

More of Me: Self-Prioritization of Numeric Stimuli

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People process stimuli that have been arbitrarily associated with the self versus with a stranger preferentially, but congruence effects can modulate self-prioritization, as when the self is paired with, for example, symmetrical versus asymmetrical stimuli. In two experiments, we examined the interaction of self-prioritization with number magnitude when participants associated the self or a stranger with specific number symbols such as “2” presented as natural, negative, and ordinal number types (Experiment 1), or abstract numeric concepts, such as “larger than 5” (Experiment 2). Empathy and personal distance were also assessed. While self-prioritization emerged in both experiments, number type (natural, ordinal, and negative) had no effect on performance. Furthermore, correlations with empathy and personal distance did not emerge consistently. An interaction between number magnitude and self-assignment was observed for the magnitude comparison matching task (e.g., >5) (Experiment 2), but not in the specific number (e.g., “8”) matching task (Experiment 1). The null interaction may reflect the fact that encoding symbol identity, but not number magnitude, was sufficient for the symbol-matching task. The order of numbers and self-associations also had an effect. In sum, this study is the first to show that self-prioritization emerges for symbolic numbers and can even occur with abstract categories, such as a range of numbers (e.g., >5). Furthermore, congruence effects between number concepts and labels (e.g., for the stranger, less is better) may also affect performance. However, this would appear to depend on the task context, such as whether numeric magnitude was needed to complete the task.

Public Significance Statement

This study demonstrates self-prioritization when the self or a stranger is paired with symbolic numbers or more complex arithmetic concepts such as “larger than 5,” highlighting the ubiquity of self-prioritization effects even in highly specialized processes like numeric cognition.

Keywords: self-prioritization, self-reference, self, numbers, congruency

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Social information affects human information processing. Stimuli are processed more rapidly, more accurately, and/or more efficiently when they happen to be relevant to the self, as compared to when they are not (Northoff, 2016; Rogers, 1977; Sui & Humphreys,

2017a; Sui et al., 2012). Advantages for self-relevant information have been observed in attention (Alexopoulos et al., 2012; Brédart et al., 2006; Humphreys & Sui, 2016; Moray, 1959; Zhao et al., 2018), memory for trait words (Rogers, 1977; Symons & Johnson,

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1997), working memory (Yin et al., 2019, 2021, cf. Constable et al., 2019), and overt motor responses (Constable et al., 2011; Desebrock et al., 2018; Desebrock, Barutchu, & Spence, 2022).

A seminal development in the field was the introduction of Sui et al.'s (2012) matching task in which participants match geometrical shapes (e.g., a triangle) with labels such as "Yourself" and "Stranger" according to previously learned arbitrary rules (e.g., triangle = "Yourself"). Participants associated labels such as "self," "friend," or "stranger" with geometric shapes such as a triangle or square. Then, participants viewed pairs of labels and stimuli. They decided whether these pairings match the associations learned during training. Sui et al. reported that considering labels paired with their correct shape, participants responded more rapidly and more accurately to self-paired shapes than to nonself-paired shapes.

As the shape stimuli can be assumed to have no intrinsic connection with the self, this experimental design neatly controls for familiarity and overlearning confounds. This advantage for information that is paired with the self—even when the pairing is completely arbitrary, such as between labels like "self" and geometric shapes—is known as the self-prioritization effect (SPE). However, when given a choice, participants may prefer to assign some symbols (e.g., a circle) to themselves (Manippa & Tommasi, 2023).

The SPE has been widely replicated (e.g., see Cunningham & Turk, 2017; Sui & Humphreys, 2017a for reviews). The SPE persists even when potentially familiar labels (e.g., "Yourself") are replaced by tones (Stolte et al., 2021), and when both the labels and the simple geometric shapes used by Sui et al. (2012) are replaced with unfamiliar visual stimuli (Woźniak & Knoblich, 2019). The SPE also emerges when the self is paired with visual features (e.g., symmetry) or feature conjunctions rather than shapes or objects (Schäfer et al., 2015; Vicovaro et al., 2022). Finally, the SPE has been observed in crossmodal paradigms where labels are replaced by tones that were previously associated with the self (Stolte et al., 2021), or where the self-association is learned in a modality other than the one used for the judgment task (Schäfer et al., 2021; Scheller & Sui, 2022b). However, the SPE may depend on whether the self-association is relevant to the task at hand—it may not emerge in tasks that do not require explicit reference to the self, such as in stimulus detection paradigms (Caughey et al., 2021; Desebrock, Barutchu, & Spence, 2022).

The SPE demonstrates that humans show processing advantages for self-associated stimuli, even when the stimuli are novel and the association is arbitrary. However, in the real world, many stimuli are meaningful. For example, your neighbor may offer you £10 to mow her lawn. Arguably, you would associate "£10" with yourself: you may process this information preferentially, for example, remembering it for longer as compared to when your friend had just received this offer. Nevertheless, "£10" is also meaningful in its own right (e.g., it is different from £100). This raises the question of whether the meaning of a stimulus like "£10" interacts with the SPE: for example, would there be a stronger processing advantage if you were just told that you had receive £100 for mowing the lawn?

Perspectives on the Self

William James' (1890) distinguished an active *subject self* ("I") and a passive, conceptual *object self* ("Me"). Historically, the subject self has been seen as a "higher-order" function of cognitive processes. More recently, a basis model (Northoff, 2016) has emerged

that understands the subject self or self-as-mechanism as a fundamental and basic cognitive process that modulates information processing. Here, we will adopt this latter meaning, using the words "subject self" and "self-as-mechanism" interchangeably.

The subject self has been conceptualized as an active, domain-general binding mechanism, with self-relatedness posited to act as a form of "perceptual glue" (Humphreys & Sui, 2016; Scheller & Sui, 2022a, 2022b; Sui & Humphreys, 2017a). This "integrative" function of the self may be supported by ventromedial prefrontal cortex and the left posterior superior temporal sulcus, as well as perigenual and posterior cingulate cortex (e.g., D'Argembeau, 2013; Northoff, 2016; Northoff & Bermpohl, 2004; Northoff et al., 2006; Sui et al., 2013; Sui, Chechlacz, et al., 2015; Sui, Liu, et al., 2015). At the neural level, this "integrative" self may be supported by temporal integration across various time scales (Kolvoort et al., 2020; Wolff et al., 2019). That said, there is debate as to whether the SPE reflects biases in perception, decision-making, and/or memory (Falbén et al., 2020; Golubickis et al., 2018; Janczyk et al., 2019; Reuther & Chakravarthi, 2017).

The *object self* is a store of self-related content including, for example, one's own name or face, attitudes and beliefs about oneself, autobiographic information, a representation of one's own interoceptive state as well as one's relationships to others (e.g., Conway, 2005; D'Argembeau, 2013; Northoff, 2016). Acknowledging debate on how to differentiate these aspects (e.g., Truong & Todd, 2017; Woźniak, 2018), this article will be largely concerned with attitudes and beliefs about the self (e.g., "I am good"; see Congruency and the Self section). The term "self-as-concept" will be used with the restricted meaning of "the set of attitudes and beliefs relating to the self."

Currently, the SPE sits uncomfortably between the notions of the subject self and the object self. The prioritization of self-related information (Northoff, 2016; Sui & Humphreys, 2015) requires assigning self-relevance to incoming external stimuli—in this sense it forms part of the subject self. However, it is based on *content* stored in memory, which forms part of the object self. To illustrate, Sui et al.'s task requires recognizing a constellation of a shape and the label "self." Self-related processing in the SPE would require (a) some basic perceptual processing of the incoming stimulus, (b) accessing information stored within the self-as-a-concept (such as a belief "in this task, the self is paired with a circle"), and (c) assigning self-relevance based on the external input and internally stored information (a function of the subject self).

This raises an important question: It is possible that the semantic structure of the self-as-concept may interact with the SPE. That is, just as "Up" and "Good" go together (Lakoff & Johnson, 1980; Proctor & Cho, 2006), the SPE may be more pronounced for those stimuli that are congruent with the self-as-concept. For example, a task-relevant association (e.g., "in this task, the self is paired with a large number") may be more readily accessible, if it agrees with the content of the self-as-concept more broadly. Given a positive attitude toward yourself ("I am good") and the belief that "bigger is better," you may be quicker to assign self-relevance to a generous 100 associated with yourself versus a measly 10 (even if the numbers themselves are meaningless).

Numbers, Congruency, and Metaphor

To investigate the role of the self-as-concept in the SPE, one could consider congruency effects. Congruency effects emerge when a

conceptual or perceptual congruency between two stimuli, features, or dimensions facilitates information processing (e.g., Lakens, 2012; Spence, 2011). For example, participants are quicker to respond to positive words (“moral,” “good,” “God”) when they are presented at the top versus the bottom of the screen (Lakens, 2012; Proctor & Cho, 2006), and show congruence-related biases in memory (Crawford et al., 2014). Similarly, participants have been shown to respond more rapidly to positive words paired with other hierarchies such as the right versus the left of a screen (Lin & Oyserman, 2021)—though there may be differences across different modalities (e.g., “sweet” is up, but not right—Velasco et al., 2019).

Research on numbers which draws on the idea of a mental number line grounded in the human perceptuomotor system (Fischer & Shaki, 2018; Restle, 1970; Winter et al., 2015), suggests that it is a rich area for congruency effects. For example, consider the spatial numerical association of response code (SNARC) effect: participants perform parity judgments on numbers more rapidly if the smaller number happens to be paired with a left versus right response button (Dehaene et al., 1993; Winter et al., 2015)—even when the numbers are negative (Fischer, 2003). Similarly, showing participants a small number results in their attention being shifted to the left side of space while large numbers result in a shift to the right instead (Fischer et al., 2003; Myachykov et al., 2016). Furthermore, SNARC-like effects have been demonstrated with other non-numeric magnitudes (Macnamara et al., 2018) such as size (Wühr & Seegelke, 2017) or pitch (Cho et al., 2012; Nishimura & Yokosawa, 2009). Such results could be taken to suggest that numbers may draw on a generalized modality-independent magnitude system (Cohen Kadosh et al., 2008; Walsh, 2003).

Similar associations exist in vertical space. When performing parity judgments with one button located above the other, participants are quicker to respond to small numbers using the lower button and to large numbers using the top button (Hartmann et al., 2014; Winter et al., 2015). Similarly, participants are more likely to look upwards when they generate larger random numbers in a random number generation task (Loetscher et al., 2010).

Congruency and the Self

There is initial evidence that similar congruency effects may extend to the concept of the self. Participants are quicker to judge posters as self-owned according to arbitrary rules, if they find the poster more desirable (Golubickis et al., 2021). A stronger SPE also emerges when the self is paired with a happy face versus a sad face (Constable et al., 2021), and participants have a larger SPE for stimuli associated with the “good part” versus “the bad part” of themselves (Hu et al., 2020). Furthermore, the SPE in the matching task is diminished after negative mood induction (Sui et al., 2016). This mirrors the long-standing observation that, by and large, people tend to have a positive attitude toward themselves (Sedikides et al., 2003, 2005, cf. Heine, 2005) and that participants make attributions that serve to maintain such positive attitudes (Mezulis et al., 2004).

On the other hand, positively valenced and rewarding information is special as it is likely to be particularly relevant to an individual’s behavior. Indeed, the association between positive affect and self-biases does not appear to be consistent: a recent study failed to find consistently lower self-biases in a sample of participants with depression compared to a nondepressed control group (Hobbs et al., 2023). Therefore, the question arises as to whether the SPE is

also affected by the relationship between the self-as-concept and other concepts, such as number.

The self has been shown to give rise to congruency effects with stimulus dimensions that are, metaphorically, positive: Constable et al. (2021; Experiment 2) had their participants associate the self or a stranger with a light or a dark shade of gray. In line with the consistent association of light with positive and darkness with negative valence (Meier et al., 2007), the participants showed a larger SPE when the self was paired with the light versus the dark color.

Similarly, the magnitude of the SPE may depend on more complex stimulus properties such as symmetry (Vicovaro et al., 2022): In a matching task, participants associated either vertically axial symmetric or asymmetric dot patterns with the self and a stranger. On each trial, the participants were presented with a novel symmetric or asymmetric random dot pattern paired with a label and judged whether the pairing of pattern symmetry and label matched those initially learned. Intriguingly, the SPE emerged when the self was paired with the symmetrical dot pattern but not when it was paired with the asymmetric dot pattern. This may be taken to suggest that there is a perceptual congruency effect when the self is paired with symmetrical versus asymmetrical shapes—which, again, may reflect general association of visual symmetry with positive affect (Pecchinenda et al., 2014).

Finally, the results of another recent study (Stolte et al., 2021) suggest that the size of the SPE may interact with basic, scalar properties of the stimuli used in the task such as the pitch of a tone relative to a baseline (cf. Spence, 2019). Participants were given three labels *myself*, *friend*, and *stranger* and were trained to associate them with a shape (triangle, circle, and square) and a tone (low, mid, or high pitch). In the main study, the participants were presented with pairs of two of the three stimuli (e.g., self–triangle; triangle–high tone; self–high tone) and judged whether these pairings matched those they learnt during training. Intriguingly, when the self was paired with high or low tones, a stronger SPE emerged as compared to when it was paired with a medium tone. This result suggests that pairing the self with extreme versus nonextreme locations on the hierarchy of tones may help to facilitate self-relevance judgments. Furthermore, Stolte et al. (2021) also reported a similar interaction of pitch and processing advantages for reward.

In sum, there is evidence to suggest that the self-as-a-concept interacts with the stimuli used in the perceptual matching task. In many cases, metaphorical associations with positive valence or reward may help elucidate this relationship.

The Present Study

To date, no study has investigated congruence effects between the self-as-concept and symbolic numbers. The latter are particularly interesting because of their versatility. Symbolic numbers are abstract and may occur, for example, as positive, negative, or ordinal numbers, and may take on various meanings on different kinds of scales (Stevens, 1946). Similarly, numbers may have a different valence in different settings: higher numbers may, for example, be desirable when looking at your bank account, but lower numbers may be more desirable when listing athletes according to their place in a race. Therefore, this study tested whether the SPE shows perceptual congruency effects with numbers. In two experiments, the interaction of the SPE with number symbols was investigated by pairing the self with natural, negative, and ordinal numbers

(Experiment 1), and with more abstract arithmetic concepts (larger or smaller than 5; Experiment 2).

Measures of personal distance and empathy were also included as potential covariates. Previous studies have documented an association between the SPE and *personal distance* (a subjective measure of the perceived closeness between others and the self; e.g., Desebrock, Barutcu, & Spence, 2022; Sui & Humphreys, 2015; Yankouskaya et al., 2020). For example, a reduced self-advantage in the matching task has been associated with a close personal distance between self and stranger (Sui & Humphreys, 2015). A recent study also found that the self-advantage in a movement adaptation of the shape–label matching task was predicted by explicit empathy (Desebrock, Barutcu, & Spence, 2022). However, just as the SPE has been demonstrated to be sensitive to both stimuli and task parameters (e.g., Desebrock, Spence, & Barutcu, 2022; Golubickis & Macrae, 2021; Stolte et al., 2021), the associations between the SPE and subjective measures of self-as-object representations have also been shown to be inconsistent across studies (Sui & Humphreys, 2015, 2017b).

Experiment 1: Associating the Self With Number Symbols

Experiment 1 investigated the interaction of the SPE with different types of numbers (natural, ordinal, and negative). The hypotheses were:

Hypothesis 1: There would be an advantage for self- versus stranger-assigned information.

Hypothesis 2: The magnitude of the number would interact with the self-advantage, and the direction of the interaction would depend on number type.

Given that more is considered better in many situations, such as in the context of salaries or the number of objects one owns, Experiment 1 tested the hypothesis that participants would show a larger SPE when the self was paired with a larger natural number (e.g., “8”) versus a smaller number (e.g., “2”). Placing numbers in different contexts may also affect the SPE. Therefore, a second condition included ordinal numbers. Ordinal numbers typically order entities such that lower numbers are more desirable (e.g., places in a race, being someone’s second or eighth best friend, etc.). Thus, one would naturally expect an opposite pattern compared to natural numbers: that a larger SPE would emerge when the self is paired with smaller (e.g., “2nd”) versus larger (e.g., “8th”) ordinal numbers.

The last condition investigated negative whole numbers. Negative numbers are interesting because of their inherent conceptual friction (e.g., Fischer, 2003). While, by analogy with positive numbers, larger absolute values of negative numbers are more “extreme,” negative numbers with larger absolute value may often signal *negatively valenced* information such as the lack of something (e.g., a loss of money). Since Stolte et al. (2021) reported facilitation when the self was paired with extreme (high or low) versus a midtone regardless of direction, the absolute value of a number might be more important than its sign. This gives rise to the hypothesis that the SPE would be larger when the self was paired with a negative number with a larger (“–8”) versus smaller (“–2”) absolute value.

This experiment focused on whole numbers as they are (a) familiar and understandable and (b) unrestricted in interpretation. For example, a whole number like “8” may refer to the number of cars

you own or a distance of 8 m—more abstract classes of numbers such as real numbers, for example, $8/3$ or 2.25, could refer to distance but not account of objects and are therefore more constrained in terms of their meaning. The number symbols “2” and “8” were chosen as they were both single-digit even numbers as far away from one another as possible, and did not have potentially idiosyncratic meaning (e.g., “to be number one”).

In all conditions, a block of pseudostimuli was included as a control, to confirm that self-advantages do emerge in our study design. Given concerns about the potential familiarity of simple shapes (Woźniak & Knoblich, 2019), more abstract shape stimuli whose overall form was similar to the number of stimuli used were incorporated.

Method

Participants

In total, 123 participants were recruited via Prolific (www.prolific.co). In line with previous studies, which have often used around 30 participants per study (e.g., Sui et al., 2012), our goal was to analyze 90 participants, and randomly assign 30 participants to each group (natural, ordinal, and negative numbers). To ensure that there were enough accurate trials for reaction time (RT) analyses, if a participant’s accuracy fell below 60% overall, or 48% in a single block, this participant was excluded and a replacement recruited. In total, 19 of the participants who started the experiment on prolific failed to complete it. A further 14 participants failed the accuracy criterion.

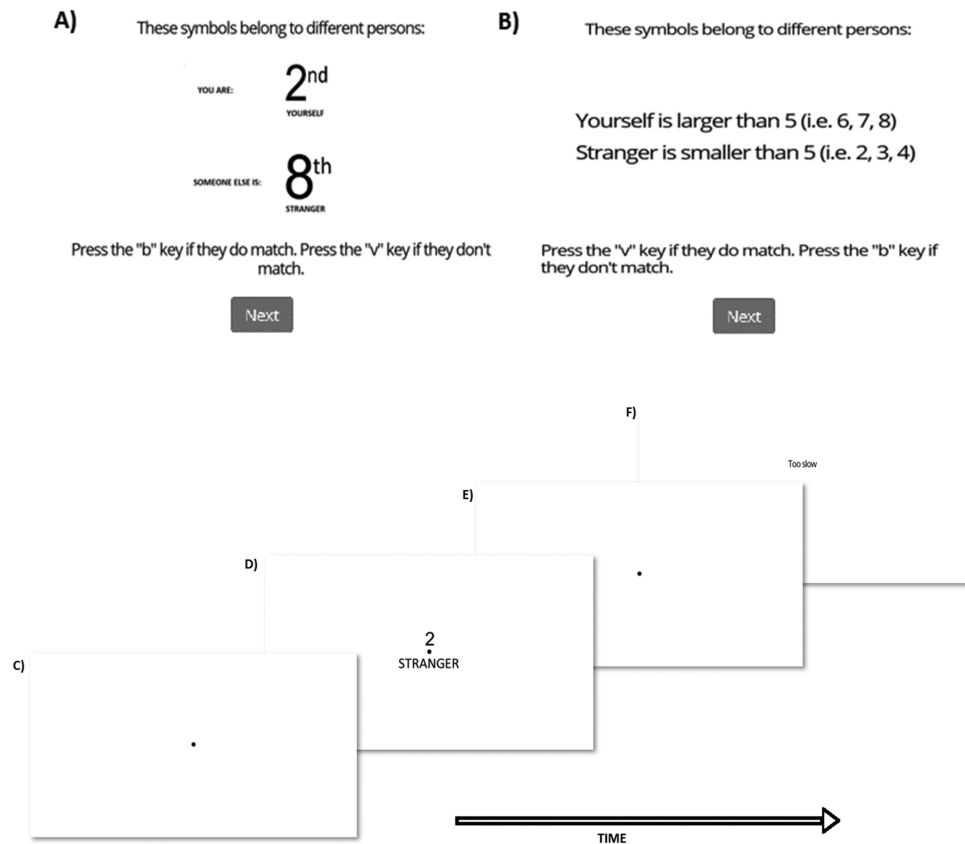
Descriptive statistics of participants for each group are reported in Table 1. All participants were fluent in English, right-handed, had normal or corrected-to-normal vision, and reported no language- or number-related disability (e.g., dyslexia, dyscalculia). Informed consent was obtained from all participants prior to their taking part, according to procedures approved by the University of Oxford Medical Sciences Division Ethics Committee (Reference: R81744/RE001). Data collection took place in 2022.

Stimuli

The matching task based on Sui et al. (2012) is illustrated in Figure 1. Two number symbols (2 and 8) or pseudonumber symbols generated by manually scrambling the numbers in image processing software (height 1° , line width c. 0.1°) were displayed 1° above a central fixation dot (radius 0.15°). All symbol stimuli had a comparable area, filling approximately 25% of their square grid. Two labels, “Yourself” and “Stranger” ($4.6^\circ \times 1^\circ$, line width c. 0.1°) were presented in all capitals 1° below the fixation dot. The participants had to judge whether the pairing of symbol

Table 1
Descriptive Participant Statistics in Experiment 1 by Condition

Condition	Sample size	Age (years)			Gender
		<i>M</i>	<i>SD</i>	Range	
Negative	30	25.43	4.89	19–37	17 Male
Ordinal	29	24.10	4.18	19–38	18 Male
Natural	30	26.47	6.16	18–40	23 Male
Total	89	25.35	5.19	18–40	58 Male

Figure 1*Task Instructions*

Note. (A) Presentation of symbol–label pairings in Experiment 1. (B) Presentation of pairings in Experiment 2. The order of instructions (self first or stranger first) and assignment of buttons (e.g., b is match, v is no-match) were counterbalanced across participants. (C) Fixation dot/intertrial interval, 800–1,200 ms, calculated as 800 ms plus a multiple of 16.66 ms. (D) Stimulus onset: number–label pairing for 200 ms in Experiment 1 and 400 ms in Experiment 2, RT is measured from stimulus onset. (E) 1,000 ms fixation dot. (F) 500 ms of feedback. If participants had not responded by the onset of this screen, their response was considered too slow. (Note that the image is not displayed to scale.) RT = reaction time.

and label (e.g., 2—YOURSELF) matched according to previously learned arbitrary rules. For each experimental condition, the stimuli were presented in blocks of 168 trials each.

Instructions for each experimental condition were presented at the start of each block. For example, the instructions for all numbers were: “In this part of the study, you will see number symbols which will represent yourself or a stranger. Throughout the task, you will see a fixation dot in the middle of the screen. Please try to fixate on this dot. Please try to respond as rapidly and accurately as possible.” If the block contained numbers (rather than pseudostimuli), participants also viewed a short statement, intended to help them consider the numbers as numerical quantities rather than symbols: “The numbers represent some kind of measurement (e.g., distance, temperature).” Originally, a slightly different wording was to be shown for ordinal numbers, “The numbers represent the order of events or positions (e.g., an athlete’s place in a race).” However, due to a technical error, the first sentence was used in every case. The participants then viewed a screen showing the symbol–label pairing (see Figure 1A).

The experiment ran online on the participant’s PC using gorilla.sc (Anwyl-Irvine et al., 2020). Other devices (e.g., smartphones) were not eligible. Gorilla’s inbuilt screen calibrator function was used to display the stimuli at comparable sizes across devices. This required participants to adjust the size of a rectangle until its size matched that of a standard-size credit card, and to estimate their distance from their computer screen in cm. A majority (69%) of the participants reported using a screen refresh rate of 60 Hz (range = 40–165 Hz). Four participants were unable to determine their refresh rate but were nevertheless included in the analysis.

Psychometric Measures

Personal distance was measured using an adaptation of the personal distance scale used by Sui and Humphreys (2015). Participants were instructed to “Please mark three points on the following lines to indicate where three people fall in relation to one another. Just move the slider to represent the position of each person.” They then indicated where “Yourself,” “Stranger,” and “Friend” fell on three sliders. We

used three sliders with one identity per line, rather than one line for two identities as in Sui et al.'s study due to technical constraints.

Empathy was measured using the interpersonal reactivity index (IRI; Davis, 1983; Keaton, 2018; Muddaluno et al., 2022). The IRI consists of 28 items across four subscales, personal distress, perspective taking, fantasy, and empathic concern. An example item from perspective taking would be "I sometimes try to understand my friends better by imagining how things look from their perspective." Ratings were given on a 5-point Likert scale from *does not describe me well* to *describes me very well*.

Finally, a short form of the Edinburgh Handedness Inventory (Veale, 2014) was used to confirm that participants were right-handed. In the Edinburgh handedness inventory, participants indicate on a 5-point Likert scale from *always left* to *always right* which hand they use for certain activities (e.g., writing).

Procedure

After filling out a screening questionnaire, including the Edinburgh Handedness Inventory (Veale, 2014), participants completed the main task. The participants were assigned to one of three conditions based on the number stimuli used—natural numbers (2, 8), negative numbers (−2, −8), and ordinal numbers (2nd, 8th).

Each participant group completed three blocks of the matching task: two blocks for each number association pattern (e.g., "2 belongs to Yourself" and "8 belongs to the Stranger" and vice versa), and one block with the two different pseudostimuli assigned to the self and the stranger. The association of the pseudostimuli with the self and stranger was counterbalanced across participants. Participants completed the blocks in Latin-square counterbalanced order.

At the beginning of each block of trials, the participants were presented with their allocated number–label associations (see Figure 1A). Then, on each trial, they had to judge whether a given combination of number symbols and labels (e.g., 2—Yourself) matched those initially presented. They gave their responses by pressing one key if the two matched and another if they did not. The "b" and "v" keys were used, and the meaning of the keys (match or no match) was counterbalanced across participants. A schematic representation of an experimental trial in the matching task is shown in Figure 1.

Each block had two parts: first, participants completed a short training sequence of 16 trials during which they received feedback after each trial (correct, incorrect, too slow). At the end of the practice block, the participants were informed of their overall accuracy. They repeated the practice block up to three times, until they reached an accuracy of over 60% in at least one practice block. This was followed by the main part, containing 168 trials. In the main part of the study, feedback was only given when the participants gave an incorrect response. If the response was correct, the feedback screen was instead left blank for 500 ms.

After the main task, the participants completed the IRI questionnaire (Davis, 1983; Keaton, 2018), a measure of personal distance (Sui & Humphreys, 2015), and a debriefing questionnaire. The main task, personal distance measure, and debriefing questionnaire are publicly available at <https://app.gorilla.sc/openmaterials/446049>. Due to potential copyright concerns, all other psychometric measures (e.g., the IRI) cannot be made available.

Data Analysis

The design of the experiment consisted of a between-groups variable with three levels (number type: neutral, ordinal, and negative)

and two within-participants repeated measures: the symbol shown with three levels (symbol type: 2, 8, and pseudo), and the association type with two levels (association: self and stranger).

Furthermore, to explore whether the observed effects were influenced by IRI (Davis, 1983; Keaton, 2018), and personal distance (Sui & Humphreys, 2015), we correlated empathy and the three personal distance measures (self–friend, friend–stranger, self–stranger) with our d' and relative RTs. To maximize power, we focused on only the pseudosymbols, which were the same for all participants. In case a significant correlation was observed, the analysis was repeated using the significant predictors as covariates.

Following previous studies, all of the analyses were based on matching trials. Match-trial stimuli (e.g., a self-associated shape and self-associated label) involve one association, thus in behavioral paradigms effects in mismatch trials cannot be extricated. Match and mismatch trials have typically been analyzed separately (e.g., Janczyk et al., 2019; Sui & Humphreys, 2017b; Woźniak et al., 2018), and commonly mismatch trials are treated as fillers (Schäfer, Wesslein et al., 2021).

Accuracy was operationalized as d' , calculated as the proportion of hits and false alarms for each symbol (2, 8, pseudo). RT was measured from stimulus onset and operationalized as relative RT (see Equation 1), using a participant's RT for a given symbol and association as "experimental" and their overall RT in that block as baseline. We chose relative RT because it is more robust to device-specific interparticipant variation in online studies (Pronk et al., 2020).

$$\text{RelativeRT} = 100 \times \frac{\text{Baseline} - \text{Experimental}}{\text{Baseline} + \text{Experimental}}. \quad (1)$$

Equation 1 represents relative RT measure. A larger relative RT indicates faster responses. In Experiment 1, the experimental measure was participants' RT on a given symbol and association (e.g., 2 assigned to self), and the baseline was their overall RT in that block.

Responses faster than 100 ms were removed, affecting c. 0.85% of trials. RTs were winsorized at the trial level: Responses more than 3 standard deviations above or below the participants' overall mean were replaced with the $M \pm 3$ SDs. This affected 0.13% of trials. Participants were considered outliers, if they had a relative RT or d' of 3 SDs above or below the overall mean in any condition. Data from one participant in the ordinal condition were excluded from parametric analyses as an outlier, yielding a total sample size of 89. Relative RTs and d' measures were analyzed using a 3 (number type: natural, negative, ordinal) \times 2 (association: yourself and stranger) \times 2 (symbol type: 2, 8, and pseudostimulus) mixed analysis of variance (ANOVA). As there was some evidence for kurtosis on relative RT measures (e.g., for stranger-associated pseudostimuli in the negative number group, $Z = 2.40$), all significant effects were confirmed with a nonparametric test. All post hoc comparisons were adjusted using Bonferroni corrections, and Greenhouse–Geisser Correction was applied where appropriate (i.e., for violations of the assumption of sphericity).

All analyses were conducted at the $\alpha = .05$ significance level. Throughout the study effect sizes are reported as partial eta-squared (η_p^2).

Power Analysis

The minimal effect size that could be detected with a power of .8 with the sample size of $n = 90$ used here was calculated using More

Power Software (Version 6.0.4; Campbell & Thompson, 2012). For the first hypothesis, that participants would respond faster/more accurately to self-assigned versus stranger-assigned stimuli, the minimal detectable effect size with a power of .8 and an α value of .05 was $\eta^2 = .083$. Therefore, the study was adequately powered to detect SPE previously reported by published studies (e.g., Stolte et al., 2021; Sui et al., 2012; Vicovaro et al., 2022) in the order of $\eta_p^2 = .4$ –.6. For example, across the four experiments using the SPE reported in Sui et al.'s (2012) original description of the SPE, the mean effect sizes were $\eta^2 = .52$ for RT and $\eta^2 = .33$ for d' .

The second hypothesis concerned a 3 (within, association: self, or stranger) \times 3 (within, symbol type: 2, 8, or pseudo) \times 3 (between, number type: natural, negative ordinal) interaction. Here, the minimal effect size detectable at a power of .8 and an α of .05 was $\eta^2 = .065$. For correlational analysis, the smallest correlation that could be detected with a power of .8 and α of .05 was $r = .29$. A prior study testing a similar interaction by Stolte et al. (2021) has found an effect size of $\eta_p^2 = .30$ in d' and $\eta^2 = .25$ in RT was found for the interaction of self-assignment and the stimulus-person mapping (e.g., when high, low, or medium tones were assigned to the self). Consequently, it was assumed that this experiment had sufficient power to detect effect sizes similar to those reported in past studies.

Transparency and Openness

We report how we determined our sample size, all data exclusions, all manipulations, and all measures in the study, and we follow JARS (Kazak, 2018). This study's design and its analysis were preregistered. The preregistration, all data, analysis code, and research materials are available at <https://doi.org/10.17605/OSF.IO/MCQFP>. Data were analyzed using IBM SPSS (Version 28.0.0) and R (Version 4.2.2; R Core Team, 2018) including the tidyverse (Version 1.3.0; Wickham et al., 2019) and ggplot2 (Version 3.3.3; Wickham, 2016) packages.

Results and Discussion

RT

Mean RTs were faster for self than stranger-associated stimuli (see Figure 2A). Consistent with this pattern, relative RTs for self-associated stimuli were consistently negative unlike stranger-associated stimuli (see Figure 2B). The ANOVA revealed a significant main effect of association, $F(1, 86) = 100.04$, $p < .001$, $\eta_p^2 = .538$, which reflected faster responses to self-paired stimuli versus stranger-paired stimuli, $M_{\text{difference}} = 4.41$, $SE = 0.44$, $p < .001$. There was no main effect of symbol type, $F(1.94, 166.70) = 2.45$, $p = .092$, $\eta_p^2 = .028$ or number type, $F(2, 86) = 3.07$, $p = .052$, $\eta_p^2 = .067$.

The interactions between association and number type, $F(2, 86) = 0.96$, $p = .388$, $\eta_p^2 = .022$, association and symbol type, $F(1.72, 147.93) = 1.56$, $p = .215$, $\eta_p^2 = .018$, or number type and symbol type, $F(3.88, 166.7) = 2.20$, $p = .074$, $\eta_p^2 = .049$, were all nonsignificant. There was no three-way interaction between association, symbol, and number type, $F(3.44, 147.93) = .22$, $p = .908$, $\eta_p^2 = .005$.

We considered the possibility that any effect of numbers may potentially have been masked by the within-participant counterbalanced procedure that was used; the learnt association's specific numbers had to be relearned across blocks. Therefore, an additional analysis was conducted showing that the order in which the number associations were learnt did indeed significantly interact with self-

association and the number type (see Supplemental Material 1 in the online supplemental materials for details).

d'

As can be observed in Figure 2C and D, mean accuracy and d' measures were higher for self-associated stimuli than stranger-associated stimuli. Consistent with the results of the relative RT analysis, there was a significant main effect of association, $F(1, 86) = 79.64$, $p < .001$, $\eta_p^2 = .481$, reflecting larger d' for self-paired versus stranger-paired stimuli. This difference was confirmed by a Wilcoxon signed-rank test, $W = 3,667$, $p < .001$, $n = 90$. There was also a main effect of number type¹: $F(2, 86) = 5.15$, $p = .008$, $\eta_p^2 = .107$. The participants responded more accurately to negative as compared to ordinal numbers, $M_{\text{difference}} = 0.50$, $SE = 0.16$, $p = .008$, but negative and natural numbers did not differ significantly, $M_{\text{difference}} = -0.11$, $SE = 0.16$, $p = .758$. The difference in d' for natural and ordinal numbers was not significant, $M_{\text{difference}} = 0.38$, $SE = 0.16$, $p = .052$.

When followed-up with Wilcoxon signed-rank tests, the difference between negative and ordinal numbers remained significant, $W = 647$, $p = .003$, $n = 30$, while the difference between natural and ordinal, $W = 595$, $p = .32$, $n = 30$, did not.

There was no main effect of symbol, $F(1.65, 141.89) = 1.54$, $p = .217$, $\eta_p^2 = .018$. None of the two-way interactions of association and number type, $F(2, 86) = 1.69$, $p = .191$, $\eta_p^2 = .038$, nor association and symbol type, $F(1.75, 150.44) = 1.10$, $p = .329$, $\eta_p^2 = .013$, nor of symbol type and number type, $F(3.30, 141.88) = 1.09$, $p = .360$, $\eta_p^2 = .025$, were significant. Finally, there was no evidence of a three-way interaction between association, number type, and symbol, $F(3.50, 150.44) = .99$, $p = .409$, $\eta_p^2 = .022$. The order of learnt number and self-associations did affect d' measures (see Supplemental Material 1 in the online supplemental materials).

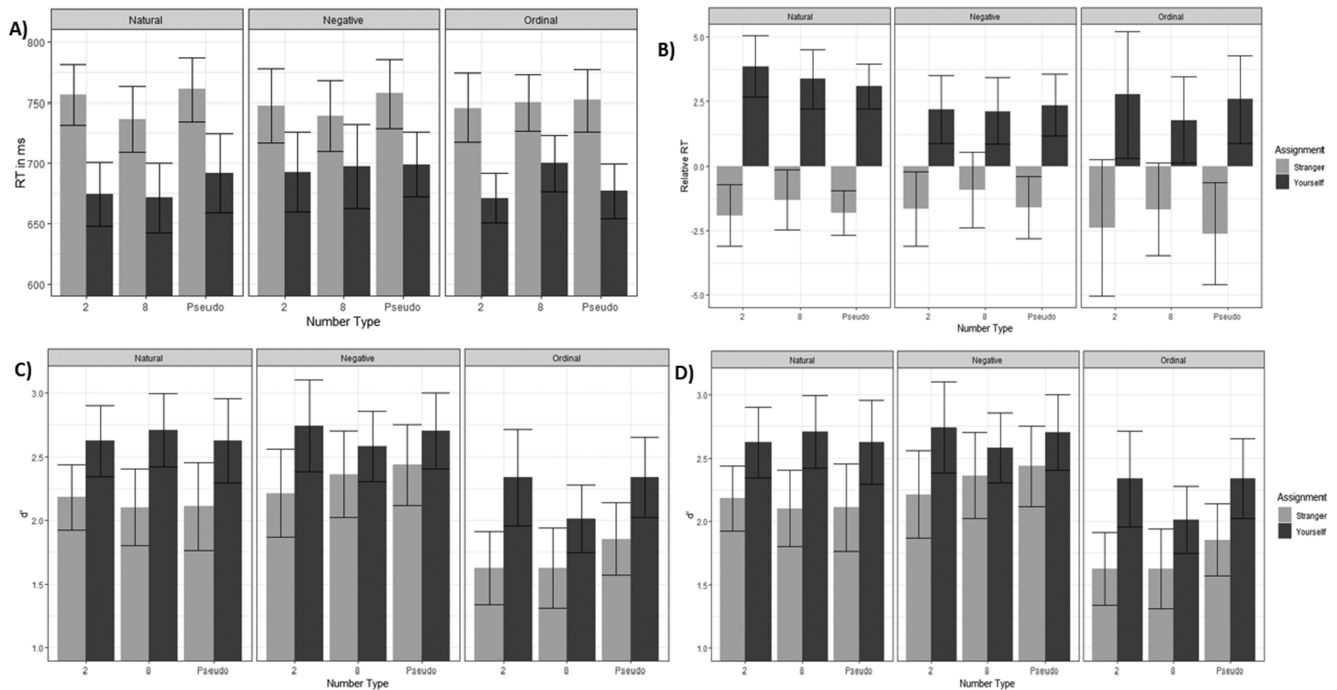
Personal Distance Measures

Participants in all three groups completed the pseudostimulus conditions. Therefore, all participants were included in the correlation analysis assessing the relationship between relative RT and d' prime measures for the pseudostimuli and personal distance measures. Not surprisingly, most relative RT and d' measures revealed moderate to low correlations with each other (see Table 2). Only the distance measures between self–stranger and friend–stranger correlated with each other. For pseudostimuli, there was a significant correlation between friend–stranger difference and d' on stranger-assigned trials, $r(88) = -.272$, $p = .010$. However, upon inspection of the scatterplot for this correlation, it was apparent that there were two cases that deviated strongly from the observed pattern, by having a friend–stranger difference of 0. After removing the two cases, the correlation was no longer significant, $r(87) = -.15$, $p = .18$ (see Table 2).

As further exploratory analyses, the correlations between relative RT measures, d' , and personal distance for each group were also assessed noting the low participant numbers and possible Type II errors (see Supplemental Material 3 in the online supplemental materials).

¹ This finding is further discussed in Supplemental Material 1 in the online supplemental materials.

Figure 2
Results From Experiment 1



Note. (A) Absolute RT in milliseconds; (B) relative RT, where larger values represent quicker responses; (C) accuracy, calculated as the mean proportion of trials answered correctly, where 1 = 100%; (D) accuracy, calculated as d' . Values shown here are not adjusted for covariates. Error bars represent 95% confidence intervals. RT = reaction time.

Empathy Measures

There were no significant correlations between performance on pseudosymbols in our matching task and the IRI subscales (Davis, 1983; Keaton, 2018). Thus, empathy was not considered further.

In summary, Experiment 1 found evidence for self-prioritization in relative RT and d' when participants associated the self with the number symbols 2 and 8 for different number types (natural, negative, ordinal numbers). There was no evidence for an interaction of self-association, number type, and the symbol shown—though additional analyses indicated that an interaction could have been masked by association learning order effects. Incidentally, there was also a significant main effect of number type, suggesting that participants had a larger d'

when responding to natural numbers versus negative numbers, with ordinal numbers falling in between.

Experiment 2: Associating the Self and Stranger With Symbol-Independent Quantities

Experiment 2 was designed to test the hypothesis that, if a relationship of the SPE to number reflected numerical quantity—rather than the specific number symbols used in the task—it should also occur when quantities above or below a reference value, rather than number symbols, are associated with the self. Furthermore, by using a range of symbols, this approach can counteract any biases that result from visual features that may be associated with specific number symbols (e.g., consider how “2” is asymmetric whereas “8” is symmetrical—see, e.g., Vicovaro et al., 2022). Therefore, in Experiment 2, the participants had to associate the self with a quantity (e.g., smaller or larger than 5) rather than a specific number (e.g., 2 or 8). As such, Experiment 2 tested the hypotheses (a) that an advantage for self-paired versus stranger-paired quantities will emerge and (b) that, as bigger is better, there will be an interaction of self-association and quantity such that the self-advantage will be more pronounced for bigger numbers.

Method

Participants

In line with previous studies, which have often used around 30 participants per study (e.g., Sui et al., 2012) or goal was a sample size of 30. In total, 50 participants were recruited via Prolific according to the

Table 2

Pearson's Correlations Between Distance Measures for Self, Friend, Stranger, d' , and Relative RT for Self and Stranger Pseudostimuli After Correcting for the Two Outliers

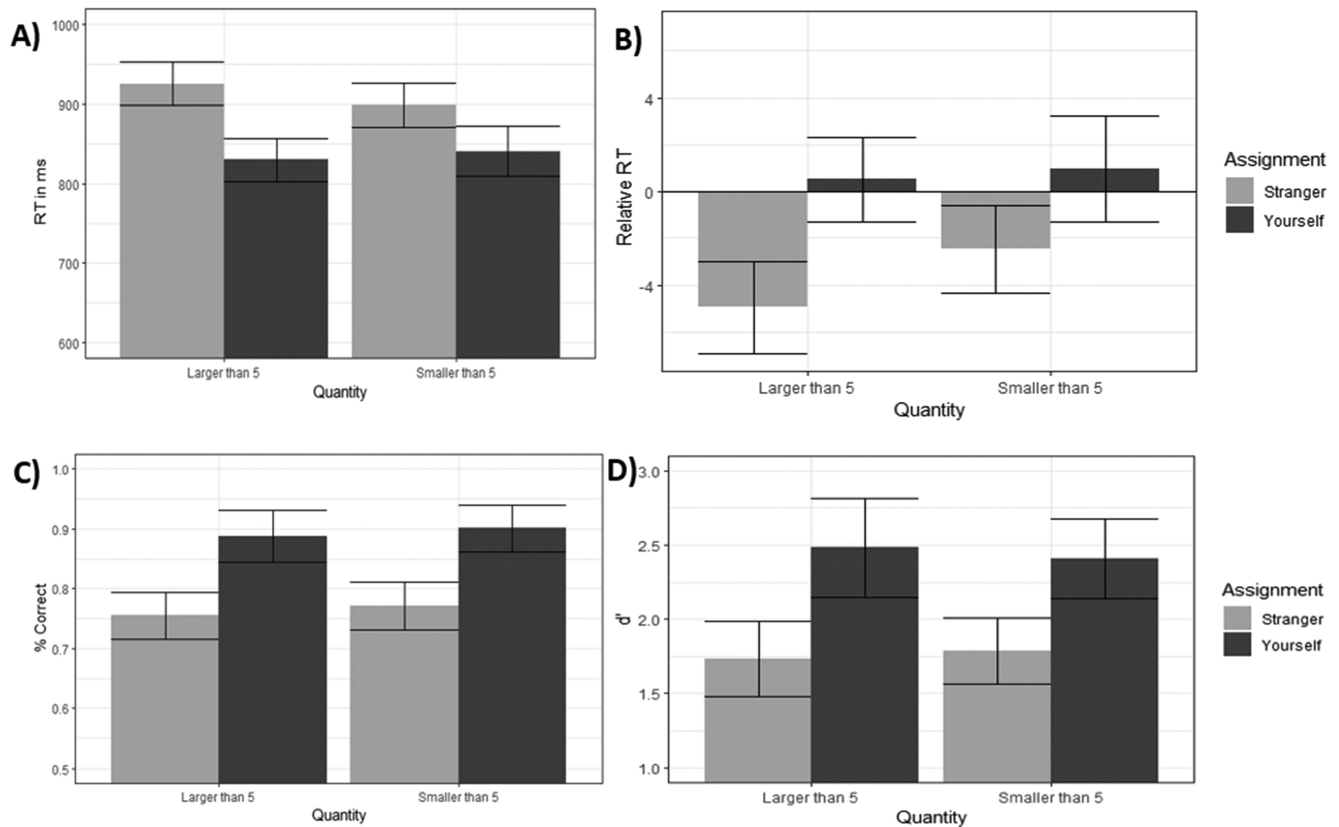
Variable	1	2	3	4	5	6	7
Dis Self-Fr	—	.18	-.11	.07	-.08	-.07	-.001
Dis Self-Str		—	.63**	.02	-.04	.04	.03
Dis Fr-Str			—	.13	.02	-.03	-.15
relRT Self				—	-.68**	.23*	-.25*
relRT Str					—	-.26*	.09
d' Self						—	.60**
d' Str							—

Note. Dis = distance, Fr = friend, Str = stranger, relRT = relative RT; RT = reaction time.

* $p < .05$. ** $p < .001$.

There was no significant main effect of quantity, $F(1, 29) = 2.54$, $p = .122$, $\eta_p^2 = .081$. The interaction of quantity and association did not reach significance, $F(1, 29) = 3.98$, $p = .056$, $\eta_p^2 = .121$. Given its noticeable effect size (e.g., above the median effect size reported in the psychological literature) and the possibility of a Type II error with a $p = .056$ bordering on significance, the interaction was explored further with post hoc comparisons. Participants responded equally rapidly to small and large numbers paired with the self, $M_{\text{difference}} = .45$, $SE = 1.18$, $p = .705$. However, participants

Figure 3
Results From Experiment 2



Note. (A) Absolute RT (in ms); (B) relative RT, where larger values represent faster responses; (C) accuracy, calculated as the mean proportion of trials answered correctly, where 1 = 100%; (D) accuracy, calculated as d' . Values shown here are not adjusted for covariates. Error bars represent 95% confidence intervals. RT = reaction time.

appeared to respond more rapidly to stranger-paired quantities, if they were smaller than 5 compared to larger than 5, $M_{\text{difference}} = 2.49$, $SE = 0.91$, $p = .010$. This difference persisted with a Wilcoxon signed-rank test, $W = 359$, $p = .029$ even after correcting for multiple comparisons. Thus, this follow-up analysis is indicative of a possible Type II error, which needs to be explored by further research.

As there was no evidence for an interaction of association and quantity with d' , this interaction may have been an artifact from the calculation of the relative RT measure. Therefore, deviating from the preregistered analysis, the analysis was repeated using absolute RTs as the dependent variable. This also supported a main effect of association, $F(1, 29) = 90.56$, $p < .001$, $\eta_p^2 = .757$, and found evidence for a significant interaction of association and quantity, $F(1, 29) = 4.36$, $p = .046$, $\eta_p^2 = .131$, with comparable effect size. This interaction also reflected faster responses to small stranger-paired stimuli, $M_{\text{difference}} = 26.44$, $SE = 11.07$, $p = .024$, while there was no comparable effect for self-paired stimuli, $M_{\text{difference}} = 10.75$, $SE = 16.34$, $p = .516$. The relative RT is more conservative as it only highlights differences above the overall mean in the pseudolabel condition. Thus, given that the interaction is significant with absolute values, the nonsignificant interaction of quantity and assignment in relative RTs may further reflect a Type II error.

d'

As shown in Figure 3C and D, accuracy was higher for self than stranger-assigned stimuli. There was a significant main effect of association, $F(1, 29) = 64.20$, $p < .001$, $\eta_p^2 = .689$, reflecting more accurate responses to self-paired stimuli compared to stranger-paired stimuli, $M_{\text{difference}} = .68$, $SE = 0.09$, $p < .001$. There was no main effect of quantity, $F(1, 29) = .074$, $p = .788$, $\eta_p^2 = .003$. There was also no interaction of quantity and association, $F(1, 29) = 0.06$, $p = .940$, $\eta_p^2 < .001$.

We considered the possibility that an interaction of symbol and association may have been masked by relearning effects related to the within-participant counterbalanced procedure that was used; therefore, an additional analysis was conducted showing that the order in which the number associations were learnt did indeed significantly interact with self-association and the number type (see Supplemental Material 2 in the online supplemental materials).

Personal Distance

For relative RT, higher self–friend distance predicted slower RT to self-paired stimuli that were larger than 5, $r(29) = -.363$, $p = .049$. Full correlational analyses are reported in the online supplemental

materials. Thus, an exploratory 2×2 within-participants analysis of covariance (ANCOVA) was conducted on relative RT, using assignment to self or stranger and quantity as independent variables and self–friend distance as a covariate. The main effect of self-association remained significant, $F(1, 28) = 34.05$, $p < .001$, $\eta_p^2 = .549$. Furthermore, after adjustment, a significant interaction of association and size, $F(1, 28) = 6.98$, $p = .013$, $\eta_p^2 = .200$, was documented. The pattern of the interaction was the same as above: for stranger-associated numbers, there was a significant advantage for smaller versus larger numbers, $M_{\text{difference}} = 2.49$, $SE = 0.93$, $p = .012$, but no such difference emerged for self-associated numbers, $M_{\text{difference}} = .45$, $SE = 1.15$, $p = .696$.

For d' , a larger self–stranger distance predicted a higher d' for responses to stranger-paired stimuli larger than 5, $r(29) = .394$, $p = .031$. Thus, a 2×2 within-participants ANCOVA was conducted on d' including self–stranger distance as covariate. However, adding the covariate did not change the overall pattern of results. The main effect of size remained significant, $F(1, 28) = 11.42$, $p = .002$, $\eta_p^2 = .290$. There were no other significant effects.

Empathy Measures

As in Experiment 1, there was no significant correlation between interpersonal reactivity subscales (Davis, 1983; Keaton, 2018) and our outcome variables (see the [online supplemental materials](#)). Thus, empathy was not considered further.

In summary, Experiment 2 found evidence for prioritization of self-paired stimuli, when the self was paired with simple abstract numeric concepts (e.g., “larger than 5”). Higher self–friend distance significantly predicted lower RTs to self-paired numbers larger than 5. After adjusting the association of RT and friend–stranger distance, there was a significant interaction of self-association and symbol in RT, reflecting slower responses when large numbers are paired with the stranger compared to when small numbers are paired with the stranger.

General Discussion

This study is the first to demonstrate that the SPE can be observed with symbolic number—both for specific number symbols and abstract concepts such as “larger than 5.” The results of Experiment 1 provide evidence in favor of the first hypothesis, that participants respond more rapidly and more accurately to self-paired versus stranger-paired stimuli when specific number symbols (2 and 8) were linked with the self. A similar advantage for self-assigned information emerged in Experiment 2, when participants associated the self with a more abstract numeric magnitude (larger or smaller than 5).

In particular, the present findings expand on earlier studies showing that SPEs emerge with naturally occurring features of stimuli such as conjunctions of basic features like numerosity, color or shape (Schäfer et al., 2015), tone frequency (Stolte et al., 2021), and symmetry (Vicovaro et al., 2022). However, our study shows that self-expansion may also consider more complex information, such as the identity and magnitude represented by symbolic number—even though symbolic number stimuli are culturally specific artifacts that require highly specialized processing in the brain (e.g., Fischer & Shaki, 2018). Thereby, they speak to a basis model of the self (Northoff, 2016) which postulates that self-expansion (e.g., assigning relevance to the self to stimuli) is domain general that is, unrestricted in the information it can take into account.

Interactions between assignment to self or stranger, the size of numbers, and the frame of numbers were also investigated. In Experiment 1, no interaction of self-association, number type (natural, negative, ordinal), and/or the number symbol shown (2, 8, or pseudo) was observed. Thus, there was no evidence against the null hypothesis that the SPE was not affected by numeric value (2 or 8) or the context in which the number is placed (e.g., natural, ordinal). This might suggest that the embodied representation of symbolic number does not show congruence-related processing benefits with the self-as-concept. However, the observed effects may have been affected by the counter-balanced order of the associations made with self and stranger (e.g., self is 8, then stranger is 2; vice versa).² A follow-up analysis presented in [Supplemental Material 1 in the online supplemental materials](#) revealed that the order of conditions interacted with assignment to the self and stranger and symbol type. When 2 was associated with the self first, the participants were significantly faster on the 8-stranger pair than when 8 was paired with the self first. Therefore, it is possible that association-related learning order effects may have masked the effect of numbers on the SPE. Future studies should use a between-group design to avoid cross-over learning effects.

It is important to note that Experiment 1 only used two number symbols: 2 and 8. The magnitude difference may have been too small to elicit an interaction. For example, if the difference was more extreme (e.g., 2–800), an interaction may have been more likely. Using only two numbers, strategically, participants may have also perceived the numbers as symbols (e.g., assign the self to the symbol “8”) and ignored the value or the magnitude of the numbers (e.g., assign the self to the larger number). Previous research has suggested that self-prioritization often occurs only when the self-association is task-relevant (Caughy et al., 2021; Desebrock, Barutchu, & Spence, 2022)—thus, if participants used symbolic identity-based encoding, no interactions may have emerged simply because the numeric values of the numbers were task-irrelevant. Experiment 2 further showed that an interaction does indeed occur in a task that required to actively use numeric value.

In Experiment 2, there was no significant interaction between quantity and the associations formed between self and stranger for relative RT, nor for d' . However, for RT, the interaction became significant after adjusting for friend–stranger distance which predicted slower RT to self-paired stimuli smaller than 5. Participants may have responded more rapidly to stranger-assigned numbers below five as compared to stranger-assigned numbers above five. There was no such effect for self-assigned numbers. Interestingly, the learnt order of the associations between self and stranger and <5 and >5 had no effect in Experiment 2 (see [Supplemental Material 2 in the online supplemental materials](#)). In Experiment 2, the magnitude of the numbers had to be processed consciously to solve the task (i.e., if a number is higher or lower than five), unlike in Experiment 1 where number associations with self could be made symbolically. Associating labels with numeric quantities requires more conscious effort than associating labels with symbols, thus overriding (potentially subconscious) order effects. Collectively,

² Additionally, due to a technical failure, the instructions used in the ordinal condition provided a general, rather than specifically ordinal frame. While the frame was still consistent with the use of ordinal numbers, this may have impacted results.

these studies provide some of the first evidence that there are number-related congruence effects in the SPE matching task. However, we acknowledge the risk of both Type I and Type II errors, and that larger-scale studies are needed to confirm these findings.

Furthermore, the interaction pattern did not support our original hypothesis, that performance would be faster, and more accurate, when the self is paired with large versus small numbers. Instead, stranger-paired numbers smaller than five were advantaged compared to stranger-paired numbers that were larger than five, without a comparable effect for self-assigned stimuli.

Negative attitudes and behaviors toward strangers (e.g., avoidance, anxiety) are a hallmark of normal child development (e.g., Ainsworth & Bell, 1970), so there may be a semantic association between strangers and negative valence. Similarly, empathy-related brain responses to others' gains on gambling tasks are attenuated for strangers compared to familiar others (Ma et al., 2011; Motomura et al., 2015). If "less is bad," this would explain a congruence effect characterized by processing advantages for a pairing of strangers with small numbers. Similarly, people may have a bias to assign less to the stranger than to themselves, which may often be overridden by conscious effort (e.g., when deciding which piece of cake to give to someone else). This might also explain why participants were quicker to respond to smaller numbers paired with the stranger, compared to larger numbers paired with the stranger.

Our findings may also reflect social attention: It may be advantageous to consider how much others have, rather than to focus on the self (e.g., for trade, and when comparing oneself to others). In particular, information concerning strangers who have less than oneself, or are assigned a lower number, may be prioritized, because this information invites a positive, self-serving comparison (Mezulis et al., 2004; Sedikides & Strube, 1997; Sedikides et al., 2003, 2005; cf. Heine, 2005). Still, one might therefore expect a link with empathy or personal distance, which did not emerge in this study. In a previous study, empathy predicted the SPE (Desebrock, Barutchu, & Spence, 2022). However, these authors used a movement adaptation of the shape-label matching task and in-person testing. For personal distance, the measure had to be adapted in this study due to technical constraints. Future studies should test whether task parameters or features of the online testing environment or adaptation of IRI or personal distance may influence the relationship between empathy, personal distance, and the SPE.

Furthermore, observed facilitation when the stranger was paired with small numbers raises the question why we did not observe the reverse effect, that is, an advantage for the self when paired with large numbers.

First, we could challenge the metaphor that the concepts of the self and stranger fall on a continuum, like high and low, with other concepts like "Friend" or "Mother" falling in between (e.g., Stolte et al., 2021; Sui et al., 2012). This fits with the idea that self-specificity is assigned to external stimuli by matching it to information stored within the object self (i.e., "does this sequence of sounds match my name?"). Consequently, congruence effects involving the self could emerge, because of the semantic structure of the self-as-concept (e.g., it may be easier to store or retrieve self-stimulus associations which agree with beliefs about the self). However, there is no a priori reason to assume that stored schemata concerning the concept of the "stranger" ("for strangers, less is better") should have analogs in the self-as-concept ("for myself, more is better"). Thus, congruence effects involving the stranger need not imply that there should be an analogous effect for the self.

Intriguingly, the results of Experiment 2 demonstrated an interaction in RT, but not for d' . Potentially, participants prioritize accuracy in our matching task, thus masking any potential interaction in d' . Participants may adjust speed-accuracy tradeoffs to maximize rewards while minimizing punishments (e.g., Edwards, 1965; Gold & Shadlen, 2002; Heitz, 2014). In the present study, participants were given negative feedback for incorrect responses—therefore, responding accurately may have been reinforced, while there was no comparable reinforcement for responding quickly.

Furthermore, our study found that, in Experiment 2, personal distance, in particular, self-friend distance and friend-stranger distance correlated with RT and d' , respectively, when participants associated abstract quantities with the self or stranger (see [Supplemental Material 2 in the online supplemental materials](#)). At the surface, this is in line with previous research which found that a larger personal distance between the self and the stranger affects performance on the matching task (Desebrock, Spence, & Barutchu, 2022; Sui & Humphreys, 2015). However, in this study, the effect of personal distance was not observed when the participants paired the self with specific number symbols. In addition, the observed effect only emerged in some conditions. For example, self-friend difference predicted slower RTs specifically to small numbers paired with the self. Similarly, while previous studies found that empathy affects performance on the matching task (Desebrock, Spence, & Barutchu, 2022), no such effect was evident here.

This may have several reasons. First, research on individual differences in the SPE has typically focused on self-bias, a composite measure for the relative advantage for self-assigned compared to nonself-assigned stimuli (Desebrock, Spence, & Barutchu, 2022; Moseley et al., 2022; Sui & Humphreys, 2015). To avoid collapsing across the self/stranger assignment condition, this study did not use self-bias. Instead, personal distance and empathy were correlated with raw performance measures (relative RT, d') within each condition. While self-bias encodes how performance in the self- and stranger-conditions relates, this information was not available in the raw performance measure. Thus, the observed inconsistencies with previous research may reflect the choice of dependent variables in this study.

Furthermore, the impact of personal distance may depend on task context. For example, in Experiment 2, a larger self-friend distance predicted slower RTs to numbers over 5 assigned to the self. No similar effect was observed for numbers smaller than 5. This is surprising, as, typically, larger personal distance is linked to an increase in self-prioritization and quicker performance for self-paired stimuli (Desebrock, Spence, & Barutchu, 2022; Sui & Humphreys, 2015). Speculatively, this may reflect a shift in response strategy—In this study, participants received positive feedback for correct answers, but not fast answers. As noted above, this reinforcement may lead participants to prioritize accuracy over speed. Possibly, a larger personal distance may increase participants' responsiveness to such reinforcement, resulting in prioritization of accurate responding and slower RTs. However, it is not entirely clear why this would be specific to number stimuli larger than 5. Further research is needed in order to understand when and how representations of the closeness between others and the self may influence the SPE across task contexts.

It is important to acknowledge some limitations: First, our studies have used only a small set of number symbols. Further research should test self-stranger matching tasks with unrestricted number

sets (e.g., randomly drawn rational numbers). Second, our experiments were affected by attrition—for example, in Study 2, only 30 out of 50 participants completed the task and scored above our minimum accuracy threshold. Therefore, our sample may have differed from the wider population of eligible Prolific participants (e.g., in conscientiousness). However, most studies of the SPE have recruited university students, which also differ from the general population in important respects (Henrich et al., 2010; Woods et al., 2015). Third, unlike in-person experiments, participants completed our study without any in person interaction with the experimenters, though the perceived presence or absence of the experimenter may affect performance (Barutchu & Spence, 2020).

In conclusion, this study demonstrates that the SPE emerges for both concrete number symbols such as “2,” and for more abstract numeric evaluations (“numbers larger than 5”), showing that self-biases emerge even for complex socially and culturally defined concepts like symbolic numbers. Our findings also suggest that the SPE is not limited to individual symbols, but can apply to a range (e.g., <5 or >5 in our case) or perhaps even categories of objects. There was also some evidence of a complex interaction between the SPE on RTs and the magnitude of numbers. The interaction also depended on whether participants matched specific number symbols or more abstract concepts (e.g., >5) with the self or a stranger, and the order in which associations were learned. This interaction effect may indeed reflect congruence effects.

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