

**The influence of empathy and perceived closeness  
on self- and friend-biases in arm-movements**

**Clea Desebrock<sup>1,2</sup>, Ayla Barutcu<sup>1</sup>, & Charles Spence<sup>1</sup>**

**<sup>1</sup>Department of Experimental Psychology, University of Oxford**

**<sup>2</sup>Department of Psychology, University of Bath**

Corresponding author: Clea Desebrock ([Clea.Desebrock@psy.ox.ac.uk](mailto:Clea.Desebrock@psy.ox.ac.uk)), Crossmodal  
Research Laboratory, Department of Experimental Psychology, University of Oxford, OX2  
6GG

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[clea.desebrock@psy.ox.ac.uk] upon request.

## Abstract

Manual motor responses to newly self- as compared with other-associated stimuli in a matching task are typically enhanced. Little, however, is known about the representations of self and other underlying these responses. An emerging theoretical view is that self-bias in these responses is not influenced by consciously-accessible constructs of the self, such as explicit self-esteem, and instead reflects implicit (automatic and preconscious) self-related processing. An alternative view is that self-bias *is* influenced by explicit self-representations and self-reflective processing. To decide between these two accounts, we introduced the friend variable to a movement adaptation of the matching task, and 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). Associations were revealed between the subjective measures and the biases in the manual 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 suggest 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. We discuss implications of our findings for understanding the operation of different aspects of the self in cognition and action, and across divergent populations, for example, in Autism Spectrum Disorder.

**[Key words: self-prioritization, self-relevance, arm-movements, empathy, personal distance]**

**Public significance statement:**

Responses to newly self- as compared with other-associated stimuli in a matching task are typically enhanced. An emerging view suggests that self-biases are not influenced by consciously-accessible constructs of the self, such as self-esteem. In a novel demonstration we show that this self-bias in rapid arm-movement responses is influenced by people's self-reported responsiveness to others (empathy). People's conscious perceptions of the closeness between the self and others also influenced friend-stranger bias. Contrary to previous thought, this study thus indicates a link between subjective perceptions of self-other relations and implicit self- and friend-stranger biases in manual responses. We discuss implications of our findings for understanding operation of the self in action through implicit and explicit representations of the interrelations between others and the self.

## **Key findings**

- Self-bias but not Friend-stranger bias was documented in ballistic arm-movements in a matching task
- Empathy was a predictor of Self-stranger bias
- Personal distance was a predictor of Friend-stranger bias
- Self- and Friend-biases may be influenced by higher-level representations related to subjective empathy and perceived closeness
- Biases in the matching task may reflect representations of the interrelations between others and the self

Self-relevance has been demonstrated to confer a performance advantage across a diverse range of experimental tasks (e.g., Cunningham & Turk, 2017; Dalmaso et al., 2019; Desebrock et al., in press; Golubickis et al., 2021; Macrae et al., 2018; Moray et al., 1959; Rogers et al., 1977; Schäfer et al., 2016; Sui et al., 2013; Woźniak et al., 2018). The matching procedure first introduced by Sui and colleagues (Sui et al., 2012) now provides the standard method for those wanting to investigate the effects of self-relevance without the confounds of stimulus familiarity and overlearning. In the prototypical task, participants are instructed to associate neutral geometric shapes (e.g., a circle, a square, and a hexagon; replacing highly-familiar stimuli such as the participant's own name, face, or attributes) with person-identity labels (e.g., self, stranger, friend). In the main task, participants indicate whether the sequentially-presented shape-label pairs 'match' the designated associations or not using keypresses. These manual motor responses are consistently found to be faster and more accurately-selected in the self-associated shape-label matching condition. In other words, association with the self appears to enhance task performance. This is known as the Self-Prioritization Effect (SPE), or simply, self-bias.

Imaging studies have revealed that distinct neural circuitry underpins the self-advantage (Sui et al., 2013; Yankouskaya et al., 2017), which is not simply driven, for example, by reward value (Stolte et al., 2021; Sui & Humphreys, 2015), or emotional valence (Schäfer, Wentura, et al., 2020; Stolte et al., 2017). A robust self-advantage has also been documented in the execution as well as initiation of arm-movement responses<sup>1</sup> (Desebrock & Spence, 2021; Desebrock et al., 2018). Little is known, however, about the self and other representations underlying self-bias in the matching task motor responses.

## **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, 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, 2019). 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, 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, 2019). Indeed, the latter researchers found 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 people with Autism Spectrum Disorder (ASD) show a reduced or absent SRE (Dawson

& McKissick, 1984; Henderson et al., 2009; Lombardo et al., 2007; Toichi et al., 2002), 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 & Frings, 2019; Schäfer, Wesslein, et al., 2020).

### **Self-bias and self–other relations**

Explicit representations of *self–other relations* also exert a potent influence on our behaviour, however. 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 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), and 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.

### **Self-bias and personal distance**

A handful of studies have documented an association between self-bias and ‘personal distance’ (Sui & Humphreys, 2015—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, 2017; 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, 2015). 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, 2015), while in another study only the friend–stranger personal distance and friend-stranger bias in sensitivity ( $D'$ ) were associated (and in an elderly but not a young sample of participants; Sui & Humphreys, 2017). 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 needed to determine whether there is a relationship between explicit representations of self–other relations and self-bias.

### **Arm-movements and representations of self–other relations**



As noted earlier, the self-advantage in the matching task has been documented using both keypress and arm-movement motor responses, although the biases are not identical across the two types of response. For example, self-bias has been demonstrated in the execution stage of arm-movement responses (Desebrock & Spence, 2021; Desebrock et al., 2018) but not of keypress responses (Janczyk et al., 2019). Effect sizes of the self-advantage are also typically larger in the initiation of arm-movements ( $\eta^2 = .67$ ; Desebrock & Spence, 2021, Experiment 1) than in keypress responses (e.g.,  $\eta^2 = .25$ ; Sui et al., 2012), and the initiation and execution stages of responses exhibit differential magnitudes of self-bias. Self–other biases may manifest more strongly in arm-movement responses than 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 study, for the first time, we further examine the relationship between personal distance and self-bias in the matching task using ballistic arm-movement responses.

### **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.

### **Friend-stranger bias**

Another measure yielded by both the personal distance scale (PDS; Sui & Humphreys, 2015) 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 has been observed in both RT and accuracy in certain studies (e.g. Sui et al.,

2013), or in 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, 2015). Adaptations of the matching task using arm-movement responses have also used only self and stranger associations to date (Desebrock & Spence, 2021; Desebrock et al., 2018). 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.

## Summary and aims

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, 2019; 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. We therefore aimed to discriminate between these two proposals. We introduced the Friend variable to a movement adaptation of the matching task in order to measure both Self- and Friend-stranger biases in IT, MT, percentage of correct scores, and  $d'$ . We then examined whether there was a 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, 2015) and empathy  
(Davis, 1983).

To the best of our knowledge, no previous studies have examined the relationship  
between empathy and self-biases in the matching task motor responses, or between the biases  
in arm-movement responses and personal distance. Examining the relationship between self–  
other biases and underlying self–other representations will likely increase our understanding  
of the operation of the self in our cognition and action. We 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.

## Methods

### Participants

The effect size for the self-advantage in IT (RT) and MT in Desebrock and Spence's (2021)  
study, which used the same task set-up and movement response, was  $\eta^2 = .67$  and  $\eta^2 = .46$ ,  
respectively (paired-samples t-test). (NB in conducting our power analyses, we converted all  
effect sizes to a common metric,  $\eta^2$ , following Correll et al., 2020.) However, in contrast to  
Desebrock and Spence's previous study, the present study used 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 rather than arm-movement responses were  
used). Therefore, in order to allow for the detection of an effect 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, 2015; Yankouskaya et al., 2020; cf. Enock et al., 2018; Moseley et al., 2021; Sui & Humphreys, 2017), 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  $21.51 \pm 5.03$ ) 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).

### **Stimuli and apparatus**

The experiment 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). 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 1A).

Insert Figure 1 about here

The stimuli consisted of three geometric shapes from the following set (circle, square, triangle, hexagon, pentagon, or octagon, each subtending  $3.2 \times 3.2$  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 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.

### **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* (Sui & Humphreys, 2015), 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 others' 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).

The 'Personal Distance' scale developed by Sui and colleagues has been used in numerous studies of self-prioritization (e.g., Enock et al., 2018; Sui & Humphreys, 2015, 2017). 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.

## **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. (Participants were then fitted with electrode caps in order to record their electrophysiological data, using EEG, during the behavioural task—data not reported here.)<sup>2</sup> Next, the participants carried out Desebrock and Spence's (2021; Experiment 1) movement-time adaptation of Sui et al.'s (2012) computer-based matching task. The participants first read onscreen text instructing them to memorize three shape and identity pairings. They associated one of their allocated 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 Desebrock and 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 1B.

## **Data analysis**



There were four main motor output measures. We assessed 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) for correctly-initiated and completed arm-movement responses. We also assessed 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 previous research (Desebrock et al., 2018; Desebrock & Spence, 2021). (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 percentage correct data). 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 (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. In matching trials, movement execution errors following correct movement initiation that involved hitting the incorrect target button

(i.e. relating to response outcome type 2) constituted  $\approx 1\%$  of the total errors, thus suggesting a floor effect and were not analysed further. As such, in behavioural terms, errors in valid movement responses constituted missing the target key (i.e. response outcome type 4), not pressing the wrong target button. 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 1a). 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 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 correct MTs could not be executed erroneously too fast.

Normalised differential scores—self-bias index scores (e.g., Constable et al., 2021; Desebrock & Spence, 2021; Schäfer et al., 2016; Sui & Humphreys, 2017)—were analysed to examine the self-advantage across the initiation and execution response stages, and to assess the relationship between the behavioural 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, 2017; 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 (see Desebrock & Spence, 2021; Schäfer 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 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, 2017). See Table 1 for the respective calculations. Positive values indicate an advantage for self (or friend, for Friend-stranger bias).

Insert Table 1 here

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 Humphreys (2017). The self-friend personal distance (hereafter referred to as Self-PD) was given by the formula:  $\text{Self-PD} = \text{self-friend distance} / \text{self-stranger distance}$ , 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- and Friend-stranger bias measures and the subjective measures of empathy and personal distance (Table 2; for the full correlation matrix of all self-report and bias metrics, see Appendix, Table A4. Note: as some bias metrics and subjective measures were not normally distributed, Spearman's rank correlations are reported in Table A4). In general, moderate to high correlations for each bias type were found across metrics (see Table A4 in Appendix). Therefore, mean composite scores of Self-bias and Friend-stranger bias measures (see *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 ( $\eta_p^2$ ) for ANOVAs (Lakens, 2013). To adjust for multiple comparisons, Holm-Bonferroni corrections at an  $\alpha$  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 ( $\epsilon$ ) was  $< .75$ ) or Huynh-Feldt corrections were applied (if  $\epsilon$  was  $> .75$ ) (J. P. Verma, 2015).

#### **Transparency and openness**

We report how we determined our sample size, all data exclusions, all manipulations, and all measures in this study. The data are available on request. Requests can be emailed to the lead author at: [clea.desebrock@psy.ox.ac.uk]. Data were analysed using IBM SPSS Statistics Version 27. This study's design and its analysis were not pre-registered.

### **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  $21.23 \pm 4.67$ ) 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 (percentage correct; PC-1), and movement execution correct-completion (movement execution PC-2), see Figure 2. Mismatch-trial data are presented in Table A1 in the Appendix.

Insert Figure 2 here

### **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 condition was affected, we chose 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 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, we calculated Bayes factors 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

522 difference between IT in friend-associated as compared with stranger-associated responses  
523 was  $BF_{01} = 4.93$ , indicating that there was ‘substantial’ or ‘positive’ evidence for the null  
524 model (Jeffreys, 1998; Raftery, 1995).

525         One studentized residuals outlier ( $>3$  in absolute value) was detected in the movement  
526 initiation accuracy (PC-1) data. A related-samples Friedman’s two-way analysis of variance  
527 by ranks revealed a main effect of Association,  $\chi^2(2) = 41.03, p < .001$ , with greater accuracy  
528 in self-related responses ( $Mdn = 94, SD = 5.55$ ) as compared with friend-related ( $Mdn = 75,$   
529  $SD = 12.65$ ) and stranger-related ( $Mdn = 74, SD = 13.96$ ) responses (for both  $p < .001$ ). There  
530 was no difference between the friend and stranger response types,  $p = .40$  (see Figure 2e). To  
531 provide further support for the non-significant difference between the friend and stranger  
532 responses types, we calculated Bayes factors using the Bayesian-t-tests/Wilcoxon signed-rank  
533 module of JASP (Version 0.12.2; JASP Team, 2020) and the JASP default prior. The Bayes  
534 factor in favour of the null model for the friend response type accuracy (PC-1) compared with  
535 the stranger response type accuracy (PC-2) was  $BF_{01} = 5.31$ , indicating that there was  
536 ‘substantial’ or ‘positive’ evidence for the null model (Jeffreys, 1998; Raftery, 1995).

537         Sensitivity index scores (D-prime;  $d'$ ) for movement initiation were analysed using a  
538 one-way repeated-measures ANOVA and revealed a main effect of Association,  $F(2, 68) =$   
539  $30.79, p < .001, \eta_p^2 = .48$ .  $d'$  scores for self-related responses were higher (for both  $p < .001$ )  
540 than friend-related and stranger-related responses, and there was no significant difference  
541 between friend and stranger response types,  $p = .04$  (see Figure 2d). To provide further  
542 support for the non-significant difference between the friend and stranger responses types, we  
543 calculated Bayes factors using the Bayesian-t-tests module of JASP (Version 0.12.2; JASP  
544 Team, 2020) and the JASP default prior. The Bayes factor in favour of the null model for the  
545 friend response type  $d'$  scores compared with the stranger response type  $d'$  scores was  $BF_{01} =$

0.75, indicating that there was ‘anecdotal’ or ‘weak’ evidence for the null model (Jeffreys, 1998; Raftery, 1995).

### **Movement execution**

Movement times (MTs) were assessed using a one-way repeated-measures ANOVA which revealed a main effect of Association,  $F(2, 68) = 46.97, p < .001, \eta^2 = .58$ . 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 2b). To provide further support for the non-significant difference between the friend and stranger responses types, we calculated Bayes factors 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  $BF_{01} = 5.44$ , indicating that there was ‘substantial’ or ‘positive’ evidence for the null model (Jeffreys, 1998; Raftery, 1995).

A related-samples Friedman’s two-way analysis of variance by ranks was carried out on the Movement execution correct-completion (PC-2) data. The analysis revealed a main effect of Association,  $\chi^2(2) = 44.65, p < .001$ , 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 2f). To provide further support for the non-significant difference between the friend and stranger responses types, we calculated Bayes factors 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  $BF_{01} = 5.74$ ,



indicating that there was ‘substantial’ or ‘positive’ evidence for the null model (Jeffreys, 1998; Raftery, 1995).

### **Comparing the relative advantage for self in initiation and execution response stages**

Following previous research (Desebrock & Spence, 2021; Desebrock et al., 2018), we assessed 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 *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,  $F(1.32, 44.80) = 41.95, p < .001, \eta_p^2 = .55$ . 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 2c). There were no other significant main or interaction effects.

The change in the extent of self-bias in percentage correct across movement initiation (PC-1) and movement execution (PC-2) was also assessed. Two studentized residuals outliers were detected ( $> \pm 3$  in absolute value), and two conditions were not normally distributed. 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 2g). Non-parametric tests confirmed the parametric pairwise comparisons.

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

For mean PD and empathy scores (Tables A2 and A3 in Appendix), and comparison of the magnitudes of the absolute PD scores with one another, see Appendix. For Pearson bivariate correlations between the Self- and Friend-bias measures and the subjective measures of empathy and personal distance, see Table 2 (for the full correlation matrix of all self-report and bias metrics, see Appendix, Table A4).

Insert Table 2 here

As can be seen in Table 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 3a–c.

We 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 we chose 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 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, Table A5.)

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<sup>1</sup>, 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 bias ( $R^2 = .36$ , Adjusted  $R^2 = .32$ ). In contrast to Self-Bias, Friend-stranger bias was predicted by Self-PD (Figure 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, Table A6)

Insert Figure 3 here

## 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, 2019; 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. Our findings support the latter view. Using a movement adaptation of Sui et al.'s matching task, we examined for the first time whether there was a relationship between self- and friend-stranger biases in fast ballistic arm-movement responses and subjective measures of empathy and personal distance

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<sup>1</sup>  $n$  = 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 ( $< 2\sqrt{((k+2)/(n-k-2))}$ ), DFBetas for the two predictor variables were 0.010 and 0.026 (both  $< 2/\sqrt{n}$ ).

(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 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, 2019; Schäfer, Wesslein, et al., 2020).

#### **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 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 self-bias reflects 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 self-esteem (Schäfer & Frings, 2019).

One interpretation of our 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 Desebrock & Spence, 2021). 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. We suggest that these biases may be *indirectly* influenced by consciously-accessible representations of self-other relations.

### **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 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). If the representations we use to report on ‘the individual self’ and those we use to report on ‘the self-in-relation-to-others’ are differentially linked to lower-level processes, this could also account for the null relationship between self-bias and self-esteem (Schäfer & Frings, 2019).

Within this framework, our findings are both consistent with the view that biases in the matching task reflect implicit self-related processing, while also allowing for a link between an aspect of the consciously-accessible narrative self and the lower-level biases. Importantly, however, we did not aim in the present study 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.

### **Self-bias**

We 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) found that increased autistic traits<sup>3</sup> were associated with increased self-bias in RT in the standard matching task—notably, empathy deficits are associated with autism (Baron-Cohen & Wheelwright, 2004). We also documented that Friend-PD (the friend-stranger relative to self-stranger personal distance) tended to negatively-correlate with Self-friend bias (see Table A4 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, 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's findings for non-autistic participants, we similarly found in our 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 to further explore profiles of the interrelations between self-bias in the matching task motor responses and perceptions of Self-other and Friend-stranger personal distance across different populations.

### **Friend-stranger bias**

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 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, 2015), 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, we 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, we 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). 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 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.

### **Self- and friend-biases in arm-movement responses**

In the present study, arm-movement responses rather than keypress responses were used. These motor-response types have different real-world functions and associated uses; thus, it could be argued that their differential interpretation 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, 2019). Indeed, previous research suggests 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 (Desebrock & Spence, 2021), but only in the initiation and not the execution of keypress responses (Janczyk et al., 2019—Experiment 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 our findings from previous research (e.g., Schäfer & Frings, 2019). 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, 2015; 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.

Our movement adaptation of the matching task also provides a somewhat richer source of information about self-bias in action than total-response-time keypress paradigms. For example, we documented that self-bias in accuracy increased from movement initiation to execution, consistent with our previous research (Desebrock & Spence, 2021; Desebrock et al., 2018). In contrast, however, self-bias in IT and MT did not differ significantly. Furthermore, Friend-stranger bias was unchanged across the response stages. We also observed a less marked disadvantage for stranger-related movement executions relative to their initiation than we previously documented using dichotomous Self and Stranger identities (Desebrock & Spence, 2021). These findings suggest that the relationship between the initiation and execution response stages of arm-movements and their respective biases may be altered by the combination of identities.

### **Wider implications**

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; Humphreys & Sui, 2016), 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, 2019; Tao et al., 2012). Our findings 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, our findings indicate that exploring constellations of lower-level biases in the matching task and measures of self-other relations across populations, such as in ASD, disorders of the self, and across the life-span, is likely to be fruitful, and could use our task set-up as a starting point. Research suggests that there are deficits in higher-level self-referential processing in ASD, but basic self-other differentiation

is intact in this population. Future studies could examine profiles of matching task biases in relation to subjective perceptions of self-other relations in ASD.

## Conclusions

Using a movement adaptation of a matching task, we 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. Our 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. Our findings support the alternative view.

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**Notes**

<sup>1</sup>Following the terminology used by Desebrock and Spence (2021), *movement initiation* refers to the information processing that occurs between stimulus onset and the onset of the overt movement response. *Movement execution* refers to the overt movement response. *Arm-movement response* refers to the entirety of the arm-movement response; i.e. including both the initiation and execution of the arm-movement response.

<sup>2</sup>The EEG data collected was not analysed in the present study due to data loss which reduced the sample size. Thus to preserve the validity of the analyses of the subjective measures and facilitate faster report of the novel findings, we present the behavioural study here.

<sup>3</sup>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.

## Appendix

### Descriptive statistics for the mismatch-condition data

**Table A1.** Mean movement initiation times (IT) and movement times (MT) in ms (SD), and percentage of correctly-initiated movements, and correctly-completed movements, with standard deviations, as a function of Association (self vs. stranger) in the mismatch-trial data.

| Performance indices      | Shape-based Association | Mismatch condition |
|--------------------------|-------------------------|--------------------|
| IT                       | 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.

**Table A2.** Mean Personal Distance (PD) absolute scores.

|                        | PD (in mm)      |
|------------------------|-----------------|
| <b>Self-Friend</b>     | 77.30 (54.29)   |
| <b>Self-Stranger</b>   | 427.20 (170.59) |
| <b>Friend-Stranger</b> | 379.31 (162.59) |

Standard deviations in parentheses.

### 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,  $\chi^2(2) = 49.91, p < .001$ . 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 A3.** Mean empathy scores (SD)—Interpersonal Reactivity Index (IRI) total scores—and for the four IRI subscales: Empathic Concern; Fantasy; Personal Distress; Perspective Taking.

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

### 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 A4, and revealed moderate to high significant correlations between each subscale of the IRI and the total Empathy score. Therefore, only the Total score was used in further regression analyses. Table A4 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.

Insert Table A4 here

**Table A5.** 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.

| Model |             | <b>b</b> | <b>SE-b</b> | <b>Beta</b> | <b>Pearson r</b> | <b>Sr<sup>2</sup></b> | <b>Structure coefficient</b> |
|-------|-------------|----------|-------------|-------------|------------------|-----------------------|------------------------------|
| 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  $r$  /  $R$ ]

**Table A6.** 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.

| Model |            | <b>b</b> | <b>SE-b</b> | <b>Beta</b> | <b>Pearson r</b> | <b>Sr<sup>2</sup></b> | <b>Structure coefficient</b> |
|-------|------------|----------|-------------|-------------|------------------|-----------------------|------------------------------|
| 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  $r$  /  $R$ ]