.)

6.3.4. Procedure

Each participant completed a single experimental testing session. At the start of the session, the participants completed the computer-based IRI and personal distance survey measures, the order of which was counterbalanced across participants. (The participants were then fitted with electrode caps in order to record their electrophysiological data, using EEG, during the behavioural task—an outline of this second phase of the study is presented in Appendix D.)[22] Next, the participants carried out the movement-time adaptation of Sui et al.’s (2012) computer-based matching task used in Study C5.1 (Desebrock & Spence, 2021), which this time also included the Friend variable. The participants first read onscreen text instructing them to memorize three shape and identity pairings. They associated one of their allocated

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[22] The EEG data collected was not analysed in the present chapter due to data loss which reduced the sample size. Therefore, to preserve the validity of the analyses of the subjective measures, the behavioural data is presented in this chapter. Appendix D presents an outline of the EEG study.

geometric shapes with themselves (e.g., ‘the triangle is yourself’), a second shape with a named best friend (e.g., ‘the square is your friend’), and a third with a named stranger (e.g., ‘the circle is the stranger’). The order of instructions pertaining to ‘self’, ‘friend’, and ‘stranger’ associations were counterbalanced across participants. The participants then completed the matching task, judging whether simultaneously-presented shape and label pairs matched or mismatched the associations that they had learnt. Before the first trial, and continuously throughout the task, the participants held down both response-box ‘home’ buttons with their index fingers, except when making a response. To make a response, the participants released a response-box ‘home’ button by lifting an index finger and moving the hand forward to depress a target key with that index finger. The participants were instructed to make their response to the stimuli as rapidly and accurately as possible. Following Study C5 (Desebrock & Spence, 2021), right-hand (i.e., dominant-hand) responses were made for those shape-label pairs participants judged as matching, and left-hand responses for those pairs judged to be mismatching.

Preceding the main task, there was a practice block of 24 practice trials with a performance-accuracy threshold set at 60% correct (that is, the participants had to achieve 60% correct before they could proceed to the main task). Onscreen feedback was presented (*Correct, Incorrect, Too Slow*) at the end of each trial. At the end of each block, the participants were informed of their overall accuracy for the block that they had just completed. The matching task consisted of 12 blocks of 48 trials separated by breaks. After each break, the participant manually started the next block when they were ready. There were 576 trials, and 6 conditions; thus, there were 96 trials per condition. A schematic representation of an experimental trial in the matching task is shown in Figure 6.1.

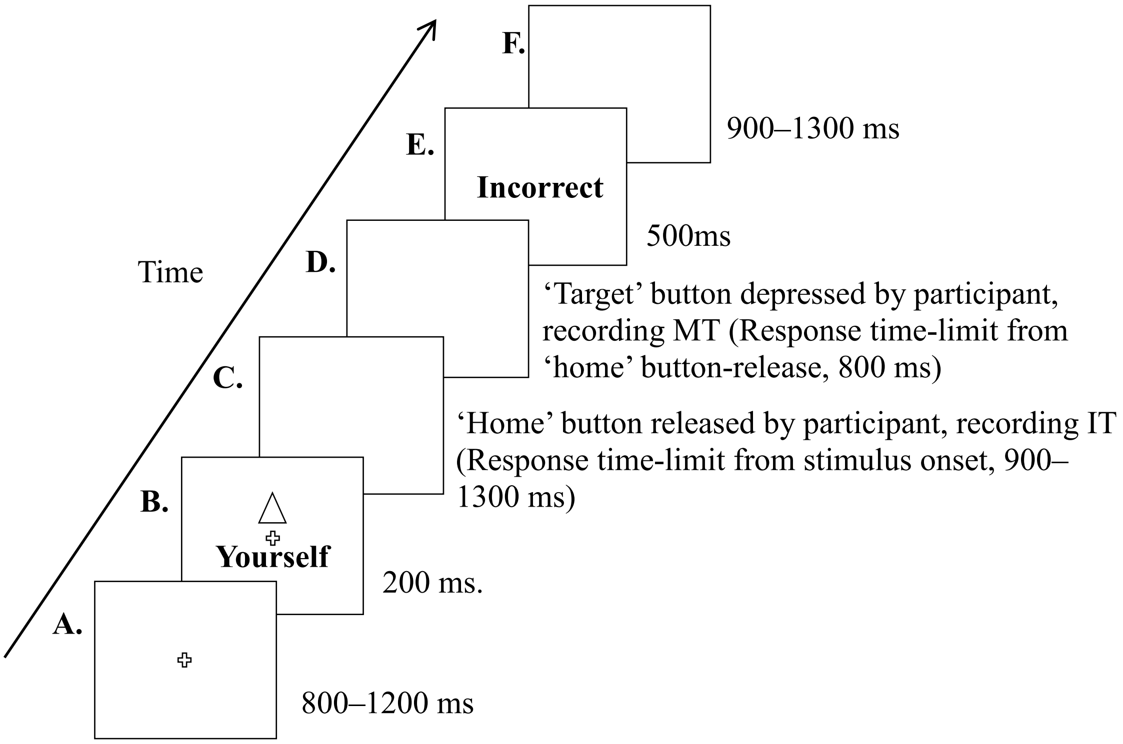

Figure 6.1. Schematic overview of an experimental trial sequence (displayed elements not to scale). **A**. Fixation cross. **B**. Stimulus onset (example shape-label pair shown). **C**. Blank screen. IT = movement initiation time. **D**. Blank screen. **E**. Onscreen feedback – "Correct" / "Incorrect" / "Too slow". **F**. Inter-trial intervals generated at random. IT response time-limit = the time limit measured from stimulus onset within which a participant had to select their response and initiate the onset of the movement by releasing the 'home' button. MT response time-limit = the time limit measured from the release of the 'home' button within which a participant had to complete their movement response by depressing the 'target' button. (Adapted from: Desebrock et al., 2022, *Journal of Experimental Psychology: Human Perception & Performance*, APA).

6.3.5. Data analysis

Following Chapters 3 and 5, there were four main motor output measures: Movement initiation time (IT; measured from stimulus onset to the release of the response-box home button) for correctly-initiated movements, movement execution time (MT; measured from the release of the response-box home-button to the depression of the target key) for correctly-initiated and completed arm-movement responses; movement initiation accuracy (*movement initiation PC-1*; the percentage of correctly-initiated movements), and movement execution correct-completion (*movement execution PC-2*; the correctly-completed movement executions, following correct movement initiation, as a percentage of the total number of trials). (Note: the IT, MT, and *d′* data were analysed using Analysis of Variance (ANOVA), and non-parametric tests—related-samples Friedman's two-way analysis of variance by ranks—were used to analyse the percent correct data). Possible response outcomes in relation to accuracy in the task followed Chapters 3 and 5 (see Section *3.4.4 Data analysis*, Chapter 3). An error in a valid movement response consisted in not depressing the target key (missing the target key) or hitting the incorrect target key, following a correct initiation response. Movement execution errors consisting of hitting the incorrect target key constituted ≈1% of the total errors, thus suggesting a floor effect and were not analysed further. Errors in valid movement responses thus constituted missing the target key, rather than pressing the wrong target button, consistent with Chapters 3 and 5. As in Study C5.1, these errors were due to the speeded nature of the task and the fact that the participants' hands and the response box were occluded from the participant's view. This set-up increased task difficulty and required the participants to plan and execute ballistic arm-movement responses in the absence of any visual feedback (see Chapter 5, Figure 5.1).

Following the previous studies in this thesis and previous research (Sui et al., 2012), a signal detection approach was used to calculate an index of sensitivity (D-prime; *d′*; Green & Swets, 1966). Hits were coded as *yes* responses to match trials, and false alarms were coded as *yes* responses to mismatch trials with the same shape; thus, sensitivity scores were derived from right (match)-hand responses only (namely, the same effector). Mismatch conditions were defined as shape-based (i.e., a self-mismatch trial consisted of the self-associated shape and the stranger-associated label, a stranger-mismatch trial consisted of the stranger-associated shape and the self-associated label). ITs were based on correct responses, and ITs above or below 2.5 SDs from individual means were trimmed (< 2% of ITs in the matching- and mismatching-trial data were excluded). Similarly, MTs were based on correct movement executions following a correct initiation-response. MTs greater than 2.5 standard deviations above individual means were excluded, eliminating < 2% the trials in the matching-trial MT data, and < 1% in the mismatching-trial data. MTs faster than 2.5 SDs below individual means were retained since MTs for correct responses could not be executed erroneously too quickly.

Normalised differential scores—self-bias index scores (e.g., Constable et al., 2021; Desebrock & Spence, 2021; Schäfer, Wesslein, et al., 2016; Sui & Humphreys, 2017c)—were analysed following Chapters 3 and 5 in order to examine the self-advantage across the initiation and execution response stages, and also to assess the relationship between the movement and self-report measures. These scores provide an index of the relative magnitude of the difference in performance between self- and stranger-related responses. Different types of responses are made to the matching versus mismatching stimuli (Janczyk et al., 2019; Sui & Humphreys, 2017c; Woźniak et al., 2018; Yankouskaya et al., 2020). Match-trial stimuli (e.g., a self-associated shape and self-associated label) involve one association, thus in behavioural paradigms where effects in mismatch trials cannot be disentangled, matching-trial responses index self- and stranger-related processing (Sui et al., 2012). Researchers in this area typically treat mismatch trials as fillers (Schäfer, Wesslein et al., 2020). Therefore, in accordance with the aims of the present chapter, and following the rationale detailed in Chapter 5, the focus of the analysis reported here was on the match-trial data. Self-bias and friend-bias index scores were calculated using matching-trial ITs, MTs, and the percentage of correctly-initiated and -executed responses (following Sui & Humphreys, 2017c). See Table 6.1 for the respective calculations. Positive values indicate an advantage for self (or friend, for Friend-stranger bias).

To examine the relations between the self-reported personal distance scores and the self-bias measures, self-reported personal distance scores were normalised following Sui and

Table 6.1. Formulas for calculating the bias index scores, using the matching-trial data, for Self-stranger bias, Self-friend bias, and Friend-stranger bias in movement initiation time (IT), movement time (MT), percentage of correctly-initiated movements (PC-1), percentage of correctly-completed movements (PC-2), and sensitivity (D-prime; *d′*) in Study C6.

Performance indices	Self-stranger bias	Self-friend bias	Friend-stranger bias
IT	(stranger − self) / (stranger + self)	(friend − self) / (friend + self)	(stranger − friend) / (friend + stranger)
MT	(stranger − self) / (stranger + self)	(friend − self) / (friend + self)	(stranger − friend) / (friend + stranger)
Movement initiation PC-1	(self – stranger) / (stranger + self)	(self – friend) / (friend + self)	(friend − stranger) / (friend + stranger)
Movement execution PC-2	(self – stranger) / (stranger + self)	(self – friend) / (friend + self)	(friend − stranger) / (friend + stranger)
d′	self – stranger	self – friend	friend – stranger

Note: '−' = deduct, '+' = add, '/' = divide. (Adapted from: Desebrock et al., 2022, *Journal of Experimental Psychology: Human Perception & Performance*, APA)

Humphreys (2017). The self-friend personal distance (hereafter referred to as Self-PD) was given by the formula: Self-PD = self–friend distance / self–stranger distance, providing a scaled measure of how close the participant feels to friends in relation to unfamiliar others. A smaller score indicates increased closeness to friends as compared with strangers. The friend-stranger personal distance (hereafter, referred to as Friend-PD) was given by the formula: Friend-PD = friend–stranger distance / self–stranger distance, so providing a scaled measure of how close the participant perceives friends and unfamiliar others to be in relation to how close the participant feels to unfamiliar others. A lower score indicates greater perceived closeness between friends and strangers than between the self and unfamiliar others.

An exploratory regression analysis was also conducted in order to identify possible predictors of the self-bias in arm-movement responses. First, Pearson bivariate correlations were used to assess the relationship between the Self-bias and Friend-stranger bias measures and the subjective measures of empathy and personal distance (Table 6.2; for the full correlation matrix of all self-report and bias metrics, see Appendix C2, Table C2.4. Note: as some bias metrics and subjective measures were not normally distributed, Spearman's rank correlations are reported in Table C2.4).

In general, moderate to high correlations for each bias type were found across metrics (see Table C2.4 in Appendix). Therefore, mean composite scores of Self-bias and Friend-stranger bias measures (see Section *6.3.5 Data analysis*) were calculated to minimise collinearity between measures, to save statistical power, and facilitate exploration in the subsequent regression analyses of whether PD and empathy predicted the Self- and Friend-stranger biases across the whole arm-movement response.

Mean composite self-bias scores were calculated, given by the following formulae: Self-bias (Self-Stranger) composite score = [self-bias in IT (self-stranger) + self-bias in MT (self-stranger) + self-bias in *d′* (self-stranger) + self-bias in movement execution PC-2 (self-stranger)]/4; Self-bias (Self-Friend) composite score = [self-bias in IT (self-friend) + self-bias in MT (self-friend) + self-bias in *d′* (self-friend) + self-bias in movement execution PC-2 (self-friend)]/4; Friend-stranger bias (Friend-Stranger) composite score = [friend-stranger bias in IT + friend-stranger bias in MT + friend-stranger bias in *d′* + friend-stranger bias in movement execution PC-2]/4. In addition, the correlational analyses revealed positive moderate to high correlations between the empathy subscale measures and total empathy scores, and no significant associations between empathy scores (including the subscales) and the normalised PD measures. Therefore, only the total empathy score was used in regression analyses.

Effect sizes were calculated using partial eta-squared (η_p^2) for ANOVAs (Lakens, 2013). To adjust for multiple comparisons, Holm-Bonferroni corrections at an α value of .05

were applied (Holm, 1979), with unadjusted significance values reported. For violations of sphericity (Mauchly's test), where appropriate, Greenhouse-Geisser corrections were applied (if epsilon (ε) was < .75) or Huynh-Feldt corrections were applied (if ε was > .75) (J. P. Verma, 2015).

6.4. Results

The data from five participants were excluded for having chance accuracy (*M* < 55%) and (< 30% correct in any of the conditions). The data from one participant were excluded because they did not complete the personal distance scale (PDS) or the Interpersonal Reactivity Index (IRI) scale. The data were assessed for outliers (median values < Q1 − 3*IQR & > Q3 + 3*IQR), and one participant's data were identified as an outlier in the Friend-PD data, and another participant's data were identified as an outlier in self-bias (self-stranger) in *d′*, and in composite self-bias (self-stranger). The data from 35 participants (11 male, ages 18-37 years, mean age 21.23 ± 4.67) were therefore used in the analyses. A sample size of 35 participants allowed for the detection of an effect size of $\eta^2 = .20$ with a probability of $1 - \beta = .80$, and an alpha value of .05 (MorePower 6.0.4 program; Campbell & Thompson, 2012).

For absolute measures in *d′* and (match-trial data) in IT, MT, movement initiation accuracy (percent correct; PC-1), and movement execution correct-completion (movement execution PC-2), see Figure 6.2. Mismatch-trial data are presented in Table C2.1, Appendix C2.

6.4.1. Movement initiation

Movement initiation times (ITs) for one condition were not normally-distributed. Since Analysis of Variance (ANOVA) is fairly robust to deviations from normality, and only one

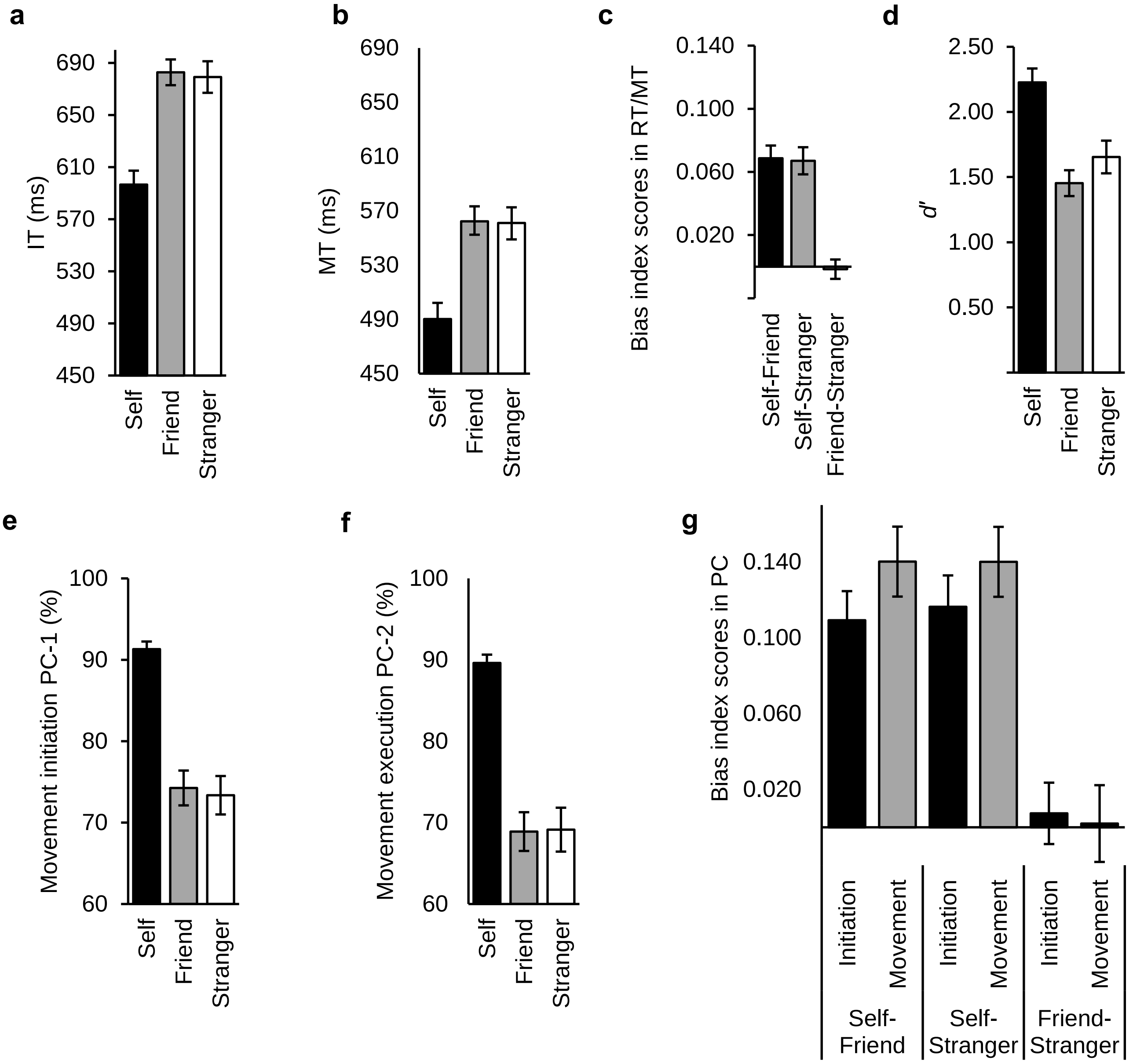

Figure 6.2. **a.** Mean movement initiation time (IT) as a function of Association (self, friend, stranger). **b**. Mean MT (movement time) as a function of Association. **c.** Mean normalised bias index scores in RT and MT collapsed across bias type (self-friend, self-stranger, friend-stranger) as a function of response stage (initiation, movement). **d**. Mean *d'* (D-prime; sensitivity index) scores as a function of Association. **e**. Mean movement initiation accuracy (percent correct; PC-1) as a function of Association. **f.** Mean Movement execution PC-2 (correctly-completed movement executions, following correct movement initiation, as a percentage of the total number of trials for the condition) as a function of Association. **g**. Mean normalised bias index scores in percent correct (PC-1/PC-2) as a function of bias type (self-friend, self-stranger, friend-stranger) and response stage (initiation, movement), in Study C6. Error bars represent SE. (Adapted from: Desebrock et al., 2022, *Journal of Experimental Psychology: Human Perception & Performance,* APA.)

condition was affected, the decision was made not to transform the data. A one-way repeated-measures ANOVA revealed a significant main effect of Association, $F(2, 68) = 50.89$, $p < .001$, $\eta_p^2 = .60$. ITs for self-related responses were shorter ($ps < .001$) than for friend-related and stranger-related responses, and there was no difference between the friend and stranger response types, $p = .82$ (see Figure 6.2a). Non-parametric tests validated the results of the parametric analysis. To provide further support for the non-significant difference between the friend and stranger responses types, Bayes factors were calculated using the Bayesian-t-tests/Wilcoxon signed-rank module of JASP (Version 0.12.2; JASP Team, 2020) and the JASP default prior (Cauchy 0.707). The Bayes factor in favour of the null model for the difference between IT in friend-associated as compared with stranger-associated responses was BF01 = 4.93, indicating that there was ‘substantial’ or ‘positive’ evidence for the null model (Jeffreys, 1998; Raftery, 1995).

Normality was violated and one studentized residuals outlier (>3 in absolute value) was detected in the movement initiation accuracy (PC-1) data. A related-samples Friedman’s two-way analysis of variance by ranks revealed a main effect of Association, χ^2 (2) = 41.03, $p < .001$, with greater accuracy in self-related responses (*Mdn* = 94, *SD* = 5.55) as compared with friend-related (*Mdn* = 75, *SD* = 12.65) and stranger-related (*Mdn* = 74, *SD* = 13.96) responses (for both $p < .001$). There was no difference between the friend and stranger response types, $p = .40$ (see Figure 6.2e). To provide further support for the non-significant difference between the friend and stranger responses types, Bayes factors were calculated using the Bayesian-t-tests/Wilcoxon signed-rank module of JASP (Version 0.12.2; JASP Team, 2020) and the JASP default prior. The Bayes factor in favour of the null model for the friend response type accuracy (PC-1) compared with the stranger response type accuracy (PC-2) was BF01 = 5.31, indicating that there was ‘substantial’ or ‘positive’ evidence for the null model (Jeffreys, 1998; Raftery, 1995).

Sensitivity index scores (D-prime; *d′*) for movement initiation were analysed using a one-way repeated-measures ANOVA and revealed a main effect of Association, $F(2, 68) = 30.79$, $p < .001$, $\eta_p^2 = .48$. *d′* scores for self-related responses were higher (for both $p < .001$) than friend-related and stranger-related responses, and there was no significant difference between friend and stranger response types, $p = .04$ (see Figure 6.2d). To provide further support for the non-significant difference between the friend and stranger responses types, Bayes factors were calculated using the Bayesian-t-tests module of JASP (Version 0.12.2; JASP Team, 2020) and the JASP default prior. The Bayes factor in favour of the null model for the friend response type *d′* scores compared with the stranger response type *d′* scores was BF01 = 0.75, indicating that there was ‘anecdotal’ or ‘weak’ evidence for the null model (Jeffreys, 1998; Raftery, 1995).

6.4.2. Movement execution

Movement times (MTs) were assessed using a one-way repeated-measures ANOVA which revealed a main effect of Association, $F(2, 68) = 46.97$, $p < .001$, $\eta_p^2 = .58$. MTs for self-related responses were shorter (for both $p < .001$) than friend-related and stranger-related responses, and there was no significant difference between the friend and stranger response types, $p = .86$ (see Figure 6.2b). To provide further support for the non-significant difference between the friend and stranger responses types, Bayes factors were calculated using the Bayesian-t-tests module of JASP (Version 0.12.2; JASP Team, 2020) and the JASP default prior. The Bayes factor in favour of the null model for the friend response type MTs compared with the stranger response type MTs was BF01 = 5.44, indicating that there was ‘substantial’ or ‘positive’ evidence for the null model (Jeffreys, 1998; Raftery, 1995).

Normality was violated in the movement execution correct-completion (percent correct; PC-2) data. A related-samples Friedman’s two-way analysis of variance by ranks was carried out on the PC-2 data. The analysis revealed a main effect of Association, $\chi2$ (2) =

44.65, *p* < .001, with greater accuracy in self-related responses (*Mdn* = 92, *SD* = 6.05) as compared with friend-related (*Mdn* = 69, *SD* = 14.08) and stranger-related (*Mdn* = 71, *SD* = 15.96) responses *(p* < .001 for both). There was no difference between the friend and stranger response types, *p* = .74 (see Figure 6.2f). To provide further support for the non-significant difference between the friend and stranger responses types, Bayes factors were calculated using the Bayesian-t-tests/Wilcoxon signed-rank module of JASP (Version 0.12.2; JASP Team, 2020) and the JASP default prior (Cauchy 0.707). The Bayes factor in favour of the null model for the friend response type movement execution PC-2 compared with the stranger response type movement execution PC-2 was BF01 = 5.74, indicating that there was 'substantial' or 'positive' evidence for the null model (Jeffreys, 1998; Raftery, 1995).

6.4.3. Comparing the relative advantage for self in initiation and execution response stages

Following Chapters 3 and 5 (Desebrock & Spence, 2021; Desebrock et al., 2018) to assess whether the extent of the self-advantage was modulated across the two-stage response, the self-advantage in ITs and MTs, and in the percentage of correctly-initiated and -executed movement responses, were compared using normalized self-bias and friend-stranger bias index scores (see Section *6.3.5 Data analysis*). The change in the extent of self-bias across movement initiation (IT) and movement execution (MT) was assessed using a 2 (Stage: initiation, execution) x 3 (Bias type: friend-self, stranger-self, friend-stranger) repeated-measures ANOVA on the normalised self-bias and friend-stranger bias scores. The analysis revealed a main effect of Bias type, *F*(1.32, 44.80) = 41.95, *p* < .001, η_p^2 = .55. Self-bias (self-friend) and self-bias (self-stranger) were both greater than friend-stranger bias, *p* < .001 for both, and the two types of self-bias were not significantly different (self-friend, self-stranger), *p* = .69 (see Figure 6.2c). There were no other significant main or interaction effects.

The change in the extent of self-bias in percent correct across movement initiation (PC-1) and movement execution (PC-2) was also assessed. Two studentized residuals outliers were detected (> ± 3 in absolute value), and two conditions were not normally distributed. Parametric tests were conducted, followed by non-parametric tests which supported the findings of the parametric tests. First, a 2 (Stage: initiation, execution) x 3 (Bias type: self-friend, self-stranger, friend-stranger) repeated-measures ANOVA was conducted on the normalised bias scores for the percentage of correct responses in the initiation and execution of the movement responses. The analysis revealed a significant main effect of stage, $F(1, 34) = 15.93$, $p = .001$, $\eta_p^2 = .32$; bias increased ($p < .001$) across the response stages from movement initiation ($M = .078$, $SE = .011$) to movement execution ($M = .094$, $SE = .014$). A main effect of Bias type was also revealed, $F(1.25, 42.56) = 20.75$, $p < .001$, $\eta_p^2 = .38$. The magnitude of bias was greater (*ps* < .001) in Self-friend bias ($M = .12$, $SE = .02$) and Self-stranger bias ($M = .13$, $SE = .02$) than for Friend-stranger bias ($M = .005$, $SE = .02$), with no significant difference between Self-friend and Self-stranger bias, $p = .82$.

The analysis also revealed a significant interaction between Stage and Bias Type, $F(1.18, 40.26) = 13.71$, $p < .001$, $\eta_p^2 = .29$. Probing the interaction revealed that Self-friend bias increased ($p < .001$) across the response stages from movement initiation ($M = .11$, $SE = .02$) to movement execution ($M = .14$, $SE = .02$), as did Self-stranger bias in movement initiation ($M = .12$, $SE = .02$) through to movement execution ($M = .14$, $SE = .02$, $p < .001$). Friend-stranger bias did not change across the response stages (movement initiation: $M = .01$, $SE = .02$, movement execution, $M = .002$, $SE = .02$) (see Figure 6.2g). Non-parametric tests confirmed the parametric pairwise comparisons.

6.4.4. The relationships between self-bias and friend-stranger bias, personal distance (PD), and empathy

For mean PD and empathy scores (Tables C2.2 and C2.3, Appendix C), and comparison of the magnitudes of the absolute PD scores with one another, see Appendix C2. For Pearson bivariate correlations between the Self- and Friend-bias measures and the subjective measures of empathy and personal distance, see Table 6.2 (for the full correlation matrix of all self-report and bias metrics, see Appendix C, Table C2.4).

Table 6.2 Pearson bivariate correlations between the Composite Bias Scores, Personal Distance (PD), and Empathy in Study C6.

	Variable	1	2	3	4	5	6	7	8	9	10
1	Self-friend bias	--	.60*	−.44*	−.23	−.34	−.33	−.42*	.07	−.30	−.35
2	Self-stranger bias		--	.46*	.18	−.17	−.51*	−.56*	−.17	−.43*	−.36
3	Friend-bias			--	.46*	.19	−.21	−.17	−.27	−.15	−.01
4	Self-PD				--	.16	−.22	−.22	−.15	−.20	−.09
5	Friend-PD					--	.14	.13	.11	.10	.07
6	Empathy (total)						--	.89*	.72*	.55*	.82*
7	Empathic concern							--	.46*	.42*	.74*
8	Fantasy								--	.12	.52*
9	Personal distress									--	.16
10	Perspective-taking										--

Note. Self-friend bias = Self-friend bias composite score, Self-stranger bias = Self-stranger bias composite score, Friend-bias = Friend-stranger bias composite score, Empathy (total) = Empathy total score, Self-PD = self-friend personal distance scaled by the self-stranger personal distance, Friend-PD = friend-stranger personal distance scaled by the self-stranger personal distance. *Significant after FDR (Benjamini-Hochberg) correction at the .05 alpha level (2-tailed). (Adapted from: Desebrock et al., 2022, *Journal of Experimental Psychology: Human Perception & Performance*, APA.)

As can be seen in Table 6.2, the composite Self-stranger bias was negatively-associated with empathy (total scores; and also with the subscales, empathic concern, and personal distress), and Friend-stranger bias was positively-associated with Self-PD. Both Self-bias measures (i.e., Self-stranger and Self-friend bias) exhibited moderate to high correlations with each other; therefore, Self-bias was further analysed using Self-stranger bias (rather than Self-friend bias). In contrast, Friend-stranger bias was positively-correlated with Self-stranger bias, and negatively-correlated with Self-friend bias. For scatterplots depicting the relationship between the composite bias scores, see Figure 6.3a–c.

This chapter then explored whether explicit empathy (total scores) and perceptions of the closeness between the self and others (personal distance) could predict the Self-bias and Friend-stranger biases (composite scores) in arm-movement responses using two Stepwise regression analyses. In the first analysis, empathy (total score), Self-PD, Friend-PD, and Friend-stranger bias (friend-stranger; composite score) were used to predict Self-stranger bias (composite score). All of the variables were normally-distributed, except for Self-PD. However, Self-PD was only borderline-positively skewed, so as before the decision was made not to transform the data. The prediction model maintained two of the four predictors, $F(2, 32) = 10.03$, $p < .001$, and accounted for approximately 35% of the variance of Self-bias ($R^2 = .39$, Adjusted $R^2 = .35$). Self-bias ($p = .005$) was predicted by empathy (see Figure 6.3d) and the Friend-stranger bias composite score (although Friend-stranger bias was not significant after Bonferroni correction, unadjusted p-value = .014). Empathy was identified as the best predictor of self-bias in the model (semi-partial correlation $r = -.42$), followed by Friend-stranger bias (semi-partial correlation $r = .36$). Thus, empathy and Friend-stranger bias uniquely accounted for approximately 18% and 13% of the variance of self-bias, respectively (see Appendix C, Table C2.5).

Empathy (total score), Self-PD, Friend-PD, and Self-stranger bias (composite scores) were also used in a Stepwise linear regression analysis to predict Friend-stranger bias (composite scores). A studentized deleted residuals data point >3 in absolute value was detected, but was not an influential case[23], and when removed from the analysis did not change the findings. The prediction model maintained two of the four predictors, $F(2, 31) = 8.95$, $p = .001$, and accounted for approximately 32% of the variance of the Friend-stranger

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[23] n = sample size, k = number of terms in the model. It was determined that the studentized deleted residuals outlier was not an influential case: Cook's D = 0.095 (i.e. a value < 4/(n–1–k)), leverage value = 0.006 (i.e. a value < 2*((k+1)/n), difference in fit (DFFIT) = 0.015 (< 2√((k+2)/(n–k–2)), DFBetas for the two predictor variables were 0.010 and 0.026 (both < 2/√n).

bias ($R^2 = .36$, Adjusted $R^2 = .32$). In contrast to Self-Bias, Friend-stranger bias was predicted by Self-PD (see Figure 6.3e) and Self-bias. Self-PD received the strongest weight in the model (semi-partial correlation $r = .39$), followed by Self-bias (semi-partial correlation $r = .38$). Self-PD and Self-bias uniquely accounted for approximately 15% and 14% of the variance of Friend-stranger bias, respectively (see Appendix C, Table C2.6).

6.5. Discussion

An emerging theoretical view is that self-bias in the matching task is not associated with higher-level consciously-accessible self-representations. Instead, it is thought that self-bias may relate to the function of making a basic distinction between self and other, reflecting implicit self-related processing (Northoff, 2016; Schäfer & Frings, 2019b; Schäfer, Wesslein, et al., 2020). An alternative view is that self-bias in the matching task motor responses *is* associated with consciously-accessible self-related representations. The findings of this chapter support the latter view. Using a movement adaptation of Sui et al.'s (2012) matching task, this chapter (Desebrock et al., 2022) examined for the first time whether there was a relationship between social biases in fast ballistic arm-movement responses and subjective measures of empathy and personal distance (the perceived closeness between the self and others). Associations were revealed between the subjective measures and the biases in the motor responses. Regression analyses revealed that empathy was a significant predictor of Self-bias, and personal distance was a significant predictor of Friend-stranger bias. These findings therefore indicate that biases in the matching task motor responses may be (directly or indirectly) influenced by explicit representations of the interrelations between others and the self; namely, those related to empathy and perceived closeness. These biases may therefore not operate independently of higher-level self-related constructs as has been suggested previously (Moseley et al., 2021; Northoff, 2016; Schäfer & Frings, 2019b; Schäfer, Wesslein, et al., 2020).

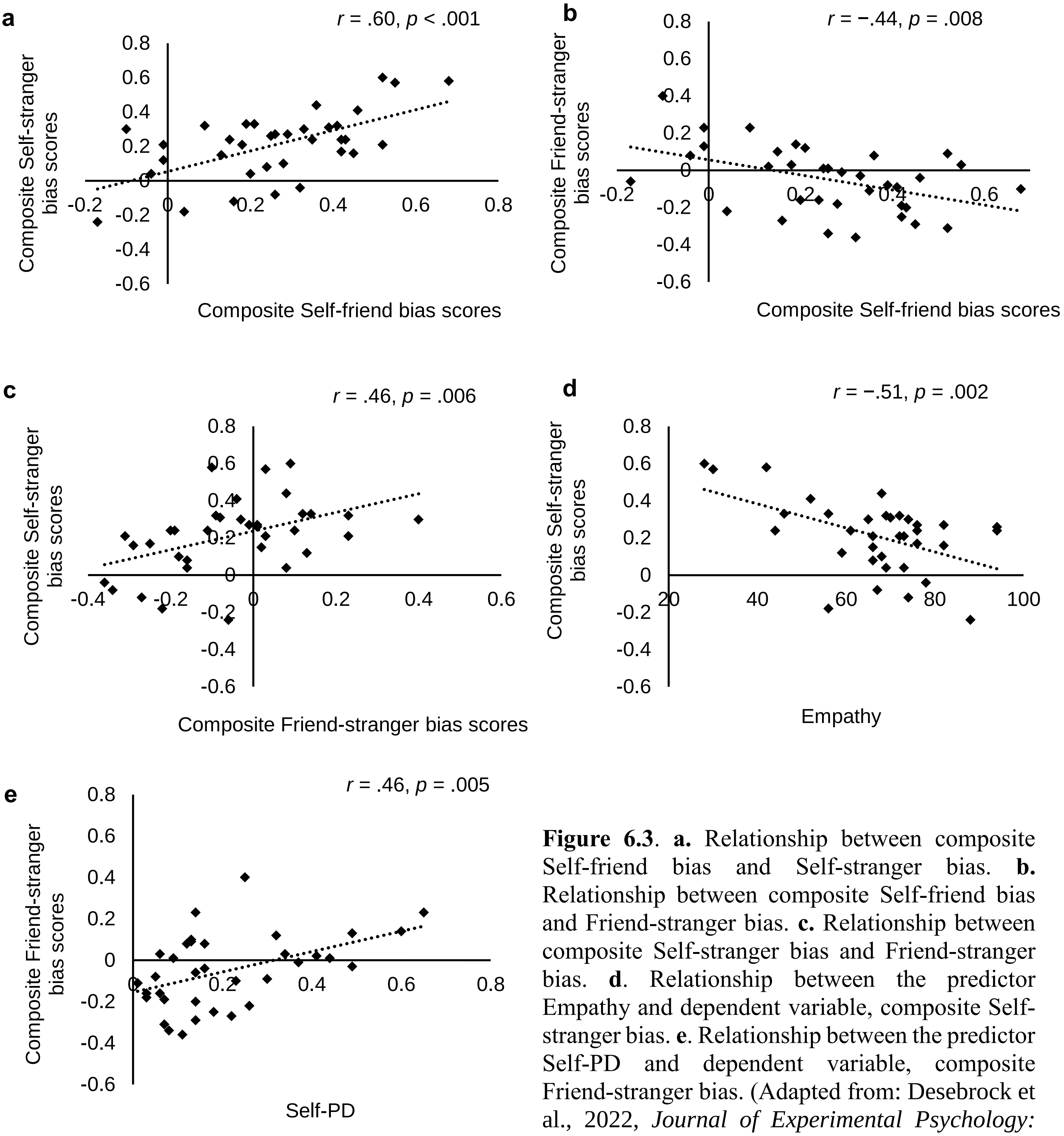

Figure 6.3. **a.** Relationship between composite Self-friend bias and Self-stranger bias. **b.** Relationship between composite Self-friend bias and Friend-stranger bias. **c.** Relationship between composite Self-stranger bias and Friend-stranger bias. **d**. Relationship between the predictor Empathy and dependent variable, composite Self-stranger bias. **e**. Relationship between the predictor Self-PD and dependent variable, composite Friend-stranger bias. (Adapted from: Desebrock et al., 2022, *Journal of Experimental Psychology: Human Perception & Performance*, APA)

6.5.1. Self-bias and the consciously-accessible (narrative) self

Higher-level self-referential processing (e.g. evaluating one’s traits or self-esteem) draws on representations pertaining to the narrative self. However, the narrative self is comprised of different kinds of explicit self-representations. Indeed, Sedikides and Brewer (2001; Sedikides et al., 2011) make a tripartite distinction between the *individual self* (comprising one's personal characteristics), *the relational self* (comprising one's relational characteristics and interpersonal attachments), and the *collective self* (comprising characteristics of one's social groups). Explicit self-esteem, for example, may be thought of as a consciously-accessible trait or aspect of the individual self. Conversely, empathy necessarily emerges from interpersonal interactions; and, for example, Moseley et al. (2021) conceive of Friend-stranger bias as a form of in-group bias. If biases in the matching task reflect the operation of the relational and collective self, this could account for the relationship between self-bias and empathy, and Friend-stranger bias and personal distance, and explain the lack of relationship between self-bias and, for example, self-esteem (Schäfer & Frings, 2019b).

One interpretation of these findings is that the biases in arm-movement responses in the matching task are directly influenced by explicit representations of empathy and perceived closeness; in other words, through a top-down consciously-controlled bias. Given the ballistic nature of the arm-movements, however, this seems unlikely and more probable that the biases operate on a somewhat automatic level (see Chapter 5). Furthermore, no significant difference was documented between Friend- and Stranger-associated responses, and yet a relationship was revealed between Friend-stranger bias and personal distance, something that would be difficult (if not impossible) to consciously-control. Instead, it may be that these biases are *indirectly* influenced by consciously-accessible representations of self–other relations.

6.5.2. Direct and indirect influences of explicit self–other relations on self-bias

The minimal self is traditionally conceptualised to arise in the differentiation between the self and other entities (i.e. objects and other people), and as such is embodied, but not yet social.

In contrast, the narrative self is social by virtue of linguistic processes (see Kyselo, 2016; Zahavi, 2014), and thought to develop later through memory processes (Blanke & Metzinger, 2009; Cermolacce et al., 2007; Hommel, 2019; Noel et al., 2017). However, Zahavi (2014) argues that the minimal self is already relational, and, socially so. Even the basic movements of neonates are structured by intentionality (Silver et al., 2021) and are predominantly engaged in social interaction, albeit pre-linguistic and pre-reflective. Zahavi thus posits a third dimension, the *interpersonal self*, which is closely-bound with empathy-related processes, and bridges operations between the minimal and narrative self (Kyselo, 2016; Zahavi, 2014). It may be that responses in the matching task are directly influenced by implicit empathy- and perceived-closeness representations related to the interpersonal self. Indeed, self-reflective processes, along with behaviour change, can shape implicit representations in line with the notion that conscious processes become automated over time (and the concept of therapeutic change, more generally). The representations we use to report on ‘the individual self’ and those that we use to report on ‘the self-in-relation-to-others’ may be differentially linked to lower-level processes. Such a notion could also account for the null relationship between self-bias and explicit evaluations of self-esteem and self-identification (Schäfer & Frings, 2019b; Woźniak et al., 2022).

Within this framework, the findings of this chapter are both consistent with the view that biases in the matching task reflect implicit self-related processing (e.g. Schäfer & Frings, 2019b), while also allowing for a link between an aspect of the consciously-accessible narrative self and the lower-level biases. Importantly, however, this chapter did not aim to differentiate between direct and indirect influences of self–other relations on the matching task biases, but to test the theory that there is a relationship between the biases and higher-level constructs of self. Future studies could further investigate which aspects of the narrative self are reflected in basic motor responses and the nature of this relationship.

6.5.3. Self-bias

This chapter documented that empathy negatively-predicted self-stranger bias; as empathy increased, the self-advantage decreased. Consistent with this finding, a recent study conducted by Moseley et al. (2021) documented that increased autistic traits[24] were associated with increased self-bias in RT in the standard matching task—notably, empathy deficits are associated with autism (Baron-Cohen & Wheelwright, 2004; Lombardo et al., 2007). This chapter also documented that Friend-PD (the friend-stranger relative to self-stranger personal distance) tended to negatively-correlate with Self-friend bias (see Table C2.4 in the Appendix). In Moseley et al.'s (2021) study, reduced friend-stranger personal distance was associated with increased autistic traits and increased loneliness in the pooled sample of autistic and non-autistic participants (Moseley et al., 2021). If autistic traits in Moseley et al.'s pooled sample are taken as measured on a continuous scale across the non-autistic and autistic participants, these findings collectively suggest that the profile of increased Self-bias and a smaller perceived distance between friend and stranger (or a reduced differentiation between the two) may be linked to autistic traits and reduced empathy.

Indeed, the autistic participants in Moseley et al.'s study (2021) perceived that the Friend-stranger personal distance was smaller than the Self-stranger personal distance, whereas non-autistic participants perceived that the Self-stranger and Friend-stranger distances were equivalent. In addition, Self-stranger personal distance was not significantly different across non-autistic and autistic participants, while Friend-stranger personal distance was smaller for autistic participants (Moseley et al., 2021). Consistent with Moseley et al.'s

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[24] In their recent study examining the SPE with autistic and non-autistic groups, Moseley et al. (2021) reported that increased autistic traits (pooled autistic and non-autistic participants' scores on the Autism Spectrum Quotient (AQ); Baron-Cohen, Wheelwright, Hill, et al., 2001; Baron-Cohen, Wheelwright, Skinner, et al., 2001) were associated with increased self-bias in RT, decreased friend-bias in accuracy, and decreased friend-stranger personal distance; and friend-stranger personal distance was negatively-associated with loneliness (scores on the UCLA Loneliness Scale; LS; Russell, 1996), while self-friend personal distance was positively-associated with loneliness.

findings for non-autistic participants, this chapter similarly found in a sample of adults from the general population (as did Enock et al., 2018) that absolute Self-stranger and Friend-stranger PD scores were not significantly different.

Notably, however, Williams et al. (2018) documented no relationship between the magnitude of self-bias and autistic traits. Future studies are needed in order to further explore profiles of the interrelations between self-bias in the matching task motor responses and perceptions of Self–friend, Self-stranger, and Friend-stranger personal distance across different populations.

6.5.4. Friend-stranger bias

This chapter documented that Friend-stranger bias was positively predicted by Self-PD (the self-friend relative to self-stranger personal distance). In Moseley et al.'s (2021) study, as autistic traits increased, Friend-stranger bias in accuracy decreased, and loneliness was positively-associated with increased Self-friend personal distance (Moseley et al., 2021). The positive association between Self-PD and Friend-stranger bias in the present study thus seems somewhat counterintuitive. Notably, however, Self-PD is the self-friend distance scaled by the self-stranger distance. Moseley et al. found that self-friend and self-stranger personal distances did not differ across the autistic and non-autistic participant groups. The denominator (self-stranger) in Self-PD might therefore be driving these effects in the present study. Indeed, self-stranger personal distance positively-correlated with self-bias in a previous study (Sui & Humphreys, 2015b), which, as noted, was negatively related to empathy in the present study, and positively-related to autistic traits in Moseley et al.'s study. Furthermore, this chapter also documented that absolute scores of self-stranger personal distance and friend-stranger bias (composite scores) were negatively-correlated ($r_s = -.45$, $p = .007$). As the self-stranger personal distance increases, then, friend-stranger bias appears to decrease. One finding running counter to the pattern identified above was that empathy also negatively-correlated with friend-stranger bias in two performance indices (IT and MT). However, notably, Self-PD and not empathy was identified as a predictor of friend-stranger bias composite scores in the regression analysis.

Interestingly, this chapter also failed to document a significant difference between the motor responses to the Friend- and Stranger-associated stimuli in the matching task. Indeed, Friend-stranger bias has proven less robust than Self-bias across studies (Reuther & Chakravarthi, 2017; Scheller & Sui, 2022b). A Friend-other advantage (in either RT, or accuracy/*d′*, or both) has emerged in some studies (Enock et al., 2018; Moseley et al., 2021; Stolte et al., 2017; Sui et al., 2012, 2013; Williams et al., 2018) but not in others (Lee et al., 2021; Reuther & Chakravarthi, 2017). Previous research suggests that hierarchical relations between associations in the matching task may be altered across contexts; namely, by stimulus features (the frequency of tones paired with the identities; Stolte et al., 2021; or the combination of identities; A. Verma et al., 2021) or perhaps task difficulty in relation to the stimuli (Lee et al., 2021). It may be that response features (arm-movements rather than keypress responses) can also modulate these relations. Although, notably, in a keypress version of the matching task using self, friend, and stranger associations, no Friend-stranger bias was documented (Reuther & Chakravarthi, 2017). Further research is needed to unpick conditions for the emergence (or non-emergence) of Friend-other bias in the matching task motor responses. At the very least, this finding indicates that in the present task context, the Friend representation is somewhat subsumed into the Stranger representation (or vice versa), perhaps as a more unitary ‘other’. Other studies have suggested that the Friend representation may also be subsumed into the Self representation (e.g. Lockwood et al., 2018; Woźniak et al., 2022). As such, the Self representation can be flexibly extended to either include close familiar others or not (Scheller & Sui, 2022b).

6.5.5. Self- and friend-biases in arm-movement responses

In contrast to previous research on self-bias, arm-movement responses rather than keypress responses were used in Chapters 3, 5, and the present chapter of this thesis. Arm-movement and keypress motor-response types have different real-world functions and associated uses. Thus, it could be argued that their differential interpretation (on the part of the participant) may explain why no relationship was documented between higher-level self-constructs (e.g. self-esteem) and the matching task responses in previous studies (Moseley et al., 2021; Schäfer & Frings, 2019b). Indeed, it may be that self-bias effects in keypress and arm-movement responses in the matching task are not identical. For example, a self-advantage was documented in both the initiation and execution of arm-movement responses in Chapters 3 and 5. By contrast, Janczyk et al. (2019) reported a self-advantage in the initiation but not in the execution of keypress responses (Janczyk et al., 2019—Experiment 4; although cf. Chapter 4). If arm-movement responses in the matching task draw on higher-level or second-order self-representations, while keypress responses draw on lower-level representations, ostensibly this could explain the apparent departure of the present chapter's findings from previous research (e.g., Schäfer & Frings, 2019b). However, if keypress responses draw on implicit self-related representations, it is not clear why speeded ballistic non-visually-guided arm-movement responses should draw on explicit representations. Crucially, previous studies using keypress responses in the matching task have also documented relationships between the biases and personal distance (e.g., Sui & Humphreys, 2015b; Yankouskaya et al., 2020). Keypresses as a behavioural outcome, however, are a step removed from meaningful everyday actions (Baumeister et al., 2007); which indeed may account for the inconsistent findings across these studies.

The movement adaptation of the matching task (Desebrock, Barutchu, et al., 2022; Desebrock et al., 2018; Desebrock & Spence, 2021) also provides a somewhat richer source of information about self-bias in action than total-response-time keypress paradigms. For example, this chapter documented that self-bias in accuracy increased from movement initiation to execution, consistent with Chapters 3 and 5. In contrast to Chapters 3 and 5, however, self-bias in IT and MT did not differ significantly in the present chapter. Furthermore, the extent of Friend-stranger bias was unchanged across the response stages. While the findings of the present chapter in conjunction with Chapters 3 and 5 reflect the close coordination of movement initiation and execution processes, they are also consistent with their independence (Reynaud et al., 2020). (Notably, strong correlations between PC-1 and PC-2 also reflect that PC-2 is dependent as a measure on PC-1; see Section *6.3.5. Data analysis*.) Self-biases and Friend-stranger bias do not appear to behave in the same way across the response stages. Furthermore, Study C5.1 used the same motor response as the present chapter, but dichotomous Self and Stranger associations, and a marked disadvantage for stranger-related movement executions relative to their initiation was documented. By contrast, such a marked disadvantage in the stranger-related movement executions was not observed in the present chapter. Collectively, these findings suggest that the relationship between the initiation and execution response stages of arm-movements is not fixed, and their respective biases may be altered by (for example, here) the combination of identities. Study C5.1 and C6 further support the contention that the change in the extent of self-bias across the response stages does not reflect an interaction between a self-advantage arising before movement onset and the dynamics of the overt movement response (the movement response was the same across Study C5.1 and C6). If differential neural circuitry is recruited across association types as has previously been documented in studies using the standard matching task (Sui, Rotshtein, et al., 2013; Yankouskaya et al., 2017), perhaps stranger-related responses in this chapter benefitted from the recruitment of familiar-other-related circuitry (an overlap in neural representations of Friend and Stranger, with both subsumed into a more unitary ‘other’ in this task context).

6.5.6. Wider implications

Theories diverge regarding the extent to which such sub-components of the self are interconnected or whether they function independently (Gallagher, 2013; Humphreys & Sui, 2016; Nijhof et al., 2020), and empirical study of their relationship and dynamic interplay is in its infancy (Banakou et al., 2013; Maister et al., 2015; Maister & Farmer, 2016; Nijhof et al., 2020; Nowicka et al., 2018; Schäfer & Frings, 2019b; Tao et al., 2012). The findings of this chapter suggest that biases in the matching task motor responses may reflect the operation of the interpersonal or relational self (on an implicit or explicit level), at least in terms of empathy-related processes and perceived closeness. In general, these findings indicate that exploring constellations of lower-level biases in the matching task and measures of self–other relations across populations, such as in autism, disorders of the self, and across the life-span, is likely to be fruitful, and could use the present chapter’s task set-up as a starting point.

Indeed, motor skills are also thought to be affected in autism. Studies have suggested that while autistic individuals can use tactile feedback to execute fast and accurate arm-movements, they can have difficulty effectively using visual feedback (e.g. R. Zheng et al., 2019). Study C5.1 demonstrated that the self-advantage in the matching task arises in ballistic movements predominantly using proprioceptive, kinaesthetic, and tactile information (and perhaps also visual imagery elicited in the absence of relevant visual sensory information; see Chapter 5) in planning and execution. Taken together, these findings are thus consistent with the contention that the SPE is intact in autistic individuals (see Section *7 Thesis Discussion*).

In sum, research suggests that there are deficits in higher-level self-referential processing in autistic individuals, but basic self–other differentiation is intact in this population. Future studies could examine profiles of the matching task motor response biases in relation to the type of motor response and subjective perceptions of self–other relations in autistic individuals.

6.5.7. Limitations and conclusions

Using a movement adaptation of Sui et al.'s (2012) matching task, this chapter documented associations between lower-level Self- and Friend-stranger biases and subjective measures of personal distance (closeness to others) and empathy. Empathy predicted Self-stranger bias, and the Friend-stranger bias was predicted by the self-friend relative to self-stranger personal distance. These findings suggest that people's explicit representations of the interrelations between self and others in terms of empathic understanding and perceived closeness (directly or indirectly) influence biases the matching task motor responses. An emerging view is that self-bias is not associated with higher-level self-reflective processes, and instead reflects somewhat independent implicit self-related processing. An alternative view is that self-bias in the matching task motor responses *is* influenced by consciously-accessible self-related representations. These findings support the alternative view. The findings of this chapter thus increase our understanding of the representations of others and the self that underlie arm-movement motor responses in the matching task.

In the Introduction to this chapter, it was predicted that personal distance would be related to, and could potentially predict, one or both of self-bias and friend-stranger bias Contrary to the predictions, however, personal distance did not predict self-bias. Notably, there was a non-significant negative correlation between Self-friend bias (composite scores) and Friend-PD ($r = -.34$, $p = .04$). As outlined above, the profile of a smaller perceived distance between Friends and Strangers and a larger Self-bias has been associated with increased autistic traits. Thus, the direction of this correlation is consistent with interpretations so far discussed in this chapter. The present study was sufficiently powered to detect a smaller effect size than has been typically documented in previous studies (Sui &

Humphreys, 2015b; Yankouskaya et al., 2020). However, a larger sample size in future studies may reveal smaller-size effects such as a potential relationship between Self-bias and Friend-PD.

One cautionary note in respect of findings discussed in relation to autism is that mild symptoms and more extensive autistic traits may be associated with divergent profiles of self-bias. For example, a study using an ownership paradigm documented a greater self-advantage in memory in children with mild symptoms, and a reduced self-advantage in those children with severe symptoms (Gillespie-Smith et al., 2018). Whether self-bias in the matching task may be similarly altered depending on the extent of autistic traits should be explored in future studies.

Chapter 7—Thesis Discussion

7.1. Thesis overview

Self-representation is widely held to guide our cognition and action, and self-relevance has repeatedly been shown to influence performance across a diverse range of experimental tasks (e.g., Cunningham & Turk, 2017; Dalmaso et al., 2019; Desebrock, Barutchu, et al., 2022; Golubickis et al., 2021; Macrae et al., 2018; Moray et al., 1959; Rogers et al., 1977; Schäfer, Wesslein et al., 2016; Sui et al., 2013; Woźniak et al., 2018). Self-associated stimuli typically enhance our attention, perception, memory, and decision-making processes (Cunningham & Turk, 2017; Humphreys & Sui, 2016; Janczyk et al., 2019; Macrae et al., 2017; Moray, 1959; Rogers et al., 1977; Sui & Humphreys, 2015a; Turk et al., 2008; Yin et al., 2019). As documented in this thesis, self-associations can also operate across sensory modalities and modulate multisensory processes, and influence the execution of motor responses (Desebrock, Barutchu, et al., 2022; Desebrock et al., 2018; Desebrock, Spence, et al., 2022; Desebrock & Spence, 2021; Schäfer, Wesslein, et al., 2016, 2020; Scheller & Sui, 2022a; Stolte et al., 2021).

Examining our responses to self-associated stimuli and the contexts of emergence, moderation, and modulation of the self-advantage increases our understanding of the nature and operation of self-representations in cognition and action (Golubickis et al., 2017; Schäfer & Frings, 2019b; Sui & Humphreys, 2017a; see also Chapters 2 and 6). Furthermore, previous studies have demonstrated the translational research value of such enquiry. Self-reference (when compared with semantic elaboration) can facilitate memory performance in amnesia, and also attentional processes in those patients with visual extinction (Sui & Humphreys, 2013; Sui & Humphreys, 2017a). Investigations of self-referential processing in mental disorders have also shed much light on the nature and mechanisms underlying, for example, personality and psychotic disorders (Jimenez et al., 2018; Kochs et al., 2017; Sui & Gu, 2017). Disorders of the self (such as schizophrenia) and neurodevelopmental conditions (such as autism) also present with motor deficits (Dawson & McKissick, 1984; Ming et al., 2007; Morrens et al., 2014; Mostofsky & Ewen, 2011). Sensory and motor deficits are thought to influence the development of the self (Delafield-Butt & Trevarthen, 2018; Trevarthen & Delafield-Butt, 2013). In turn, motor responses may be reflective of the underlying representations of the self and others. Indeed, as discussed in Chapter 6, pre-conceptual intentionality is evidenced even in neonatal arm-movements which are organized according to their anticipated effects (Delafield-Butt et al., 2018). Social effects can shape movements throughout development (Silver et al., 2021), and the social self is thought to develop through sensorimotor exploration of the social environment. Thus, manual motor responses (particularly those that are fast and ballistic) are likely to reflect the automatic operation of representations of self–other relations at a fundamental level owing to deeply-ingrained links. Investigating self-bias in motor responses in particular is likely to have important future translational research value for progressing understanding of self-representation(s) in action across different populations.

As outlined in the previous chapters, the matching procedure first introduced by Sui and colleagues (Sui et al., 2012) now provides a standard method for those wanting to investigate the effects of self-relevance. In the prototypical matching task, which uses keypress responses and visual stimuli, participants are instructed to associate neutral geometric shapes (e.g., a circle, a square, and a hexagon) with person-identity labels (e.g., self, stranger, friend). In the main task, participants indicate with keypresses whether or not the sequentially-presented shape-label pairs ‘match’ the designated associations. These manual motor responses are consistently found to be faster and more accurately-selected in the self-associated shape-label matching condition (the Self-Prioritization Effect (SPE), or simply, self-bias). Previous studies have demonstrated that word frequency, word concreteness, word length, stimulus familiarity, reward value, and emotional valence cannot (solely) account for the self-advantage (Schäfer, Wentura, et al., 2020; Stolte et al., 2017, 2021; Sui et al., 2012; Sui & Humphreys, 2015c; Wade & Vickery, 2017; Woźniak & Knoblich, 2019; Yankouskaya et al., 2017). Distinct neural circuitry has also been documented to underpin self-bias (Sui et al., 2013; Yankouskaya et al., 2017; see Chapter 1).

Some researchers propose that the self-advantage in the matching task, and indeed across tasks, may be underpinned by the activation of a core self-representation (Humphreys & Sui, 2016; Lieberman, 2007; Sui & Humphreys, 2015a; see Chapter 1). Other evidence suggests however that processing different types of self-related stimuli and different task processes (e.g. implicit or explicit) may engage different aspects of the self (De Freitas et al., 2019; Golubickis et al., 2020; Hutchison et al., 2021; Turk et al., 2008; Woźniak & Knoblich, 2021; see Chapters 1 and 6). A growing number of studies indicate that the novel self-associations formed in the matching task do not modulate performance in the same way as those associations underpinning responses to other types of self-related stimuli, or indeed across tasks (Amodeo et al., 2021; Desebrock, Spence, et al., 2022; Nijhof et al., 2020; Orellana-Corrales et al., 2021; Schäfer & Frings, 2019b; Woźniak et al., 2022; although cf. Scheller & Sui, 2022b). On the basis of such findings, it has been suggested that self-bias may relate to the function of making a basic distinction between self and other, and reflect lower-level or ‘first order’ self-related processing. In other words, self-bias may reflect implicit (automatic and preconscious) processing that is (somewhat) independent of explicit higher-level self-referential or self-reflective processing (Northoff, 2016; Schäfer & Frings, 2019b; Schäfer, Wesslein, et al., 2020).

In line with the widely-accepted view of the self as a multidimensional and multifaceted dynamic construct (Gallagher & Daly, 2018; Golubickis et al., 2020; Hutchison et al., 2021;

Klein & Nelson, 2014; McConnell, 2011), this thesis focused exclusively on self-bias in the matching task in order to map out and thus better understand the operation of this (putative) subcomponent of self. As outlined in Chapter 1, the research thread in which this thesis is situated typically uses either manual motor, oculomotor, or verbal report measures to assess the effects of self-relevance. This thesis focused specifically on manual motor responses and the effects thereon of the novel self-associations formed in the learning phase of the matching task. Across four experimental chapters and one single-study review, this thesis examined self-prioritization (or, self-bias) in different types of manual motor responses using novel adaptations of Sui et al.'s (2012) matching task, and addressed the overarching question: What are contextual constraints on the emergence and extent of the self-advantage in manual motor responses?

7.2. Summary of experimental results

The first experimental chapter of this thesis (Desebrock, Spence, et al., 2022) focused on examining self-bias in keypress motor responses using a holistic behavioural outcome measure; namely, total response time. Total response time is measured from stimulus onset and is the time taken to process the stimulus information and make a task-designated motor response that is 'correct'. As noted in Chapter 1, manual motor responses in tasks such as the matching task are commonly used as a proxy measure of cognitive (or premotor) processes, largely based on tradition and the implicit assumption that the motor-stage is influenced by target not stimulus features (see Chapters 3–5). As outlined and discussed in Chapters 1, 3, and 5, this thesis is aligned with research that considers that the motor stage can also (theoretically) be influenced by self-relevance (Barton et al., 2020; Desebrock et al., 2018; Desebrock & Spence, 2021; Golubickis et al., 2017; Janczyk et al., 2019; Macrae et al., 2017); as such, no assumption is made about the level or stage of information processing involved in the self-advantage in keypress motor responses in the matching task (cf. Sui et al., 2012).

Self-bias has been well established to emerge in the matching task, including with auditory stimuli (B. Payne et al., 2020; Schäfer, Wesslein, et al., 2016), and so the aim of Chapter 2 was to assess the influence of moderating factors on the extent of self-bias with unisensory and multisensory stimuli. The main analyses of performance in the matching task therefore focused on normalised differential scores, which are calculated using total response times and provide an index of the extent of self-bias. By contrast, assessment of the emergence of self-bias in the multisensory detection task was examined using absolute response times. To better understand the operation of self-bias in motor responses with unisensory and multisensory stimulation, Chapter 2 aimed to examine the influence of both stimulus parameters and task-design-related factors on self-bias (in the matching task), and the emergence of self-bias when the self-associations are not relevant to the task at hand (in a multisensory simple detection motor paradigm).

Auditory labels were introduced to the matching task, and, for the first time, responses to unisensory auditory, unisensory visual, and multisensory object-label stimuli were compared across block-type (i.e. trials blocked by sensory modality type, and intermixed trials of unisensory and multisensory stimuli). Auditory stimuli were either presented at 50dB (Group 1), or 70dB (Group 2). The participants in Group 2 also completed the multisensory detection task, making simple speeded motor responses to the shape and sound stimuli as well as to their multisensory combinations.

In the matching task, self-bias was diminished in intermixed trials, and in responses to the unisensory auditory stimuli as compared with the multisensory (visual shape+auditory label) stimuli. In contrast, self-bias did not differ in responses to the unisensory visual and multisensory (auditory object+visual label) stimuli. There was also a significant interaction between association (self- vs. stranger-associated responses) and audiovisual stimulus type (A+VL vs. V+AL) for multisensory gains and costs in terms of RT. Multisensory costs were descriptively greater for self- than stranger-associated A+VL stimuli, while for the V+AL stimuli, there were costs for stranger, and multisensory gains were observed in responses to the self-associated stimuli. As such, RTs to self- vs stranger-associated stimuli were differentially influenced by the type of multisensory stimulus (auditory object+visual label or visual shape+auditory label). Self-bias was thus modulated both by block-type and the combination of object and label stimulus modalities. There was no significant self-advantage in the detection task. Taken together, these findings indicate that self-bias with unisensory and multisensory stimuli in the matching task is modulated by both stimulus and task-related parameters, while the self-advantage does not transfer to a significant motor speed gain when the self-associations are not task-relevant.

The subsequent chapters in this thesis focused on manual motor responses in the matching task. In contrast to Chapter 2, which examined self-bias in the traditional keypress motor responses, Chapter 3 used a novel movement adaptation of the matching task to examine self-bias in visuomotor arm-movement responses. Chapter 3 (Desebrock et al., 2018) was the first study to examine self-bias in motor responses beyond their selection, therefore the visual object and label stimuli were used for comparability with previous research on self-bias, and as a first point of departure. The visual shape and label stimuli were also chosen as a well-established and reliable method for eliciting a large self-advantage.

As outlined and discussed in Chapters 1 and 3, much previous research has investigated self-bias in information processing up to the level of response selection. No studies prior to Chapter 3 (Desebrock et al., 2018) had examined self-bias beyond response selection. Therefore, using a novel movement adaptation of the matching task, Chapter 3 measured movement execution separately from movement initiation (Barton et al., 2020;

Houlihan et al., 1994; Jensen & Munro, 1979; Praamstra et al., 2014; Robinson et al., 2014). A response box recorded ‘home’-button-releases measuring movement initiation time (IT) from stimulus onset, and the percentage of accurately-selected movements; and a target-key positioned 14 cm from the response box recorded MT from ‘home’-button-release to target-key depression, and the percentage of correctly-completed movement executions. MTs as well as ITs of responses to self-related as compared with stranger-related stimuli were shorter, with a higher percentage of correctly-initiated and executed movements for self-related responses. The extent of self-bias was also altered across the two-stage response. This chapter thus presented a novel demonstration (Desebrock et al., 2018) that an advantage in responses to the self-associated stimuli influences the execution, as well as the initiation, of manual motor responses (i.e. rapid-aiming arm-movements). In alignment with research suggesting that self-bias has an influence at multiple-stages (e.g. Sui & Humphreys, 2015a), this chapter presented preliminary evidence that self-bias can modulate the execution as well as the initiation of movements.

Chapter 4 presented a single-study review. The study in question (Janczyk et al., 2019) also investigated self-bias beyond response selection, but documented that the motor-stage was not influenced by self-bias. In contrast to Chapter 3, however, this study used discrete keypress responses rather than arm-movement responses. As noted in Chapters 4 and 5, it might therefore be interpreted from these collective findings that the self-advantage in overt movement depends on response features that characterise arm-movement responses but not button-press responses. Before this hypothesis was tested in Chapter 5, however, a theoretical review of the contrasting findings (Janczyk et al., 2019) was carried in order to take a closer look at the extent to which the evidence supports this conclusion. In Chapter 4, the contrasting study was re-examined in terms of a theoretical framework in the motor-control and neuroscience literature which holds that movement preparation and movement onset constitute independent processes. Closer inspection of task processes revealed plausible alternative mechanistic accounts of the dual-task study's findings, which were supported by the data. Strengths of the methodology used in Chapter 3 (Desebrock et al., 2018) in terms of theoretically accommodating mechanisms of motor processes were also highlighted. Chapter 4 therefore concluded that the question of whether the self-advantage in discrete keypress responses involves a modulation of the motor-stage remains open.

The next experimental chapter (Chapter 5; Desebrock & Spence, 2021) examined whether certain features of arm-movement responses not shared by keypress responses may account for the self-advantage in movement execution. Simultaneously, the robustness and generalisability of the movement self-advantage was also tested across different types of motor response. The first study of Chapter 5 (C5.1) used a task set-up modelled on Study C3, except that visual feedback was removed, and the travel distance was shortened. The participants also made ballistic rather than non-ballistic responses to the target. In the second study of Chapter 5 (C5.2), the set-up was identical to Chapter 3 (Study C3), except that movement responses were executed sideways, and framed as 'away' from both the participant's body and the stimuli. It was hypothesized that if the self-advantage documented in Chapter 3 does not depend on the explicit online control of movements and visual feedback in movement planning and execution, a self-advantage should arise in Study C5.1. It was further hypothesized that if the movement self-advantage does not depend on the activation of affective stimulus-response (S–R) compatibility mechanisms which facilitate arm-movements that serve to *visibly* decrease the distance between the self and these stimuli (Kozlik et al., 2015; Krieglmeyer et al., 2013)[25], a self-advantage should arise in Study C5.1 and C5.2.

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[25] As noted in Chapter 5, the evaluation of appetitive or positive stimuli is thought to activate affective stimulus–response (S–R) compatibility mechanisms automatically which, in turn, facilitate those movements that serve to visibly decrease the distance between the self and these stimuli (Kozlik et al., 2015; Krieglmeyer et al., 2013; Markman & Brendl, 2005; Piqueras-Fiszman et al., 2014; Seibt et al., 2008). Perceivable (i.e., visible) action

A self-advantage in MTs and the percentage of correctly-completed movements was documented in both experiments. These findings thus demonstrate that self-bias in movement execution does not depend on an explicit decisional response bias operating through visual-feedback-driven processes or a modulation of automatic visual-feedback-driven processes. The findings also suggest that the movement self-advantage does not depend on approach motivation through affective S–R compatibility. Study C5.1 further indicates that self-relevance can modulate ballistic movement responses using predominantly proprioceptive, kinaesthetic, and tactile information (and potentially visual imagery; see Chapter 5). These findings thus support and extend those of Chapter 3, and increase our understanding of the self-advantage at the motor-stage (Frings & Wentura, 2014; Huang et al., 2022; Janczyk et al., 2019; Macrae et al., 2017). As reviewed in Chapters 1 and 5, some studies suggest that the self-advantage emerges only in central-stage processes (Janczyk et al., 2019; i.e., during higher-level processes; Janczyk et al., 2019; Miyakoshi et al., 2007; Schäfer, Wentura, et al., 2020; Siebold et al., 2015; Stein et al., 2016; Y. Zheng et al., 2022). By contrast, other research suggests that the self-advantage arises at multiple stages (Sui & Humphreys, 2015a; Woźniak et al., 2018). Taken together, the findings of Chapters 3–5 highlight a multiple-stage influence of self-bias in motor responses.

Chapter 5 (specifically, Study C5.1) also indicated that the most parsimonious account of the movement self-advantage was that it arises in ballistic movement in the absence of visual feedback pertaining to the participant's hand and the target. In other words, self-bias may emerge in ballistic movement using proprioceptive, kinaesthetic, and tactile information in planning and execution, and potentially visual imagery (see Section *5.6 Chapter Discussion*) in movement planning and execution. Both ballistic and non-ballistic

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effects (in terms of distance regulation between the participant and the stimuli) are thought to be a precondition for automatic affective S–R compatibility effects to arise (Kozlik et al., 2015; Krieglmeyer et al., 2010; Rougier et al., 2018; van Dantzig et al., 2008).

movements share a ballistic phase or initial impulse (Elliott et al., 2010; Tremblay et al., 2013; see Chapter 5). It may be that self-bias manifests as a self-advantage in the initial impulse. Chapter 6 (Desebrock, Barutchu, et al., 2022) therefore set out to increase understanding of self-bias in the ballistic motor responses used in Study C5.1 by investigating the representations of the self and others underpinning these responses.

Little is known about the representations underlying self-bias in the matching task. An emerging theoretical view is that self-bias is not influenced by consciously-accessible constructs related to the self, such as explicit self-esteem (Schäfer & Frings, 2019b), and instead reflects implicit (automatic and preconscious) self-related processing (Northoff, 2016; Schäfer & Frings, 2019b; Schäfer, Wesslein, et al., 2020). An alternative view is that self-bias *is* influenced by explicit self-representations and self-reflective processing. To decide between these two accounts, Chapter 6 examined for the first time the relationship between Self-bias and Friend-stranger bias (the difference in performance between responses to the friend-associated and stranger-associated stimuli) and subjective measures of empathy and personal distance (the perceived closeness between others and the self). Using the task set-up of Study C5.1, this chapter introduced the Friend variable alongside the Self and Stranger variables to permit assessment of Friend-stranger bias in these motor responses and in order to test whether the movement self-advantage was robust to the use of non-dichotomous self and other identities in the task.

A self-advantage in arm-movement responses was documented, indicating that the movement self-bias reported in Chapters 3 and 5 (Desebrock et al., 2018; Desebrock & Spence, 2021) was robust to the addition of the Friend variable. The movement self-advantage thus generalised across stimulus contexts. Previous research suggests that hierarchical relations between associations in the matching task can be altered across contexts (Lee et al., 2021; Stolte et al., 2021), including by the combination of identities (Verma et al., 2021), and these stimulus contexts can modulate self-bias. The self-advantage in arm-movement responses therefore does not depend on responding to the dichotomous categories of Self versus Stranger. Associations were documented between lower-level Self- and Friend-stranger biases and subjective measures of personal distance (closeness to others) and empathy. Empathy predicted Self-stranger bias, and the Friend-stranger bias was predicted by the self-friend relative to self-stranger personal distance. These findings suggest that people's explicit representations of the interrelations between others and the self in terms of empathic understanding and perceived closeness (directly or indirectly; see Chapter 6) influence biases in the matching task motor responses. The findings of Chapter 6 therefore support the view that self-bias in the matching task motor responses is influenced by consciously-accessible self-related representations. This chapter thus presented a novel demonstration that biases in matching task motor responses may be (directly or indirectly) influenced by explicit representations of the interrelations between others and the self. These biases may therefore not operate independently of higher-level self-related constructs as has been suggested previously.

In summary, this thesis presents novel demonstrations that: (1) label and object modality and whether trials are blocked or intermixed by sensory modality type can modulate the self-advantage in manual motor responses in the matching task; (2) a comparable self-advantage does not arise in simple detection motor responses to visual, auditory, or audiovisual stimuli; (3) self-bias emerges in non-ballistic arm-movements guided by visual feedback, ballistic arm-movements in the absence of visual feedback pertaining to the hand or target, and arm-movements both directed 'toward' the stimuli, and framed as 'away' from the stimuli; (4) self-relevance in the matching task can influence both the initiation and execution of arm-movements, highlighting modulation at multiple stages; (5) manual motor responses in the matching task may reflect the (direct or indirect) operation of consciously-accessible representations of the interrelations between others and the self that are related to one's empathic traits and perceived closeness between others and the self.

7.3. Wider implications of the findings

The findings of this thesis contribute to the rapidly growing body of research investigating self-bias in the matching task (Desebrock, Barutchu, et al., 2022; Desebrock et al., 2018; Desebrock, Spence, et al., 2022; Desebrock & Spence, 2021; Golubickis et al., 2017; Golubickis & Macrae, 2021; C.-P. Hu et al., 2020; Janczyk et al., 2019; Lee et al., 2021; Moradi et al., 2015; Moseley et al., 2021; Navon & Makovski, 2021; Nijhof et al., 2020; Orellana-Corrales et al., 2021; Stolte et al., 2021; Sui et al., 2012; Svensson et al., 2021; Y. Zheng et al., 2022). In examining the influence of self-prioritization outside of visuomotor processing, beyond response selection, and in arm-movement motor responses, this thesis has furthered our understanding of the contextual constraints on the emergence and extent of the self-advantage, and made multiple novel contributions to the literature (Desebrock, 2019; Desebrock, Barutchu, et al., 2022; Desebrock et al., 2018; Desebrock, Spence, et al., 2022; Desebrock & Spence, 2021).

In Chapter 1, extant gaps in the literature were identified and research questions specific to each chapter were set out. The present chapter now revisits each of these questions and considers the wider implications of the findings of this thesis. Chapter 1 identified that prior to the inception of this thesis, little was known about the operation of self-bias outside of visuomotor responses. Alongside the research presented in Chapter 2, other studies have also begun to address this paucity of research (Schäfer, Wesslein, et al., 2016; Scheller & Sui, 2022a; Stolte et al., 2021). Specifically, Chapter 2 asked: does a self-advantage arise in motor responses to unisensory auditory and multisensory stimuli and manifest in the same way as has been demonstrated with visual stimuli? Does task-design (namely, whether the stimuli are blocked or intermixed by sensory modality) moderate the self-advantage with unisensory and multisensory stimuli? Consistent with previous research (Schäfer, Wesslein, et al., 2016), the extent of self-bias was not moderated across visual and auditory stimuli paired with visual labels, suggesting that the processes underlying self-bias with visual and auditory stimuli may be equivalent, at least when the auditory stimuli are relatively neutral in terms of hierarchical associations (cf. Stolte et al., 2021). As has been documented for V+VL stimuli (Sui, Rotshtein, et al., 2013), self-bias with auditory stimuli may similarly be supported by functional connectivity between the vmPFC and LpSTS. However, future studies are needed to establish whether such equivalent patterns of behavioural outcomes reflect the same underlying processes, as this is not always the case.

Chapter 2 also documented that self-bias *was* moderated across visual and auditory stimulus objects when they were presented with auditory labels. Differential processes may thus underlie self-bias in manual motor responses to A+AL as compared with A+VL stimuli. As discussed in Chapter 2, the findings of Study C2 in conjunction with previous studies (Schäfer, Wesslein, et al., 2016; Scheller & Sui, 2022a; Stolte et al., 2021) suggest that self-associations, as formed in the matching task, are not stronger with visual as compared with auditory stimulus objects per se. It may be then that self-bias is modulated by differential processing strategies underlying responses to the different stimulus object and label modality combinations. Indeed, overall response times were consistently longer for the unisensory auditory stimuli (A+AL) than for the other stimulus types. In a very recently published study (Scheller & Sui, 2022a), it has been further suggested that self-bias across unisensory auditory and multisensory processes may be differentially supported by the dorsal and ventral attention networks, respectively.

Indeed, Chapter 2 documented that the greater self-advantage in responses to the V+AL stimuli as compared with the A+AL stimuli was driven by greater facilitation in responses to self-associated A+VL stimuli relative to the self-associated A+AL stimuli (see

Table 2). Furthermore, while multisensory costs were documented for self- and stranger-associated A+VL stimuli, for the V+AL stimuli, there were costs for stranger, and gains were uniquely observed for self. These findings are consistent with the notion that differential processing strategies may underpin self-bias across different stimulus object and label combinations. One possibility discussed in Chapter 2 is that self-related motor responding may be more congruent with certain object and label modality combinations (e.g. V+AL). As infants, we encounter spoken words while viewing or interacting with visual objects earlier in development of the self than we do objects and visual text. Single auditory descriptors and short burst auditory phenomena are also not typically communicated together. Artefacts of culture may also instate or reinforce the familiarity and reliability of particular object and label combinations (see e.g., Hutmacher, 2019). As such particular combinations of unisensory and multisensory information may be more automatically processed in relation to self-associated responding.

As discussed in Chapter 2, the findings of Study C2 in conjunction with previous studies (Schäfer, Wesslein, et al., 2016, 2020; Scheller & Sui, 2022a; Stolte et al., 2021) suggest that self-associations as formed in the matching task do not appear to be stronger with visual as compared with auditory stimulus objects. Study C2 also indicated that whether trials are blocked or intermixed by sensory modality type can modulate the self-advantage in matching task motor responses. Specifically, the self-advantage was reduced when trials were intermixed by the sensory modality type of the stimuli. Taken together, these findings suggest that modulation or moderation of the self-advantage arising in the matching task across sensory modalities therefore is likely to be attributable to task-design or, for example, modality of the label.

Chapter 2 also asked: Can the novel unisensory and multisensory self-associations influence simple detection motor responses when the associations are not relevant to the task at hand? While a self-advantage emerged in the matching task, no significant self-advantage was documented in the detection task motor responses. These findings suggest that a comparable self-advantage does not arise in the absence of explicit self–other evaluation in visual, auditory, or audiovisual simple detection motor responses. Previous studies using other types of self-related stimuli (e.g. self-owned items) and other task paradigms (e.g., object classification tasks) have similarly documented no self-advantage when the stimuli were not semantically-evaluated or the self-associations were not relevant (or perceived as relevant) to the task at hand (Caughey et al., 2021; Dalmaso et al., 2019; Falbén et al., 2019; Macrae et al., 2017; Stein et al., 2016; Woźniak & Knoblich, 2021).

Findings from the multisensory detection task extend previous research to suggest that the dependence of self-bias on the relevance of the self-associations is not specific to visuomotor processing. Furthermore, while self-prioritization in the matching task may be (somewhat) distinct from the self-advantage arising in other task paradigms (Amodeo et al., 2021; Nijhof et al., 2020; Orellana-Corrales et al., 2021; Woźniak & Knoblich, 2021), these findings indicate that self-bias does share this particular context of emergence with certain other self-related biases. Anticipation of task-relevant stimuli in visual tasks has been demonstrated to rapidly alter neural processes (Corbetta et al., 2000; Nobre & van Ede, 2018; Stokes et al., 2009), and the emergence of self-bias may rely on such a mechanism. The self-representation underlying self-bias may share this operational feature with other self-representations or components of the self; once activated however these self-representations do not necessarily then modulate motor responses in the same way.

As discussed, the modulation of self-bias across visual and auditory stimuli when combined with the auditory label may be rooted in developmental links or artefacts of culture which establish or reinforce familiarity and reliability of particular combinations of unisensory and multisensory input (see e.g. Hutmacher, 2019). Chapter 2 also documented that the self-advantage did not emerge in motor responses when the self-associations were not relevant to the task at hand. Taken together, these findings are consistent with the notion of the conditional automaticity of self-related responding that has been documented using other self-related stimuli in other task paradigms (Caughey et al., 2021; Falbén et al., 2019). The operation of *self-bias* in motor responding also appears also to be highly adaptive and responsive to the context.

Chapter 1 also identified that prior to the inception of this thesis, no studies had examined whether the effects of self-relevance in the matching task can modulate motor responses beyond their selection. As reviewed in Chapters 1 and 2, manual motor responses in tasks such as the matching task are commonly used as a proxy measure of cognitive (or premotor) processes, largely based on tradition and the implicit assumption that the motor-stage is influenced by target not stimulus features (see Chapters 3–5). A growing number of studies recognise however that response execution can also (theoretically) be influenced by self-relevance (Barton et al., 2020; Desebrock et al., 2018; Desebrock & Spence, 2021; Golubickis et al., 2017; Janczyk et al., 2019; Macrae et al., 2017).[26] Chapter 3 therefore asked: can self-bias in the matching task influence arm-movement responses as well as keypress motor responses? Does a self-advantage emerge in the execution as well as initiation of arm-movement responses? In other words, can self-bias influence manual motor responses beyond their selection? The findings of Chapters 3, 4, 5 and 6 all bear upon these questions, and so will be discussed collectively here.

Chapter 3 provided preliminary evidence that self-bias can modulate the execution, as well as initiation, of manual responses in the matching task. However, the absence of the self-advantage in the motor-stage of keypress responses reported in another study (Janczyk et al.,

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[26] In studies using Hierarchical Drift Diffusion model analysis, for example, non-decisional processes are measured which include response execution and encoding processes (Golubickis et al., 2017; Macrae et al., 2017; Voss et al., 2013).

2019) suggested that the self-advantage may be attributed to characteristics of arm-movement responses. The self-advantage in the arm-movement responses of Chapter 3 may have been driven by approach motivation or decisional biases operating through explicit online control. Chapters 5 therefore asked: Does the self-advantage in the execution of arm-movement responses depend on a stimuli-directed or self-directed motor response, or on non-ballistic, visual feedback-guided responses? This chapter documented that self-relevance in the matching task can influence non-ballistic arm-movements guided by visual feedback, ballistic arm-movements in the absence of visual feedback pertaining to the hand or target, and arm-movements both directed 'toward' the stimuli, and framed as 'away' from the stimuli. Chapter 4 concluded that there is no clear evidence for the absence of a self-advantage at the motor-stage of keypress responses. Chapter 6 demonstrated that the movement self-advantage was robust to the addition of Friend-associated stimuli to the Self- and Stranger-associated stimuli. Taken together, these findings suggest that a robust self-advantage can emerge in movement execution. In particular, the movement self-advantage is not specific to non-ballistic visual feedback-guided movements directed towards the stimuli (Studies C5.1, C5.2, C6), to the use of dichotomous self-associated and stranger-associated identities in the matching task (Study C6), and can arise in ballistic movement in the absence of visual feedback (Study C5.1). In other words, self-bias can emerge in movement responses using predominantly proprioceptive, kinaesthetic, and tactile information in their planning and execution; and, potentially, visual imagery.[27]

Notably, both ballistic and non-ballistic movements share an initial impulse (Elliott et al., 2010; Tremblay et al., 2013). It may be that self-bias manifests predominantly or wholly in the initial impulse. Indeed, other research is consistent with the finding that self-bias

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[27] As noted in Chapter 5, self-generated movements with predictable visual consequences have been reported to generate visual imagery in the absence of relevant exogenous visual input (Dieter et al., 2014). It is therefore also possible that visual imagery arose in response to the occlusion of visual feedback in Study C5.1, and may also play a role in the movement self-advantage.

emerges in ballistic arm-movements in the absence of visual feedback. Autistic individuals have been reported to have difficulty using visual but not tactile feedback for efficient execution of arm-movements (e.g. R. Zheng et al., 2019). Furthermore, preschool children with autism were documented to have preserved initial movement phases, but difficulties with late-control-based spatial adjustment, suggestive of intact planning but disturbed online motor control (Forti et al., 2011). As reviewed and discussed in Chapters 1 and 6, growing evidence suggests that self-bias in the matching task may reflect the function of making a basic differentiation between the self and others. Basic self–other differentiation is thought to be intact in autistic individuals, and indeed the SPE has been documented as intact in autism (Moseley et al., 2021; Williams et al., 2018). Ballistic movements (the initial impulse) can be subject to a form of online regulation which compares perceived velocity and limb direction to an internal model of expected sensory consequences of the movement (Elliott et al., 2010). However, movement planning in relation to an internal model of the sensory expectations occurs prior to movement onset. As such, ballistic movement is highly-dependent on expectations about feedback. In the absence of visual feedback, ballistic movements rely heavily on pre-planning of the movement (see Chapter 5). Collectively, these findings, in conjunction with Study C5.1, are consistent with the notion that self-bias may reflect a self-advantage in the initial impulse of ballistic movement, reflective of movement planning, which operates independently of relevant exogenous visual input, and relies on non-visual information (or self-generated visual imagery). The present thesis cannot systematically distinguish between these possibilities; in accordance with the overarching aims, this thesis sought to determine *whether* and not *how* self-bias influences movement execution. Future studies are needed to systematically test these possibilities.

In addressing the overarching aim of this thesis to increase understanding of the contextual constraints on the emergence and extent of self-bias in motor responses, Chapters

3 and 5 also posed the research question: Can self-relevance in the matching task influence both the initiation and execution of arm-movement responses and thus speak to whether self-bias has a multiple-stage influence? One key feature of the methodology used in Chapters 3, 5, and 6 was the separate measurement of movement initiation and execution. There has been much debate concerning whether and how the two stages are linked (Frowein & Sanders, 1978; Haith et al., 2016; Phillips & Glencross, 1985; Reynaud et al., 2020; Weinberg, 2016). As discussed at length in Chapters 3–5, such debate bears upon whether self-bias in movement execution is simply an artefact of self-bias in premotor processes. In the service of optimal and coherent goal-oriented behaviour, one would expect to find a context-dependent relationship between the two stages. Indeed, evidence indicates that while the processes underlying movement initiation and execution are closely coordinated (and as such they interact), they are essentially independent (Barton et al., 2020; Doucet & Stelmack, 1997; Gratton et al., 1988; Praamstra et al., 2014; Reynaud et al., 2020). Reflecting the close coordination of movement initiation and execution processes, correlations between the extent of self-bias in initiation and execution were documented in Chapters 5 and 6 (although note, strong correlations between PC-1 and PC-2 also reflect that PC-2 is dependent as a measure on PC-1; see Section *3.4.4 Data analysis*). Consistent with their independence (Reynaud et al., 2020), Chapters 3, 5, and 6, documented that the *extent* of the self-bias was significantly altered across the two response stages.

Notably, across the four studies (C3, C5.1, C5.2, C6) the correspondence between self-bias in movement initiation and execution was altered. Chapter 6 documented that self-bias in accuracy increased from movement initiation to execution, consistent with Chapters 3 and 5. In contrast to Chapters 3 and 5, however, self-bias in IT and MT did not differ significantly. In addition, the extent of Friend-stranger bias was unchanged across the response stages. Self-biases and Friend-stranger bias do not appear to behave in the same way across the response stages. Furthermore, Study C5.1 used the same motor response as Chapter 6, but with dichotomous Self and Stranger associations, and a marked disadvantage for stranger-related movement executions relative to their initiation was documented. By contrast, such a marked disadvantage in the stranger-related movement executions was not observed in Chapter 6. Collectively, these findings suggest that the relationship between self-bias in the initiation and execution response stages of arm-movements is not fixed, indicating a two-stage response, and consistent with differential processes supporting self-bias in movement execution.

As reviewed in Chapter 1, little is known about the representations of self and other underlying motor responses in the matching task (cf. Golubickis et al., 2017; C.-P. Hu et al., 2020), and it is unclear whether self-bias is related to higher-level conceptual constructs of the self, or may instead draw upon distinct lower-level representations. Recent research has suggested that self-bias is not related to higher-level self-referential or self-reflective processing (Northoff, 2016; Schäfer & Frings, 2019b; Schäfer, Wesslein, et al., 2020). Instead, self-bias is thought to relate to the function of making a basic distinction between self and other, and reflect lower-level or ‘first order’ self-related processing; that is, implicit (automatic and preconscious) processing. Chapter 6 therefore asked: Is there a relationship between self-bias and friend-bias in ballistic arm-movement responses and consciously-accessible representations of the interrelations between others and the self? Chapter 6 found that empathy predicted Self-stranger bias, and the Friend-stranger bias was predicted by Self-PD (the self-friend relative to self-stranger personal distance). This chapter therefore presented a novel demonstration that people’s explicit representations of the interrelations between others and the self in terms of empathic understanding and perceived closeness influence biases in the matching task motor responses.

As discussed in Chapter 6, one interpretation of these findings is that the biases in arm-movement responses in the matching task are directly influenced by explicit representations of empathy and perceived closeness; in other words, through a top-down consciously-controlled bias. Given the ballistic nature of the arm-movements, however, this seems unlikely and more probable that the biases operate on a somewhat automatic level (Northoff, 2016; Schäfer, Wesslein, et al., 2020; Schäfer & Frings, 2019b; see also Chapter 5). In addition, no significant difference was documented between Friend- and Stranger-associated responses, and yet a relationship was revealed between Friend-stranger bias and personal distance, something that would be difficult (if not impossible) to consciously-control.

Instead biases in arm-movement responses in the matching task may be *indirectly* influenced by consciously-accessible representations of self–other relations. Empathy-related processes are thought to be integral to the *interpersonal self* which is conceptualised to operate as a bridge between the automatic processes of the minimal self and reflective processes of the narrative self (Kyselo, 2016; Zahavi, 2014). If self-bias reflects the operation of the interpersonal self, then explicit perceptions of empathy-related behaviour may be indirectly reflected in self-bias. Indeed, self-reflective processes along with behaviour change can shape implicit representations in line with the notion that conscious processes become automated over time (and the concept of therapeutic change, more generally). Biases in the matching task may be directly influenced by implicit representations of empathy- and perceived-closeness related to the interpersonal self. As such, self- and friend-biases may function at a slightly higher-level of self than the one making a basic distinction between others and the self. In addition, the consciously-accessible representations that we use to report on ‘the individual self’ may not be linked to such lower-level processes in the same way (if at all) as those representations that we use to report on ‘the self-in-relation-to-others’.

This notion could therefore also account for previous research which reported a null relationship between self-bias and explicit evaluations of self-esteem and self-identification related to the individual self (Schäfer & Frings, 2019b; Woźniak et al., 2022).

Other evidence from Chapter 2 also supports the notion that self-bias reflects the operation of a subcomponent of self which may theoretically correspond with the interpersonal self. As discussed, the findings of Chapter 2 in conjunction with previous studies (e.g. Scheller & Sui, 2022a) suggest that self-bias does not dominate in a sensory modality per se. Such operation would be consistent with the adaptive function of a subcomponent of self at a fundamental level: the minimal self must necessarily rely on efficiently (albeit flexibly) processing information across the senses, for example. However, if self-bias reflects the operation of the minimal self, one might expect that the influence of self-associations formed in the matching task should arise somewhat automatically, and, therefore, influence simple detection motor responses. The operation of self-bias in motor responding appears to be highly adaptive and responsive to the context consistent with the notion that self-bias reflects the operation of a somewhat higher-level subcomponent of self, such as the interpersonal self (Zahavi, 2014).

Theories diverge regarding the extent to which sub-components of the self are interconnected or whether they function independently (Gallagher, 2013; Humphreys & Sui, 2016; Nijhof et al., 2020), and empirical study of their relationship and dynamic interplay is in its infancy (Banakou et al., 2013; Maister et al., 2015; Maister & Farmer, 2016; Nijhof et al., 2020; Nowicka et al., 2018; Schäfer & Frings, 2019b; Tao et al., 2012). Future studies are needed to systematically examine the operation of self-bias in relation to implicit and explicit representations related to the different sub-components of the self.

7.4. Limitations and future directions

The findings of this thesis complement and extend previous research and contribute novel insights which increase understanding of self-bias in motor responses. They also highlight that investigating self-bias in motor responses is likely to have important future translational value for progressing understanding of self-representation(s) in action across different populations, and lays the foundations for such enquiry.

A number of general caveats and limitations should, however, be noted in respect of the findings of this thesis. In discussion of the wider implications of the results it was postulated that self-bias may manifest as a self-advantage in the initial impulse or ballistic movement, reflective of movement planning, operating independently of relevant exogenous visual input and relying on non-visual information (or self-generated visual imagery). It was also highlighted that patterns in other research examining, for example, motor responding in autistic individuals (who present with intact self-bias) were consistent with this notion. Future studies are needed to systematically address this hypothesis. Questions of *how* self-bias operates in motor responses—namely whether the self-advantage emerges in movement planning or online control, or relies on non-visual information and visual imagery—lie outside of the scope and aims of the present thesis.

Indeed, one key feature of the methodology used in Chapters 3, 5, and 6 was the separate measurement of movement initiation and execution. Movement execution in the present thesis was measured in terms of gross behavioural outcome measures of movement time and the percentage of correctly-completed movement responses. In accordance with the overarching aims, this thesis asked *whether* the overt movement is modulated in the matching task, and did not set out to systematically test *how* self-bias in the matching task influences movement execution. Such a line of enquiry which would implicate alternative techniques. Future studies for example could systematically examine how self-relevance modulates movement execution by analysing the kinematics of the limb trajectories. The movements could be parsed into their initial impulse and error correction phases, and the directional error measured. Such measures would provide valuable information pertaining to the quality of the movement programming, for example (Khan et al., 2006). Future studies could also investigate whether and how self-bias interacts with online movement control, for example in non-ballistic movement. Tracking modification of trajectories during online correction could determine online control effects (Khan et al., 2006).

Arm-movement and keypress motor-response types also have different real-world functions and associated uses. Chapter 4 concluded that it remains an open question whether self-bias modulates the motor-stage of keypress responses, and Study C5.1 indicated that self-bias emerges in ballistic movement that is not guided by visual feedback (which would characterise keypress responses). However, direct comparison of self-bias in other types of motor response, including for example keypresses and foot-presses, as well as arm-movement responses within the same study could systematically test whether self-bias emerges in the execution of motor responses more widely. Keypresses as a behavioural outcome are a step removed from meaningful everyday actions (Baumeister et al., 2007), and as discussed in Chapter 6, self-bias may therefore manifest differently in these motor responses.

Chapters 3, 5, and 6, demonstrated the robustness of the self-advantage in movement execution across contexts in different types of arm-movement. However, the addition of control experiments could improve this research by demonstrating explicitly that the effects of non-self-specific factors such as reward and emotional valence do not independently drive the movement self-advantage. However, as reviewed in Chapters 1 and 2, previous studies have demonstrated that effects of self-bias in the standard keypress version of the matching task are independent of word length, word frequency, word concreteness, reward, and emotional valence (Schäfer, Wentura, et al., 2020; Stolte et al., 2017; Sui et al., 2012; Sui & Humphreys, 2015c; Yankouskaya et al., 2017). Furthermore, other research using arm-movement responses indicates that while stimulus reward value can influence simple RT, reward does not influence choice RTs (when they are not cued via a warning signal; Mir et al., 2011). The authors concluded that reward speeds up the initiation and execution of manual motor responses when responses can be pre-programmed (such as in a detection task). Conversely, reward does not influence response execution when responses cannot be specified in advance (such as in the matching task). These findings stand in stark contrast to the present findings. Sense of agency over one's hand in conjunction with visual feedback in relation to one's hand has also been documented to prime manual motor responses (Longo & Haggard, 2009). Again, however, the emergence of self-bias in the absence of visual feedback in Study C5.1 and C6 indicate that self-bias appears to operate differently. Notably, the findings of Chapter 6 indicated that representations of self–other relations—namely, explicit perceptions of empathy and perceived closeness between others and the self—(partly) underpin the motor responses providing further evidence that the performance modulations of arm-movements were driven by self-related factors.

Generalisability of the present findings to other kinds of self-related stimuli and across other task paradigms is necessarily impacted by the exclusive focus on the matching task in this research (with the exception of the detection task in Study C2). However, such a focus was in accordance with the aims of the present thesis to progress understanding of the particular operation of this (putative) sub-component of self. Indeed the base assumption was that self-bias reflects the operation of a subcomponent of self that may be distinct from other kinds of self-representations. Consistent with this view, other research indicates that self-related constructs such as ownership do indeed operate differently than self-bias in movement execution. In contrast to the findings of Chapter 5, Barton et al. (2020) documented that the self-advantage in an ownership paradigm emerged in IT and MT when arm-movements were directed towards the stimuli, but only in ITs when movements were directed away from the stimuli and toward the participant’s body. Notably, however, the arm-movements in Barton et al.’s study were directed away from the stimuli, but *towards* the participant’s body. Future studies could therefore control parameters across tasks and directly pit the self-ownership-bias and self-bias in arm-movement responses to systematically test their differential operation in arm-movement responses.

One notable limitation of the present research was the use of young participant samples. Caveats regarding the representativeness of Western university undergraduate samples and their impact on the reproducibility and generalisability of findings have been raised (DeRight & Jorgensen, 2015; Henrich et al., 2010; Peterson & Merunka, 2014). For example, rather than activating task rules in response to stimuli, young, intelligent individuals tend to activate task instructions prior to stimulus onset (Iveson et al., 2016). Such task strategies may influence responding in the detection task (Study C2), for example. However, in the present thesis, samples included young adults (ages 18–40 years) from the general population from a mixed cultural background, as well as both undergraduate and postgraduate students, and also staff, from three different universities in the UK. Chapters 2 and 5 were based on university students, while Chapter 3 used a sample of young adults from the general population, and Chapter 6 on undergraduate students, postgraduate students, and staff. The absence of a significant self-advantage in the detection task, for example, was also consistent with previous studies documenting no self-advantage when the self-associations were not relevant to the task at hand. Nevertheless, future studies are needed to examine self-bias in motor responses using participant samples from more diverse populations and across cultures to establish the applicability of the present thesis findings to other groups. Generally the research presented and discussed in this thesis highlights that examining self-bias in motor responses alongside investigation of the constellations of self–other representations reflected in the lower-level self- and friend-biases is likely to be beneficial.

From a methodological perspective, future research could use the novel movement adaptations of the matching task introduced here as a starting point to examine self-bias in action across diverse populations, such as in autism, disorders of the self, and across the life-span. The novel auditory adaptation of the matching task using A+AL stimuli, for example, may also be used with groups with visual impairment. Furthermore, the present findings indicate that future research examining self-bias cannot assume that label modality will not interact with self-bias and should take into consideration the influence of the task design on the manifestation of self-bias.

Overall, this thesis took a broad approach in examining self-bias in motor responses across three main themes: in unisensory and multisensory processes, in arm-movements, and the underlying representations of self–other relations. An alternative approach could instead have focused in depth on one of these themes and its related sub-themes. Both approaches bring added value to the research area. Given the nascent status of research on self-bias in action, a strength of the present approach however is that findings provide a holistic overview of self-bias in motor responses from multiple vantage points.

7.5. General conclusions

Central to our sense of how we function in the world is the notion that at a fundamental level our ‘self’ distinguishes us from our environment and from other people. In psychology, s*elf-representation* is widely held to guide our cognition and action. The empirical evidence is consistent with the notion however that there may be multiple and distinct subcomponents of self that differentially influence our behaviour. The self-advantage in a matching task (known as self-prioritization, or self-bias) is thought to reflect implicit self-related processing related to the function of making a basic distinction between others and the self. The present thesis aimed to progress understanding of the particular operation of this (putative) sub-component of self by investigating the contextual constraints of emergence and extent of self-bias in motor responses.

Examining self-bias in motor responses outside of visuomotor responses in unisensory and multisensory processes, beyond response selection, and in arm-movement responses, this thesis has made multiple novel contributions to the literature (Desebrock, Barutchu, et al., 2022; Desebrock et al., 2018; Desebrock, Spence, et al., 2022; Desebrock & Spence, 2021). Specifically, this thesis demonstrated that: (1) self-bias in motor responses can be modulated by both stimulus- and task-related parameters; namely, by label and object modality and whether trials are blocked or intermixed by sensory modality type; (2) that the self-associations formed in the matching task do not automatically result in similar motor speed gains to unisensory and multisensory stimuli in simple detection motor responses; (3) that self-relevance in the matching task can influence both the initiation and execution of arm-movements, highlighting modulation at multiple stages; (4) that self-bias emerges in non-ballistic arm-movements guided by visual feedback, ballistic arm-movements in the absence of visual feedback pertaining to the hand or target, and arm-movements both directed 'toward' the stimuli, and framed as 'away' from the stimuli. In other words, self-bias in movement execution does not depend on an explicit decisional response bias or a modulation of automatic visual-feedback-driven processes, or on approach motivation through affective S–R compatibility; (5) that self-bias emerges in ballistic movement using predominantly proprioceptive, kinaesthetic, tactile information (and potentially self-generated visual imagery) in movement planning and execution; (6) that manual motor responses in the matching task appear to reflect the (direct or indirect) operation of consciously-accessible representations of the interrelations between others and the self that are related to one's empathic traits and perceived closeness between others and the self.

Collectively, the findings of this thesis are consistent with the view that self-bias in the matching task reflects operation of the self at a fundamental level in auditory, visual, and multisensory processes, and influences both our cognition and action. The operation of *self-bias* in motor responding however also appears to be highly adaptive and responsive to the context, and may shape or be shaped by explicit representations of the interrelations between others and the self.

Overall the findings of this thesis progress our understanding of the impact that self-relevance has on cognition and action, the particular operation of self-bias as a subcomponent of self in motor responding, and the influence that underlying representations of the self and others have on shaping our behaviour. This thesis also highlights that investigating self-bias in arm-movement responses is likely to have important future translational value for increasing understanding of self-representation(s) in action across different populations, and lays the foundations for such enquiries.

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Appendix A: Chapter 2—Study C2

A1: Absolute RTs and sensitivity index scores (D-prime; d′)

A1.1 Group 1: Matching task

There was one studentized residuals outlier (outside ∓ 3.0 in absolute value in one or more of the conditions) in RT. With the outlier removed (N=27), the matching-trial RT data were submitted to a 2 (Block type: blocked, intermixed) x 4 (Stimulus type: V-shape+VLabel, A+AL, A+VL, V+AL) x 2 (Association: Self, Stranger) repeated measures ANOVA. The analysis revealed significant main effects of Block type, $F(1, 26) = 191.85$, $p <.001$, $\eta_p^2 = .88$, Stimulus type, $F(2.19, 56.85) = 22.61$, $p < .001$, $\eta_p^2 = .47$, and Association, $F(1, 26) = 43.07$, $p < .001$, $\eta_p^2 = .62$. RTs were shorter in the Blocked (*M* = 705 ms, *SE* = 9.24) as compared with the Intermixed trials (*M* = 781 ms, *SE* = 9.49). There were significant differences in RTs between all Stimulus types (*ps* < .004), except between V+VL and V+AL (*p* = .10). RTs in self (*M* = 715 ms, *SE* = 9.58) as compared with stranger-associated trials were shorter (*M* = 771 ms, *SE* = 10.26), indicating the presence of an SPE.

There was a significant interaction between Block type and Stimulus type, $F(3, 78) = 8.55$, $p < .001$, $\eta_p^2 = .25$. There were no other significant interaction effects. Probing the interaction between Block type and Stimulus type revealed a significant difference between blocked and intermixed trial responses across all stimulus types (*ps* < .001). RTs were shorter in the blocked as compared with the intermixed stimulus type trials. In the blocked trials, only the difference in RTs between A+AL and V+AL was significant (*p* < .001). In contrast, in intermixed trials, there was a significant difference between each of the stimulus types (all *ps* < .001) except for between V+VL and V+AL (*p* = .34). (The analysis was conducted again with the outlier included and the findings were replicated.)

The *d′* data were normally distributed except for one condition (Blocked V+AL Stranger), therefore I chose not to transform the data. Sensitivity index scores were submitted to a 2 (Block type: blocked, intermixed) x 4 (Stimulus type: V-shape+VLabel, A+AL, A+VL, V+AL) x 2 (Association: Self, Stranger) repeated-measures ANOVA. There were significant main effects of Block type, *F*(1, 27) = 29.26, *p* < .001, η_p^2 = .52, Stimulus type, *F*(2.18, 58.94) = 15.67, *p* < .001, η_p^2 = .37 (Greenhouse-Geisser correction), and Association, *F*(1, 27) = 12.89, *p* = .001, η_p^2 = .32. *d′* scores were higher for responses to Blocked (*M* = 2.56, *SE* = .09) as compared with Intermixed (*M* = 1.94, *SE* = .14) trials. There were significant differences between all Stimulus types (*ps* < .01 for all) except for between V+VL and A+VL (*p* = .76). *d′* scores were higher for self- (*M* = 2.38, *SE* = .12) as compared with stranger-associated (*M* = 2.11, *SE* = .11) responses, indicating the presence of an SPE.

A1.2 Group 2: Matching task

There was one studentized residuals outlier (outside ∓ 3.0 in absolute value) in RT. With the outlier removed (N=21), studentized residuals were normally distributed except for in two of the conditions. Since the majority of the data were normally distributed, I chose not to transform the data. The matching trial RT data (N=21) were submitted to a 2 (Block type: blocked, intermixed) x 4 (Stimulus type: V+VL, A+AL, A+VL, V+AL) x 2 (Association: self, stranger) repeated measures ANOVA. There were significant main effects of Block type, *F*(1, 20) = 53.03, *p* <.001, η_p^2 = .73, Stimulus type, *F*(3, 60) = 19.83, *p* < .001, η_p^2 = .50, and Association, *F*(1, 20) = 6.05, *p* = .02, η_p^2 = .23. In contrast to the results for Group 1, there were also significant simple two-way interactions between Block type and Association, *F*(1, 20) = 9.72, *p* = .01, η_p^2 = .33, and between Stimulus type and Association, *F*(3, 60) = 4.30, *p* = .008, η_p^2 = .18, and, as for Group 1, between Block type and Stimulus type, *F*(3, 60) = 3.64, *p* = .02, η_p^2 = .15. Probing the interaction between Stimulus type and Association revealed a significant difference between self- and stranger-associated responses for the V+VL (*p* =

.005, $\eta_p^2 = .34$) and V+AL ($p = .008$, $\eta_p^2 = .30$) stimulus types, but not for the A+VL ($p = .07$, $\eta_p^2 = .16$) and A+AL ($p = .39$, $\eta_p^2 = .04$) stimulus types. Probing the interaction between Block type and Association revealed a significant difference between self- and stranger-associated responses in the Blocked trials, $F(1, 21) = 9.20$, $p = .007$, $\eta_p^2 = .32$, but not in the intermixed trials, $F(1, 21) = 2.64$, $p = .12$, $\eta_p^2 = .12$. Once again, these findings were replicated with the outlier included.

Sensitivity index scores were submitted to a 2 (Block type: blocked, intermixed) x 4 (Stimulus type: V+VL, A+AL, A+VL, V+AL) x 2 (Association: Self, Stranger) repeated-measures ANOVA. The analysis revealed significant main effects of Block type, $F(1, 21) = 40.61$, $p < .001$, $\eta_p^2 = .66$, and Stimulus type, $F(3, 63) = 14.28$, $p < .001$, $\eta_p^2 = .41$, but, in contrast to Group 1, not of Association, $F(1, 21) = 1.90$, $p = .18$, $\eta_p^2 = .08$. Self- (*M* = 2.31, *SE* = .16) as compared with stranger- (*M* = 2.15, *SE* = .20) associated *d′* scores were not significantly different. In contrast to Group 1, there was a significant interaction between Block type and Stimulus type, $F(3, 63) = 4.95$, $p = .004$, $\eta_p^2 = .19$.

A2: Analyses of auditory stimulus intensity across Groups 1 and 2 in the matching tasks

An independent *t*-test was conducted on overall RT across Groups 1 and 2 revealing no significant difference between the 50dB auditory group (*M* = 742 ms, *SD* = 46 ms) and the 70dB stimulus intensity group (*M* = 730 ms, *SD* = 54 ms), $t(48) = 0.82$, $p = .42$. Similarly, there was no significant difference between overall *d′* scores between the 50dB group (*M* = 2.25, *SD* = 0.56) and the 70dB group (*M* = 2.23, *SD* = 0.79), $t(36.31) = 0.07$, $p = .94$.

A 2 (Auditory stimulus intensity: 50dB, 70dB) x 2 (Block type: Blocked, Intermixed) x 4 (Stimulus type: V+VL, A+AL, A+VL, V+AL) ANOVA on RTs across Groups 1 and 2 with the Association (self, stranger) condition collapsed revealed no effect of auditory stimulus intensity. In particular, there was no interaction between Block type and Auditory stimulus intensity (*p* = .31), nor between Stimulus type and Auditory stimulus intensity (*p* = .57), nor was there a three-way interaction (*p* = 1.00).

A 2 (Auditory stimulus intensity: 50dB, 70dB) x 2 (Block type: Blocked, Intermixed) x 4 (Stimulus type: V+VL, A+AL, A+VL, V+AL) ANOVA on *d′* scores across Groups 1 and 2 with the Association (self, stranger) condition collapsed revealed no effect of auditory stimulus intensity: There was no interaction between Block type and Auditory stimulus intensity, *p* = .90, nor between Stimulus type and Auditory stimulus intensity (*p* = .72), nor was there a three-way interaction (*p* = .44).

A3: Self-bias and multisensory gains ANOVAs: Outliers included

Table A3.1
F-statistics for self-bias index scores in RT and *d′* assessed using 2 (between-groups Auditory stimulus intensity: 50 dB, 70 dB) x 2 (within-groups Block type: Blocked, Intermixed) x 4 (within-groups Stimulus type: V+VL, A+AL, A+VL, V+AL) mixed factorial ANOVA in Study C2.

	Self-bias in RT	Self-bias in *d′*
Block type	**F*(1, 48) = 15.51, *p* < .001, η_p^2 = .24	*F*(1, 48) = 0.25, *p* = .62, η_p^2 = .01
Block type x Intensity	*F*(1, 48) = 0.04, *p* = .85, η_p^2 = .00	*F*(1, 48) = 3.68, *p* = .06, η_p^2 = .07
Stim. type	**F*(2.32, 111.30) = 4.49, *p* = .01, η_p^2 = .09	*F*(3, 144) = 0.17, *p* = .92, η_p^2 = .00
Stim. type x Intensity	*F*(3, 144) = 0.65, *p* = .59, η_p^2 = .01	*F*(3, 144) = 0.58, *p* = .63, η_p^2 = .01
Block type x Stim. type	*F*(3, 144) = 2.46, *p* = .06, η_p^2 = .05	*F*(3, 144) = 0.24, *p* = .87, η_p^2 = .01
Block type x Stim. type x Intensity	*F*(3, 144) = 0.58, *p* = .63, η_p^2 = .01	*F*(3, 144) = 0.78, *p* = .51, η_p^2 = .02

Notes. N = 50. Outliers included (NB findings were replicated with outliers excluded—see main text). Stim. = stimulus. V+VL = Visual-shape+Visual-Label, A+AL = Auditory-object+Auditory-Label, A+VL = Auditory-object+Visual-Label, V+AL = Visual-shape+Auditory-Label. Intensity = Auditory stimulus intensity. *Significant F-statistics with *p* < .05. (Adapted from: Desebrock et al., 2022, *Attention, Perception, & Psychophysics*, Springer Nature.)

Table A3.2

F-statistics for multisensory (percentage) gains/costs for RT and *d′* assessed using 2 (between-groups Auditory stimulus intensity: 50 dB, 70 dB) x 2 (within-groups Block type: Blocked, Intermixed) x 2 (within-groups AV Stimulus type: A+VL, V+AL) x 2 (within-groups Association: self, stranger) mixed factorial ANOVA in Study C2. Pairwise comparisons for significant interactions also presented.

			MS percentage gains/costs RT	**MS gains/costs *d′***
Block type			*$F(1, 48) = 9.59$, $p = .003$, $\eta_p^2 = .17$	$F(1, 48) = 0.34$, $p = .57$, $\eta_p^2 = .01$
Block type x Intensity			$F(1, 48) = 0.01$, $p = .94$, $\eta_p^2 = .00$	$F(1, 48) = 0.54$, $p = .47$, $\eta_p^2 = .01$
AV Stimulus type			*$F(1, 48) = 45.63$, $p < .001$, $\eta_p^2 = .49$	*$F(1, 48) = 22.07$, $p < .001$, $\eta_p^2 = .32$
AV Stimulus type x Intensity			$F(1, 48) = 0.95$, $p = .33$, $\eta_p^2 = .02$	$F(1, 48) = 1.48$, $p = .23$, $\eta_p^2 = .03$
Association			$F(1, 48) = 0.05$, $p = .83$, $\eta_p^2 = .00$	$F(1, 48) = 0.06$, $p = .81$, $\eta_p^2 = .00$
Association x Intensity			$F(1, 48) = 0.31$, $p = .58$, $\eta_p^2 = .01$	$F(1, 48) = 0.03$, $p = .86$, $\eta_p^2 = .00$
Block type x AV Stimulus type			$F(1, 48) = 0.92$, $p = .34$, $\eta_p^2 = .02$	*$F(1, 48) = 6.56$, $p = .01$, $\eta_p^2 = .12$
Block type x AV Stimulus type x Intensity			$F(1, 48) = 0.00$, $p = .95$, $\eta_p^2 = .00$	$F(1, 48) = 0.41$, $p = .52$, $\eta_p^2 = .01$
Block type x Association			*$F(1, 48) = 6.15$, $p = .02$, $\eta_p^2 = .11$	$F(1, 48) = 0.02$, $p = .90$, $\eta_p^2 = .00$
Block type x Association x Intensity			$F(1, 48) = 0.15$, $p = .70$, $\eta_p^2 = .00$	$F(1, 48) = 0.10$, $p = .76$, $\eta_p^2 = .00$
AV Stimulus type x Association			*$F(1, 48) = 4.56$, $p = .04$, $\eta_p^2 = .09$	$F(1, 48) = 0.47$, $p = .50$, $\eta_p^2 = .01$
AV Stimulus type x Association x Intensity			$F(1, 48) = 0.76$, $p = .39$, $\eta_p^2 = .02$	$F(1, 48) = 0.04$, $p = .84$, $\eta_p^2 = .01$
Block type x AV Stimulus type x Association			$F(1, 48) = 0.26$, $p = .61$, $\eta_p^2 = .01$	$F(1, 48) = 0.02$, $p = .88$, $\eta_p^2 = .00$
Block type x AV Stimulus type x Association x Intensity			$F(1, 48) = 0.07$, $p = .79$, $\eta_p^2 = .00$	$F(1, 48) = 0.00$, $p = .97$, $\eta_p^2 = .00$
Pairwise comparisons				
Block types	**Stimulus types**	**Associations**		
Blocked		Self & Stranger	$p = .08$	
Intermixed		Self & Stranger	$p = .06$	
Blocked & Intermixed		Self	**$p < .001$	
Blocked & Intermixed		Stranger	$p = .38$	
	A+VL & V+AL	Stranger	**$p = .001$	
	A+VL & V+AL	Self	**$p < .001$	
	A+VL	Self & Stranger	$p = .18$	
	V+AL	Self & Stranger	$p = .05$	
Blocked	A+VL & V+AL			**$p = .04$
Intermixed	A+VL & V+AL			**$p < .001$

Notes. N = 50. Outliers included (NB findings were replicated with outliers excluded—see main text). AV = audiovisual. V+VL = Visual-shape+Visual-Label, A+AL = Auditory-object+Auditory-Label, A+VL = Auditory-object+Visual-Label , V+AL = Visual-shape+Auditory-Label. Intensity = Auditory stimulus intensity. MS = multisensory. *Significant F-statistics with $p < .05$. **Significant p-values following a

The following analyses replicate those presented in the main text, but with the outliers included (rather than excluded) in each case. The findings reported in the main text were all replicated.

A3.1 Self-bias in RTs with outliers included

F-statistics are presented in Table A3.1. There were two outliers (studentized residuals outside ∓ 3.0 in absolute value) identified in the self-bias index scores (there was one outlier which when removed revealed a second outlier). The majority of the data were normally-distributed (three conditions not normally distributed), so I chose not to transform the data. The assumption of homogeneity of variances was violated for one condition, as assessed by Levene's test for equality of variances. Given that the sample sizes of the two groups were roughly equal (ratio 1.29) and ANOVA is generally robust to violations of this assumption if group sizes are roughly equal, an ANOVA was carried out on the data. With the outliers included, a 2 (Auditory stimulus intensity: 50 dB, 70 dB) x 2 (Block type: Blocked, Intermixed) x 4 (Stimulus type: V+VL, A+AL, A+VL, V+AL) mixed ANOVA was conducted on the RT self-bias index scores. The analysis revealed main effects of Stimulus type, and Block type. Overall, the magnitude of self-bias in the Blocked trials (*M* = .04, *SE* = .007) was greater than in the Intermixed trials (*M* = .02, *SE* = .005). For Stimulus type, the magnitude of the normalised self-bias in the RT data was significantly greater (*p* = .002) in responses to V+AL (*M* = .04, *SE* = .007) as compared with A+AL (*M* = .02, *SE* = .006). There were no significant differences between any other pair of Stimulus types (all *ps* > .02). There were no other significant effects. These findings replicated those with the outliers excluded—see main text for details.

A3.2 Self-bias in sensitivity index scores (D-prime; *d′*) with outliers included

F-statistics are presented in Table A3.1. There were two studentized residuals outliers (studentized residuals outside ∓ 3.0 in absolute value) identified in the self-bias index scores (there was one outlier which when removed revealed a second outlier). The assumption of homogeneity of variances was violated for two conditions. As with the analysis of self-bias in the RT data, given that the group sizes were roughly equal, an ANOVA was carried out on the data (N=50). With the outliers included, a 2 (Auditory stimulus intensity: 50 dB, 70 dB) x 2 (Block type: Blocked, Intermixed) x 4 (Stimulus type: V+VL, A+AL, A+VL, V+AL) mixed ANOVA was conducted on self-bias index scores for *d′* (see Table 1—main text). There were no significant effects. The self-advantage in sensitivity between self- and stranger-associated responses did not differ significantly across the conditions. These findings replicated those with the outliers excluded—see main text.

A3.3 Multisensory percentage gains/costs in RT with outliers included

F-statistics and pairwise comparisons are presented in Table A3.2. There were two studentized residuals outliers whose removal produced a third outlier. With the outliers included, the data were submitted to a 2 (Auditory stimulus intensity: 50 dB, 70 dB) x 2 (Block type: blocked, intermixed) x 2 (AV Stimulus type: A+VL, V+AL) x 2 (Association: self, stranger) mixed ANOVA. There was a significant main effect of Block type, and AV Stimulus type. Negative gain values indicated that there were costs for responses to multisensory relative to unisensory stimuli. Multisensory costs were greater in participants' responses to intermixed trials (*M* = -4.99, *SE* = 0.75) as compared with blocked trials (*M* = -1.92, *SE* = 0.98), and greater in responses to the A+VL stimulus type (*M* = -6.72, *SE* = 0.94) as compared with responses to the V+AL stimulus type (*M* = -0.20, *SE* = 0.78). There was a significant interaction between Block type and Association, and between AV Stimulus type and Association. None of the other effects was significant.

Probing the interaction between the AV stimulus type and Association revealed a significant difference between stranger-associated responses to the A+VL (*M* = -5.88, *SE* = 1.14) and V+AL (*M* = -1.19, *SE* = 0.94) stimulus types, and a significant difference between self-associated responses to the A+VL (*M* = -7.55, *SE* = 1.10) and V+AL stimulus types (*M* = 0.79, *SE* = 0.92). There was no significant difference between self- and stranger-associated responses to the V+AL stimulus type, or the A+VL stimulus type.

Probing the Block type and Association interaction revealed no significant difference in multisensory costs for self-associated responses (*M* = -5.86, *SE* = 0.78) than for with stranger-associated responses (*M* = -4.13, *SE* = 0.96) in intermixed trials. There was no significant difference between self-associated responses (*M* = -0.90, *SE* = 1.17) as compared with stranger-associated responses (*M* = -2.94, *SE* = 1.11) in the blocked trials, but it is worth noting that costs were descriptively greater in stranger-associated as compared with self-associated responses. In addition, stranger-associated responses in blocked trials as compared with intermixed trials were not significantly different. In contrast, multisensory costs in self-associated responses in the blocked trials as compared with the intermixed trials were significantly different. Multisensory costs in self- as compared with stranger-associated responses were differentially modulated by block type. These findings replicated those with the outliers excluded—see main text, except that there was no significant difference between multisensory costs for self- versus stranger-associated responses in intermixed trials.

A3.4 Multisensory gains/costs in sensitivity index scores (D-prime; *d′*) with outliers included

F-statistics and pairwise comparisons are presented in Table A3.2. There were four studentized residuals outliers. With the outliers included, the data were submitted to a 2 (Auditory stimulus intensity: 50 dB, 70 dB) x 2 (Block type: blocked, intermixed) x 2 (AV stimulus type: A+VL, V+AL) x 2 (Association: self, stranger) mixed ANOVA. The analysis revealed a significant main effect of AV Stimulus type. Negative gain values indicated that there were costs for responses to multisensory relative to unisensory stimuli. There was some multisensory facilitation in responses to the V+AL stimuli (*M* = 0.06, *SE* = 0.08), and costs in responses to A+VL stimuli (*M* = -0.38, *SE* = 0.08). There was a significant interaction between Block type and AV stimulus type. There were no other significant effects. The interaction between Block type and AV stimulus type was probed revealing that multisensory costs in responses to the A+VL stimulus type (*M* = -0.25, *SE* = 0.13) as compared with the V+AL stimulus type (*M* = 0.01, *SE* = 0.13) in blocked trials were significantly different. There were multisensory gains in responses to the V+AL stimulus type (*M* = 0.10, *SE* = 0.09) as compared with multisensory costs in responses to the A+VL stimulus type (*M* = -0.51, *SE* = 0.11) in the intermixed trials. (These findings replicated those with the outliers excluded—see main text, except that there was a significant difference between multisensory costs in responses to the A+VL and V+AL stimulus types with the outliers included.)

A4: Multisensory simple detection task further analysis (N = 16)

The detection task sample included data from those participants whose data were excluded from the preceding matching task because they achieved below-threshold accuracy. This could potentially confound the transfer of the social associations because these participants may not have properly assimilated them. To check whether the low accuracy performance in the matching task could have impacted the influence of self-associations in the detection task, a further analysis was also conducted.

A4.1 Participants

Twenty-six participants completed the detection task. The data from four participants were excluded for achieving >2.5 SDs below the group percentage accuracy mean for any one condition, or for achieving <50% accuracy in any one condition in the detection task. In addition, the data from the seven participants that were excluded from analyses of the matching task data for low performance accuracy or constituting outliers (see main text) were also excluded. The data from 16 participants were used in the analysis.

A4.2 RTs

The RT data were submitted to a 2 (Association: Self, Stranger) x 4 (Stimulus type: Visual, Auditory, AV Mismatch, AV Match) repeated-measures ANOVA. There was a significant main effect of Stimulus type, $F(2.05, 30.81) = 105.01$, $p < .001$, $\eta_p^2 = .88$ (Greenhouse-Geisser correction). There was no main effect of Association, $F(1, 15) = .15$, $p = .70$, $\eta_p^2 = .01$. Pairwise comparisons between stimulus types revealed a significant difference between the unisensory and multisensory stimuli, and between the visual and auditory stimuli (all *ps* < .001). Note that the findings using the N=16 sample thus replicated the findings using the N=22 sample.

A4.3 Multisensory percentage gains/costs

Multisensory percentage gain/cost values ([(faster of unisensory – multisensory) / faster of unisensory)*100]; see Section *2.3.6. Data analysis*) were submitted to a 2 (Association: self, stranger) x 2 (AV stimulus type: match, mismatch) repeated-measures ANOVA. There were no significant effects. The findings using the N=16 sample thus replicated the findings using the N=22 sample.

A5: Analysis of auditory stimulus intensity on the self-advantage in absolute RTs

Auditory stimulus intensity did not moderate the self-bias index scores. To confirm that there were no main nor interaction effects of auditory stimulus intensity on the self-advantage in the absolute RTs, an additional ANOVA was carried out. The majority of the RT data were normally-distributed (two conditions were not normally distributed), so I chose not to transform the data. There was one studentized residuals outlier. The assumption of homogeneity of variances was violated for one condition, as assessed by Levene's test for equality of variances. As with the analysis of self-bias in the RT data, given that the group sizes were roughly equal, an ANOVA was carried out on the data. With the outlier included (N=48), RTs were submitted to a 2 (between-groups Intensity: 50dB, 70dB) x 2 (within-groups Block type: blocked, intermixed) x 4 (within groups Stimulus type: V+VL, A+AL, A+VL, V+AL) x 2 (Within-groups Association: self, stranger) mixed factorial ANOVA. The analysis revealed main effects of Stimulus type, $F(2.46, 113.10) = 40.81$, $p < .001$, $\eta_p^2 = .47$, Block type, $F(1, 46) = 187.56$, $p < .001$, $\eta_p^2 = .80$, and Association, $F(1, 46) = 55.09$, $p < .001$, $\eta_p^2 = .55$. There was a significant interaction between Block type and Stimulus type, $F(3, 138) = 10.10$, $p < .001$, $\eta_p^2 = .18$, Block type and Association, $F(1, 46) = 15.60$, $p < .001$, $\eta_p^2 = .25$, and Stimulus type and Association, $F(2.20, 100.97) = 4.34$, $p = .01$, $\eta_p^2 = .09$. There was no interaction between Association and Auditory stimulus intensity, $p = .40$, between Block type, Association and Auditory stimulus intensity, $p = .42$, between Stimulus type, Association, and Auditory stimulus intensity, $p = .53$, or between Block type, Stimulus type, Association, and Auditory stimulus intensity, $p = .53$. There were no other significant effects. These findings confirmed that there are no main nor interaction effects of auditory stimulus intensity on the self-advantage in the absolute RTs.

A6: Comparing the extent of self-bias across blocks within tasks

In Chapter 2, participants completed blocks of trials blocked by stimulus modality type prior to completing the blocks of trials with all the stimulus modality types intermixed. Familiarity with both the matching task and the 16 stimulus-response mappings (2 x Association x 2 Match-type x 4 stimulus types) gained during the blocked trials enabled the participants to complete the blocks of intermixed trials which were otherwise too difficult. Notably, the increased familiarity of the stimuli and the S-R mappings gained in the blocked trials might be expected to increase the self-advantage in intermixed trials. However, additional analyses were conducted to test whether the magnitude of the SPE significantly decreased across individual blocks within each of the Blocked and Intermixed conditions of the Matching task. Given that Stimulus modality type was balanced across individual blocks, and the previous analyses indicated that Auditory stimulus intensity had no significant effect, the Stimulus modality type and Auditory stimulus intensity conditions were collapsed. Self-bias index scores in RT were then submitted to a one-way repeated-measures ANOVA (Block number: 1, 2, 3, 4) to compare the self-advantage across the individual blocks of trials blocked by stimulus modality type. There was one studentized residuals outlier (studentized residuals outside ∓ 3.0 in absolute value), and one condition was not normally distributed. With the outlier included (N = 48), the analysis revealed no significant main effect of Block, $F(3, 141) = 2.40$, $p = .07$, $\eta_p^2 = .05$, indicating that the magnitude of the self-advantage did not decrease significantly across blocks. With the outlier excluded from the analysis (N = 47), this finding was replicated, $F(3, 138) = 2.38$, $p = .07$, $\eta_p^2 = .05$.

Self-bias index scores in RT were then submitted to a one-way repeated-measures ANOVA (Block number: 1, 2, 3, 4, 5) to compare the self-advantage across the individual blocks of intermixed trials (N = 48). There was one studentized residuals outlier, and one condition was not normally distributed. With the outlier included (N = 48), the analysis revealed no significant main effect of Block, $F(1.21, 56.94) = 0.54$, $p = .70$, $\eta_p^2 = .01$ (Greenhouse-Geisser correction), indicating that the magnitude of the self-advantage did not decrease significantly across blocks. With the outlier excluded from the analysis (N = 47), all conditions were normally distributed, and this finding was replicated, $F(3.33, 153.10) = 1.40$, $p = .24$, $\eta_p^2 = .03$ (Greenhouse-Geisser correction).

Appendix B: Chapter 5—Study C5

B1: Absolute scores in matching and mismatching trials

Table B1
Mean movement initiation times (IT) and movement execution times (MT) in ms, and percentage of correctly-initiated movements (PC-1) and correctly-completed movement executions (PC-2), with standard deviations, as a function of Association (Self vs. Stranger), and Matching condition (Matching vs. Mismatching) in Study C5.1.

Performance indices	Association	Matching condition	
		Matching	Mismatching
IT	Self	554 (59)	673 (55)
	Stranger	694 (69)	681 (50)
MT	Self	542 (53)	647 (32)
	Stranger	646 (43)	651 (34)
PC-1	Self	93 (4)	80 (14)
	Stranger	70 (11)	82 (9)
PC-2	Self	91 (7)	70 (16)
	Stranger	55 (15)	69 (13)

Note: Adapted from: Desebrock & Spence, 2021, *Attention, Perception, and Psychophysics*, **83(6)**, 2656–2674, Springer Nature.

Table B2
Mean movement initiation times (IT) and movement execution times (MT) in ms, and percentage of correctly-initiated movements (PC-1) and correctly-completed movement executions (PC-2), with standard deviations, as a function of Association (Self vs. Stranger), and Matching condition (Matching vs. Mismatching) in Study C5.2.

Performance indices	Association	Matching condition	
		Matching	Mismatching
IT	Self	627 (40)	754 (46)
	Stranger	787 (69)	744 (44)
MT	Self	845 (47)	958 (52)
	Stranger	995 (55)	953 (56)
PC-1	Self	95 (3)	87 (7)
	Stranger	77 (12)	90 (5)
PC-2	Self	93 (3)	82 (8)
	Stranger	75 (13)	87 (6)

Note: Adapted from: Desebrock & Spence, 2021, *Attention, Perception, and Psychophysics*, **83(6)**, 2656–2674, Springer Nature.

Appendix C: Chapter 6—Study C6

C1: Survey instruments

C1.1: The Interpersonal Reactivity Index (IRI; Davis, 1980)

Representation of computer-based version of the IRI measuring empathy, with horizontal lines indicating separate screens.

The following statements inquire about your thoughts and feelings in a variety of situations.

For each item, indicate how well it describes you by choosing the appropriate number on the scale at the top of the page: 1, 2, 3, 4, or 5.

When you have decided on your answer, press the corresponding number.

READ EACH ITEM CAREFULLY BEFORE RESPONDING.

Answer as honestly as you can. Thank you.

Press any key to continue.

1 ------------- **2** ------------- **3** ------------- **4** ------------ **5**

DOES NOT DESCRIBE ME WELL	DESCRIBES ME WELL

[Item]

IRI—list of items

1. I daydream and fantasize, with some regularity, about things that might happen to me. (FS)
2. I often have tender, concerned feelings for people less fortunate than me. (EC)
3. I sometimes find it difficult to see things from the "other guy's" point of view. (PT) (-)
4. Sometimes I don't feel very sorry for other people when they are having problems. (EC) (-)
5. I really get involved with the feelings of the characters in a novel. (FS)
6. In emergency situations, I feel apprehensive and ill-at-ease. (PD)
7. I am usually objective when I watch a movie or play, and I don't often get completely caught up in it. (FS) (-)
8. I try to look at everybody's side of a disagreement before I make a decision. (PT)
9. When I see someone being taken advantage of, I feel kind of protective towards them. (EC)
10. I sometimes feel helpless when I am in the middle of a very emotional situation. (PD)
11. I sometimes try to understand my friends better by imagining how things look from their perspective. (PT)
12. Becoming extremely involved in a good book or movie is somewhat rare for me. (FS) (-)
13. When I see someone get hurt, I tend to remain calm. (PD) (-)
14. Other people's misfortunes do not usually disturb me a great deal. (EC) (-)
15. If I'm sure I'm right about something, I don't waste much time listening to other people's arguments. (PT) (-)
16. After seeing a play or movie, I have felt as though I were one of the characters. (FS)
17. Being in a tense emotional situation scares me. (PD)
18. When I see someone being treated unfairly, I sometimes don't feel very much pity for them. (EC) (-)
19. I am usually pretty effective in dealing with emergencies. (PD) (-)
20. I am often quite touched by things that I see happen. (EC)
21. I believe that there are two sides to every question and try to look at them both. (PT)
22. I would describe myself as a pretty soft-hearted person. (EC)
23. When I watch a good movie, I can very easily put myself in the place of a leading character. (FS)
24. I tend to lose control during emergencies. (PD)
25. When I'm upset at someone, I usually try to "put myself in his shoes" for a while. (PT)
26. When I am reading an interesting story or novel, I imagine how I would feel if the events in the story were happening to me. (FS)
27. When I see someone who badly needs help in an emergency, I go to pieces. (PD)
28. Before criticizing somebody, I try to imagine how I would feel if I were in their place. (PT)

NOTE: (-) denotes item to be scored in reverse fashion

PT = perspective-taking scale; FS = fantasy scale; EC = empathic concern scale; PD = personal distress scale

A = 0; B = 1; C = 2; D = 3; E = 4

Except for reversed-scored items, which are scored:
A = 4; B = 3; C = 2; D = 1; E = 0

C1.2: Personal Distance Scale (PDS; Sui & Humphreys, 2015)

Representation of computer-based version of the PDS, with horizontal lines indicating separate screens.

Please mark two points on the following lines to indicate where two people fall relative to one another.
Just put ‘|’ to represent each person.

The first mark refers to the first person and the second mark represents the second person.
(Go ahead with a click)

For example, Person 1 and Person 2.
(click on the black bar).

Stranger and Self

Self and Friend

Friend and Stranger

Friend and Self

Stranger and Friend

Self and Stranger

Scoring: The distance in mm between each pair of people indexes the perceived closeness (personal distance) between them.

C2: Descriptive statistics and the relationships between the bias and survey measures

C2.1 Absolute scores in mismatching trials

Table C2.1. Mean movement initiation times (IT) and movement times (MT) in ms, and percentage of correctly-initiated movements, and correctly-completed movements, with standard deviations, as a function of Association (self, friend, stranger) in the mismatch-trial data in Study C6.

Performance indices	Shape-based association	Mismatch condition
RT	Self	724 (67)
	Friend	723 (59)
	Stranger	711 (66)
MT	Self	603 (59)
	Friend	602 (53)
	Stranger	595 (56)
Movement initiation PC-1	Self	77 (12)
	Friend	76 (10)
	Stranger	82 (9)
Movement execution PC-2	Self	68 (15)
	Friend	68 (12)
	Stranger	74 (13)

Note: Movement initiation PC-1 = percentage of correctly-initiated movements, movement execution PC-2 = correctly-completed movement executions, following correct movement initiation, as a percentage of the total number of trials. (Adapted from: Desebrock et al., 2022, *Journal of Experimental Psychology: Human Perception and Performance*, APA.)

Table C2.2. Mean Personal Distance (PD) absolute scores in Study C6.

	PD (in mm)
Self-Friend	77.30 (54.29)
Self-Stranger	427.20 (170.59)
Friend-Stranger	379.31 (162.59)

Standard deviations in parentheses. (Adapted from: Desebrock et al., 2022, *Journal of Experimental Psychology: Human Perception and Performance*, APA.)

C2.2 Comparison of the magnitudes of the absolute Personal Distance (PD) scores

The PD data (Table A2) was not normally distributed for one condition. Non-parametric analyses using a related-samples Friedman's two-way analysis of variance by ranks on absolute personal distance scores (in mm) revealed a significant effect of personal distance type, χ^2 (2) = 49.91, $p < .001$. Sign tests revealed that personal distance for the Self-friend type (*Mdn* = 66, *SD* = 54.29) was smaller (*ps* < .001) than for Self-stranger (*Mdn* = 438, SD = 170.59) or the Friend-stranger types (*Mdn* = 342, *SD* = 162.59). The analysis revealed no significant difference between the self-stranger and friend-stranger personal-distance types, $p = 1.00$.

Table C2.3. Mean empathy scores (SD)—Interpersonal Reactivity Index (IRI) total scores—– and for the four IRI subscales: Empathic Concern; Fantasy; Personal Distress; Perspective Taking in Study C6.

	Empathy score
Total score	66.63 (15.35)
Empathic concern	19.31 (5.50)
Fantasy	17.60 (5.41)
Personal distress	11.20 (4.66)
Perspective-taking	18.51 (4.91)

Note: Adapted from: Desebrock et al., 2022, *Journal of Experimental Psychology: Human Perception and Performance,* APA.

C2.3 Relationships between empathy subscales, personal distance, and bias measures

Intra-scale correlations between the empathy (IRI) total score and subscale scores are presented in Table C2.4, and revealed significant moderate to high correlations between each subscale of the IRI and the total Empathy score. Therefore, only the total score was used in further regression analyses. Table C2.4 also presents Spearman’s rho correlation coefficients used to assess the relationship between empathy subscales, personal distance, and the separate and collapsed (composite) bias measures. As can be seen, there were significant correlations between Self-bias and Empathy, Self-bias and Friend-stranger bias, Friend-stranger bias and Self-PD, and no significant correlations between Self-bias and Self-PD or Friend-PD, Friend-stranger bias and Empathy, Friend-stranger bias and Friend-PD, Empathy with Self-PD or Friend-PD, or Self-PD and Friend-PD.

Table C2.4. Bivariate Spearman's Rank correlations between the Bias Scores, Composite Bias Scores, Personal Distance (PD), and Empathy in Study C6.

		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
1	Emp_TOT	--											
2	Emp_EC	.81**	--										
3	Emp_FS	.73**	.39*	--									
4	Emp_PD^2	.41**	.34*	.05	--								
5	Emp_PT	.77**	.66**	.50**	.09	--							
6	Self_PD	−.22	−.19	−.22	−.16	−.20	--						
7	Friend_PD	.04	.10	.12	.02	.04	.02	--					
8	Se-F_IT	−.04	−.24	.20	−.28	−.17	−.28	−.42**	--				
9	Se-St_IT	−.29	−.40**	.00	−.40**	−.33	.06	−.31	.67**	--			
10	F-St_IT	−.42**	−.27	−.31	−.29	−.27	.47**	.30	−.40*	.34*	--		
11	Se-F_MT	−.01	−.19	.18	−.27	−.15	−.20	−.39**	.97**	.69**	−.34*	--	
12	Se-St_MT	−.19	−.36*	.13	−.36*	−.28	.04	−.30	.74**	.97**	.23	.77**	--
13	F-St_MT	−.43**	−.37*	−.21	−.35*	−.27	.39*	.23	−.26	.45**	.96**	−.25	.35*
14	Se-F_MI_PC	−.21	−.24	−.01	−.20	−.26	−.32	−.29	.74**	.45**	−.31	.69**	.45**
15	Se-St_MI_PC	−.42**	−.31	−.21	−.25	−.31	.09	−.05	.20	.56**	.46**	.19	.47**
16	F-St_MI_PC	−.37*	−.26	−.33*	−.20	−.21	.37*	.16	−.36*	.24	.76**	−.35*	.12
17	Se-F_M_PC	−.25	−.34*	.04	−.26	−.28	−.32	−.29	.75**	.49**	−.29	.67**	.47**
18	Se-St_M_PC	−.48**	−.35*	−.26	−.33	−.31	.13	−.04	.17	.53**	.48**	.14	.42**
19	F-St_M_PC	−.32	−.17	−.32	−.21	−.18	.47**	.23	−.43**	.14	.78**	−.38*	.04
20	d′_Se-F	−.15	−.30	.11	−.15	−.33*	−.16	−.36*	.71**	.57**	−.20	.67**	.61**
21	d′_Se-St	−.34*	−.37*	−.10	−.36*	−.28	.34*	−.06	.27	.67**	.50**	.30	.61**
22	d′_F-St	−.19	−.11	−.22	−.14	.02	.43**	.27	−.44**	.19	.77**	−.38*	.09
23	Comp_Se-F	−.15	−.33	.11	−.18	−.31	−.18	−.37*	.79**	.60**	−.24	.77**	.64**
24	Comp_Se-St	−.39**	−.41**	−.10	−.37*	−.36*	.29	−.07	.30	.74**	.53**	.33*	.66**
25	Comp_F-St	−.26	−.14	−.26	−.21	−.04	.45**	.25	−.44**	.21	.82**	−.39*	.10

Note. Emp = Empathy, TOT = total, EC = Empathic concern, PD^2 = Personal distress, F = Fantasy, PT = Perspective-taking, Se = Self, F = Friend, St = Stranger, IT = movement initiation time, MT = movement execution time, MI = response initiation, PC = percent correct, M = movement execution, *d′* (D-prime; index of sensitivity), Comp = composite bias score. *Significant at the .05 alpha level (2-tailed). **Significant after FDR (Benjamini-Hochberg) correction at the .05 alpha level (2-tailed). (Adapted from: Desebrock et al., 2022, *Journal of Experimental Psychology: Human Perception and Performance*, APA.)

Table C2.4 […cont'd]. Bivariate Spearman's Rank correlations between the Bias Scores, Composite Bias Scores, Personal Distance (PD), and Empathy in Study C6.

		13	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**
13	F-St_MT	--												
14	Se-F_MI_PC	−.23	--											
15	Se-St_MI_PC	.49**	.40*	––										
16	F-St_MI_PC	.76**	−.39*	.58**	--									
17	Se-F_M_PC	−.19	.96**	.42**	−.36*	--								
18	Se-St_M_PC	.52**	.41**	.98**	.57**	.44**	--							
19	F-St_M_PC	.73**	−.40**	.53**	.95**	−.41**	.53**	--						
20	d′_Se-F	−.10	.73**	.22	−.33	.71**	.22	−.35*	--					
21	d′_Se-St	.53**	.35*	.68**	.44**	.33*	.69*	.43**	.50**	--				
22	d′_F-St	.73**	−.38*	.53**	.84**	−.34*	.53*	.80**	−.44**	.47**	--			
23	Comp_Se-F	−.14	.80**	.26	−.36*	.79**	.26	−.38*	.98**	.49**	−.43**	--		
24	Comp_Se-St	.57**	.38*	.76**	.48**	.38*	.77**	.46**	.48**	.98**	.49**	.48**	--	
25	Comp_F-St	.78**	−.38*	.55**	.89**	−.36*	.55**	.87**	−.43**	.49**	.99**	−.44**	.51**	--

Note Se = Self, F = Friend, St = Stranger, IT = movement initiation time, MT = movement execution time, MI = response initiation, PC = percent correct, M = movement execution, *d′* (D-prime; index of sensitivity), Comp = composite bias score. *significant at the .05 alpha level (2-tailed). **Significant after FDR (Benjamini-Hochberg) correction at the .05 alpha level (2-tailed). (Adapted from: Desebrock et al., 2022, *Journal of Experimental Psychology: Human Perception and Performance*, APA.)

Table C2.5. The raw and standardized regression coefficients of the predictors together with their correlations with composite Self-stranger bias, their squared semi-partial correlations, and their structure coefficients for the stepwise multiple regression entered in two steps, in Study C6.

Model		**b**	**SE-b**	**Beta**	**Pearson r**	**Sr^2**	**Structure coefficient**
1	Constant	.65	.13				
	Empathy*	−.01	.002	−.51	−.51	.26	−.81
2	Constant	.60	.12				
	Empathy*	−.01	.002	−.43	−.51	.18	−.81
	Friend-bias	.41	.16	.37	.46	.13	.73

Note. The dependent variable was composite Self-stranger bias. Model 2: $R^2 = .39$, Adjusted $R^2 = .35$. Sr^2 is the squared semi-partial correlation. *$p < .05$ (Holm-Bonferroni correction). R = .62. Structure coefficient = [Pearson r / R]. (Adapted from: Desebrock et al., 2022, *Journal of Experimental Psychology: Human Perception and Performance*, APA.)

Table C2.6. The raw and standardized regression coefficients of the predictors together with their correlations with composite Friend-stranger bias, their squared semi-partial correlations, and their structure coefficients for the stepwise multiple regression entered in two steps, in Study C6.

Model		**b**	**SE-b**	**Beta**	**Pearson r**	**Sr^2**	**Structure coefficient**
1	Constant	−.16	.04				
	Self-PD*	.49	.16	.46	.46	.22	.77
2	Constant	−.21	.05				
	Self-PD*	.41	.15	.39	.46	.15	.77
	Self-bias*	.35	.13	.39	.46	.14	.76

Note. The dependent variable was composite Friend-stranger bias. Model 2: $R^2 = .36$, Adjusted $R^2 = .32$. Sr^2 is the squared semi-partial correlation. *$p < .05$ (Holm-Bonferroni correction). R = .60. Structure coefficient = [Pearson r / R]. (Adapted from: Desebrock et al., 2022, *Journal of Experimental Psychology: Human Perception and Performance*, APA.)

Appendix D: Outline of a planned study

Neurophysiological correlates of self-bias in arm-movements

D1: Chapter overview

Chapter 6 presented a behavioural study that was aimed at increasing understanding of the processes supporting self-bias in motor responses. The relationships between self-bias and friend-bias in arm-movements and subjective perceptions of empathy and perceived closeness were examined to better understand the self–other representations underlying these responses. Appendix D presents the outline for the second phase of this study[28] which used an electrophysiological approach to further investigate the processes underlying self-bias in these motor responses.

This study set out to investigate the relationship between self- and friend-biases in ballistic arm-movement responses and early-onset processes (related to the perceptual processes discussed in Chapter 3) and later-onset processes (related to decisional processes discussed in Chapter 5). As discussed, Chapter 2 took a holistic approach in examining motor responses by using total response time measures, while Chapters 3, 5, and 6 divided the motor responses into their initiation and execution stages. Gross behavioural outcome measures, however, reflect the combined influence of early and late stages of information processing. It is therefore not possible to examine the continuous dynamic processes that occur between stimulus onset and response completion using such measures. As noted in Chapter 1, the technique of ERP has high temporal resolution and can reveal the order and

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[28] Data loss in the EEG component of the study reduced the sample size. Therefore, the EEG data collected was not analysed in Chapter 6 in order to preserve the validity of the analyses of the subjective measures. The behavioural data was presented in Chapter 6, and Appendix D presents the outline for the ERP study.

timing of processing stages, and therefore shed further light on the processing stages influenced by self-bias. This study therefore aimed to measure ERPs to examine for the first time the time-course of self-bias in ballistic arm-movement responses, and whether the self-advantage is underpinned by a multiple-stage modulation. Further, this study also aimed to investigate whether the self-advantage in movement execution is coordinated through early-onset or late-onset processes in movement initiation by examining the relationship between early- and late-onset components and the behavioural measures. This study was not, however, completed.

D2: Introduction

As reviewed in Chapter 1, the research thread that investigates the effects of self-relevance in experimental tasks also examines the neural activity underlying the performance advantage for self. Alongside behavioural and fMRI studies (e.g., Sui, Rotshtein, et al., 2013), which have dominated in the literature (Knyazev, 2013), the effects of self-relevance have also been examined in studies using an electrophysiological approach. In particular, a number of these studies have measured ERPs to determine the time-course of effects.

An electroencephalogram (EEG) is a non-invasive means of recording electrical activity in the brain with a temporal resolution in the millisecond range. While the participant engages in a task, their underlying neuronal activity is recorded from the scalp using a cap fitted with multiple electrodes. The ERP technique measures small changes in the EEG by time-locking measures of electrical potentials to a stimulus or event. Segments or epochs of the electrical waves are extracted to calculate a grand average of the neural response evoked by each stimulus type. This neural response is characterized by different components (based on the time from stimulus onset) whose nomenclature reflects their deflection (positive or negative) and expected latency. For example, the N100 (or N1) has an expected latency of 100 ms, and is the first large negative deflection.

Earlier stages of information processing related to sensory processes are reflected in components arising less than 200 ms from stimulus onset. The later stages of information processing related to stimulus evaluation and decision-making processes start to arise at around 250 ms from stimulus onset. The high temporal resolution of ERP can therefore reveal the order and timing of processing stages from stimulus onset, and therefore shed further light on the processing stages influenced by self-bias.

D2.1. Neurophysiological correlates of self-referential processing

ERP studies examining the effects of self-relevance typically document that self-referential stimuli modulate one or both of the P3 and N2 ERP components (Fan et al., 2011, 2013; Gray et al., 2004; Knyazev, 2013; Muñoz et al., 2020; Niu et al., 2020; Sui et al., 2009; Tacikowski & Nowicka, 2010; Truong et al., 2013; Turk, van Bussel, Waiter, et al., 2011; Zhan et al., 2017; Zhou et al., 2017; Żochowska et al., 2021). The P3 is a large positivity which peaks between 300 to 500 ms after stimulus onset and is generally thought to index attentional processes arising from temporal-parietal activity and higher-order cognitive processes such as decision-making, working memory, and response preparation (the P3b component) and also stimulus-driven frontal attentional processes (the P3a component) (Doradzińska et al., 2020; Gray et al., 2004; M. Liu et al., 2016; Polich, 2007; Verleger et al., 2005, 2015; Woodman, 2010).[29] The P3 has also been evidenced as a key psychophysiological marker of disorders of the self, such as schizophrenia, and in neurodevelopmental conditions, such as autism (Cui et al., 2017; Mucci et al., 2007; van der Stelt et al., 2004; Zhao et al., 2016).

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[29] Note, the P3 component is sometimes subsumed under a broader late positive complex (LPC) which is composed of several subcomponents such as P3a, P3b, Novelty P3 (nP3), and a positive Slow Wave (+SW) (e.g., Barry et al., 2020). The P3 component has also been linked to autonomic components of the orienting response due to its modulation in response to own-name stimuli in both conscious and permanently vegetative state (Fischer et al., 2010; Morlet & Fischer, 2014).

In one study using self-name and self-face stimuli and measuring ERPs, the authors documented larger P3 amplitudes for both types of stimuli as compared with those in response to other-person names and faces (Tacikowski & Nowicka, 2010). Similarly, one's own name and online nickname modulated the P3 amplitude and latency (Niu et al., 2020). The N2 component (200–350 post-stimulus) is associated with perceptual salience, orienting of attention, and object recognition (Folstein & Van Petten, 2008; Woodman, 2010), but also reflects activity in higher-level monitoring systems that coordinate automatic and controlled processes (Y. Zheng et al., 2022). For example, self-face and self-owned objects have been shown to modulate both the P3 and N2 components (Muñoz et al., 2020; Sui et al., 2009).

Self-relevance has also been documented to modulate the P1 and N1 components (Zhan et al., 2017; Zhou et al., 2017). The P1 (at 90–100 ms post-stimulus) is thought to reflect early sensory and perceptual processing stages (Pratt, 2011; Woodman, 2010) The N1 (at 170–200 ms) is thought to be a sensory response, sensitive to perceptual salience, and the perceived significance of the stimuli. Both the P1 and N1 can also be modulated by attention (Luck & Kappenman, 2012; Rossion & Jacques, 2011; Vogel & Luck, 2000; Woodman, 2010). In one study (Turk, van Bussel, Brebner, et al., 2011), ERPs were recorded while participants were presented with onscreen images of common household items followed by a cue indicating whether the item belonged to the self or to another person. The authors documented that self-relevant cues not only modulated the P3 component, but also reduced the lateral occipital P1 component indexing attention at the visual perceptual level.

D2.2. Neurophysiological correlates of self-bias

Only a handful of studies to date have examined ERPs associated with self-bias in the matching task (Sui, Sun, et al., 2015; Woźniak et al., 2018; Y. Zheng et al., 2022). These studies appear to converge on the finding that self-bias in the matching task is associated with a reduced N2, and a larger P3 and LPC.

Using unfamiliar face-stimuli and labels presented sequentially (1500 ms apart), one study (Woźniak et al., 2018) documented that responses to the self-relevant stimuli were associated with a smaller anterior N2, a larger central-parietal P3, and a prolonged increase in amplitude of a late frontal positivity (450–750 ms), suggesting a multiple-stage, but not necessarily early-stage, influence. Another very recently published study is consistent with these findings (Y. Zheng et al., 2022). Using a matching task with the standard geometric shapes and the labels ‘self’, ‘mother’, ‘stranger’, and ‘Chinese’, the authors reported that responses to the self-associated stimuli were associated with a reduced N2 and a larger P3 and LPC (500–800 ms). The study concluded that self-bias modulated later-onset but not early-onset components (Y. Zheng et al., 2022).

In sum, the evidence from studies measuring ERPs suggests that self-relevance can modulate both early perceptual processes and higher-order stages of cognitive processing in some paradigms, but whether such an influence generalises to the matching task is by no means certain. Furthermore, no studies to date have investigated how self-bias unfolds in the processes underlying arm-movement responses.

D2.3. Perceptual self-bias or decisional self-bias in action

As outlined in the previous chapters, some behavioral studies support the view that self-bias reflects a modulation at the perceptual level (Golubickis et al., 2017; C.-P. Hu et al., 2020; Svensson et al., 2021), and in multiple levels and stages of information processing (Desebrock & Spence, 2021; Scheller & Sui, 2022a; Sui & Humphreys, 2015a). Consistent with the ERP studies, however, other behavioural research has suggested that self-bias arises in later-stage decision-making or memory processes (Janczyk et al., 2019; Reuther & Chakravarthi, 2017; Siebold et al., 2015; Stein et al., 2016). Chapter 3 (Discussion, Section

3.6) set out two potential accounts of self-bias in movement execution. These were, broadly, that perceptual-effects of self-bias may drive the movement advantage for self-related responses; or, alternatively, that self-bias in decisional processes may drive the movement self-advantage.

According to one account, it was postulated that self-bias may exert an influence on movement execution by means of bottom-up (rapid chase) processing as conceptualised in perception-to-action models in response priming paradigms (F. Schmidt et al., 2011; T. Schmidt et al., 2006; T. Schmidt & Seydell, 2008). Self-relevance is thought to 'prime' attentional responses in the pSTS to self-stimuli via activation of the vmPFC (Humphreys & Sui, 2016), and effects of self-associated stimuli have been compared to those of highly perceptually-salient stimuli (Humphreys & Sui, 2015; Scheller & Sui, 2022a; Sui et al., 2012; Sui, Liu, et al., 2013). Self-bias has also been recently suggested to emerge through a salience-driven mechanism (Scheller & Sui, 2022a). Response priming research indicates that visual attention can intensify the first waves of bottom-up visuomotor processing (T. Schmidt & Seydell, 2008), and higher-intensity stimuli have been linked to increased feed-forward activity (T. Schmidt et al., 2006), and response force (Ulrich et al., 1998).

Chapter 3 also postulated an alternative account that self-bias in decisional processes may drive the movement self-advantage in the form of an explicit decisional response bias, or through approach motivation and automatic affective S-R links. In Chapter 3, however, it was argued that the findings were not consistent with perceptual effects of self-bias driving the movement self-advantage. Furthermore, Study C5.1 indicated that self-bias in movement execution does not reflect *explicit* online adjustments to the movement to favour the self-related response. Studies C5.1 and C5.2 further suggested that the movement self-advantage does not depend on approach motivation processes.

Another possibility discussed in Chapter 5 is that the movement self-advantage may depend on the use of visual or non-visual imagery in planning and execution. Previous research has suggested that self-associations established in the matching task can modulate working memory (Yin et al., 2019). These authors suggested that self-representations may also be prioritized in endogenous attentional processes (Yin et al., 2019). They further suggest that: “prioritization of information in [working memory]…allows us to temporarily keep information in mind for additional cognitive processing and the guidance of actions” (Yin et al., 2019; p. 3). Indeed, visual imagery maintained by working memory can guide action (Ede et al., 2019). A visual image of the target and its location may be more efficiently formed, accessed, or held in mind in self-associated trials to plan and guide the movement while attention is diverted to onscreen stimuli. Such a mechanism could fit with the findings in Study C5.2 and Study C3. However, this mechanism could not explain the self-advantage in movement in Study C5.1, where no visual feedback was available pertaining to the target or participant’s hands.

Another possibility, discussed in Chapter 5, however, is that visual imagery generated in the absence of relevant visual input could play a role in guiding movement execution. One study has documented that self-generated movements that typically have reliable visual consequences can generate visual imagery in the absence of relevant exogenous visual input (Dieter et al., 2014). Although movement planning in the motor responses of Study C5.1 must rely (predominantly) on proprioceptive, kinaesthetic, and tactile information, such imagery may arise in the case that visual feedback pertaining to the participant’s hand and the target are occluded throughout the matching task. *Non-visual imagery* may also support the self-advantage in movement. The question of how such imagery and movement execution processes are related and could interact with self-bias lies outside of the scope and aims of this thesis. However, measuring ERPs underpinning the ballistic arm-movement responses of

Chapter 6 would provide valuable insight into the time-course of self-bias, the stages of processing that are modulated, and the relationship between the movement self-advantage and perceptual and decisional self-bias.

As discussed in the previous chapters (see also *Chapter 7: Thesis discussion*), the arm-movements constitute a two-stage response (the initiation of the movement and its execution). Evidence indicates that while the processes underlying movement initiation and execution are closely coordinated (and as such they interact), they are essentially independent (Barton et al., 2020; Doucet & Stelmack, 1997; Gratton et al., 1988; Praamstra et al., 2014; Reynaud et al., 2020). Reflecting the close coordination of movement initiation and execution processes, correlations between the extent of self-bias in initiation and execution were documented in Chapters 5 and 6. Consistent with their independence (Reynaud et al., 2020), Chapters 3, 5, and 6, documented that the *extent* of the self-bias was significantly altered across the two response stages, and that there is not a fixed relationship between the biases in the two stages (see also Chapter 8). Examining ERPs, would aid in elucidating whether self-bias in movement is coordinated through early- or later-stage processes in movement initiation processes.

Another key question arising from the research discussed in the previous chapters is whether self-bias in keypress responses and arm-movement responses operate in the same way. As discussed in Chapters 4–6, a study using keypress responses in the matching task documented in a preliminary finding that the motor-stage of responses was not influenced by self-bias (Janczyk et al., 2019). Chapters 4 and 5 of the present thesis collectively suggested that self-bias may arise in the motor-stage of keypress responses on two counts: the evidence of the former study was not clear; and, Study C5.1 demonstrated that self-bias arises in ballistic movement not guided by visual feedback, which characterizes keypress responses. As discussed in Chapters 6 and 8, however, arm-movement and keypress motor-response types have different real-world functions and associated uses. Keypresses as a behavioural outcome are a step removed from meaningful everyday actions (Baumeister et al., 2007); therefore, self-bias may manifest differently in these motor responses.

D2.4. The present study

The aim of the present study was therefore twofold: (1) to examine for the first time the time-course of self-bias in the initiation of ballistic arm-movement responses to determine whether the self-advantage unfolds in a manner comparable to self-bias in keypress responses (Woźniak et al., 2018; Y. Zheng et al., 2022); and (2) to examine the relationship between early- and late-onset components (namely, the N1, N2, P3 and LPC) and self-bias in the initiation and execution of arm-movement responses, and speak to whether self-bias modulates multiple stages of information processing in movement initiation.

The overarching aim of this thesis was to investigate the contextual constraints on the emergence and extent of the self-advantage in motor responses. This study planned to further understanding of the processes underlying self-bias in arm-movement responses, and determine whether the effects of self-relevance in the matching task can modulate multiple stages of information processing.

D3: Methods

D3.1. Participants

Forty-three right-handed participants (14 male, ages 18-37 years, mean age 21.51 ± 5.03) with normal or corrected-to-normal vision took part in the study. The participants were recruited via the national callforparticipants.com website, the Bath University Research Participation Scheme, and Bath University electronic noticeboard. They received monetary reimbursement (£10) or course credits for their time and effort. All participants completed a written consent form approved by the Oxford Research Ethics Committee

(R55087/RE001/RE002) and the University of Bath Psychology Research Ethics Committee (17-230). (Please see Chapter 6, Section *6.3.1* for more details.)

D3.2. Apparatus and stimuli

For the task set-up, apparatus, and stimuli for the behavioural task (the matching procedure), please see Chapter 6, Section *6.3.2*.

D3.3. Procedure

For the procedure pertaining to the matching task, please see Chapter 6, Section *6.3.4*. Electroencephalography was recorded as the participants carried out the matching task making ballistic arm-movements responses to the stimuli. The online EEG was marked at stimulus onset and movement onset to allow for the offline assessment of early perceptual and late motor processes, respectively.

D3.4. Online EEG recording

After electrode cap placement, the participants were seated in front of the response box, at a distance of 70cm from the PC monitor, in a sound and electrically shielded room. Electroencephalographic (EEG) activity was sampled at 1000 Hz using the Electrical Geodesics Incorporated (EGI) 64-electrode hydrocel sensor net, and connected to the Geodesic EEG acquisition system with NA400 amplifier, using the average of two mastoids as reference. An electrooculogram (EOG) was recorded using electrodes above the left and right eye. Electrode impedances for all electrodes were maintained below 5 kΩ/kV.

D3.5. Offline data preprocessing

The ERP preprocessing (and analysis) was performed using the EEGLAB toolbox (Version 14.1.2b; Delorme and Makeig, 2004) for Matlab (R2017b), and BrainVision Analyzer (BVA; Version 2.2.2, Brain Products GmbH, 2021). Although the EEG was recorded in an electrically shielded room there was unexpected large electrical interference and low frequency drifts in the recorded EEG. The artifacts were intermittent and affected more participants in the late phase of the data collection process, thus, unforeseeable, and very difficult to detect (in this case not detected) while recording online. Therefore, the EEG was filtered offline between 0.1–45 Hz. Low frequency electrical artifacts and drifts in the EEG (i.e., within the typical brain activity range) could not be corrected by filtering. Automatic and manual artefact rejection was carried out using BVA, and the data were segmented into epochs. A large amount of data was lost due to the unexpected electrical interference; therefore, the original planned analysis could not be finalized. Alternative procedures to treat the data are currently being explored (ongoing).

D3.6. Planned data analysis

The electrode sites were selected as follows: frontal (F3, Fz, F4), frontal-central (FC3, FCz, FC4), central (C3, Cz, C4), central-parietal (CP3, CPz, CP4), parietal (P3, Pz, P4), and occipital (O1, Oz, O2, PO3, PO4). Based on previous studies (Woźniak et al., 2018; Y. Zheng et al., 2022; Zhou et al., 2017), components were specified as approximately: N1 (80–100), N2 (280–340 ms), P3 (350–420 ms), and LPC (450–800 ms). A 4 (Association: self, friend, stranger) x 5 (Electrode site: frontal, frontal-central, central, central-parietal, and parietal) repeated-measures analysis of variance (ANOVA) will be conducted on component amplitudes (N1, N2, P3, LPC). Analysis of epochs time-locked to movement onset was also planned, but due to motor movement noise in the data cannot be carried out (the literature on motor-related components is therefore not reviewed in this outline). Correlational analyses will be conducted between amplitudes of the ERP components and the behavioural measures of movement initiation (RT, accuracy, and *d'*) and of movement execution (MT, percentage of correctly-completed movements). Time-frequency analyses may also be attempted, focusing on the Alpha and Beta range associated with perception, attention, and motor action.