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# Does self-prioritization affect perceptual processes?

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**ABSTRACT**
The tendency to prioritize information related to the self (or socially salient information) has been established for several cognitive tasks. However, earlier studies on this question suffered from confounds such as familiarity and intimacy. Recently, a series of studies overcame this limitation using newly learnt associations between geometric shapes and identities. Results from these studies have been argued to show that self-prioritization affects perceptual processing. In two studies, we replicated and extended the original shape-identity association paradigm to test an alternative hypothesis that self-prioritization does not affect perceptual processes but arises from potential memory differences introduced during the formation of associations. We found that induced memory differences lead to response patterns similar to those that have been attributed to changes in the perceptual domain. However, even extended learning undertaken to equate memory for various identity-based associations did not eliminate the effects of self-prioritization, leaving the question open if the differences are cognitive or perceptual in nature. The current evidence can be explained both in terms of memory differences and perceptual effects. Hence, we strongly recommend that the existence of perceptual effects of self-prioritization should be investigated directly rather than through changes in reaction times in match–non-match tasks.

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We are confronted daily with more information than can be processed. How we cope with this flood of information has been studied for at least 50 years (Carrasco, 2011; Cherry, 1953; Maunsell, 2015; Moray, 1959). One criterion that is likely to influence the selection and processing of information is its relation to the self. Information that is related or that has been considered in relation to the self seems to be preferentially processed relative to any other information. Interestingly, such references to the self have been shown to influence several cognitive mechanisms. That is, self-reference has been argued to guide attention (e.g., Bargh, 1982; Moray, 1959; Wood & Cowan, 1995), influence perception (e.g., Sui, He, & Humphreys, 2012; Sui, Liu, Mevorach, & Humphreys, 2015), modulate preference (Debevec & Romeo, 1992; Koole, Dijksterhuis, & van Knippenberg, 2001; Nuttin, 1985) and enhance memory (e.g., Bower & Gilligan, 1979; Rogers, Kuiper, & Kirker, 1977; Turk, Cunningham, & Macrae, 2008).

Specifically, attention has been shown to be captured quickly and automatically by stimuli related to the self (Alexopoulos, Muller, Ric, & Marendaz, 2012), even when it is disadvantageous (Alexopoulos et al., 2012; Bargh, 1982; Brédart, Delchambre, & Laureys, 2006; Wolford & Morrison, 1980; but see Devue & Brédart, 2008). Early studies investigating the effect of self-related information, also referred to as *social salience*, employed established self-associations like the participants' own names as stimuli. A famous example for self-reference guided selective attention is the *cocktail party problem*. Cherry (1953) and other researchers who conducted similar studies (e.g., Moray, 1959; Wood & Cowan, 1995) found that, in a noisy environment (e.g., a party), we can follow one conversation by ignoring all other conversations to the point where we cannot recall anything that was mentioned in these ignored conversations. Yet when our name is mentioned in such an ignored conversation, our attention is automatically diverted to the source (Moray, 1959), and remains there for a short period of time (Wood & Cowan, 1995). This ongoing monitoring of the ignored "channels" has been considered useful, as information presented after self-referential information is likely to be of importance to oneself (Wood & Cowan, 1995). However, one's own name is not the only form of self-referential information that has been shown to capture attention. In a

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study using descriptive attributes (e.g., independent, arrogant, ambitious), participants' attention was shown to be drawn to these attributes only for participants that had previously reported that they apply to them (Bargh, 1982).

As noted above, these social psychological studies are based on self-associations that have been learnt over a lifetime (e.g., one's own name). Such stimuli have the obvious confound that they are over-learnt and hence any effects they produce might be attributed to familiarity and the extent of learning rather than associations with the self. More recently, therefore, effects of social salience have been explored using newly formed associations between stimuli and the self (Sui et al., 2012). For example, in the study by Sui and colleagues, participants were asked to quickly form associations between simple geometric shapes (e.g., circle, triangle, square) and different identities (e.g., themselves, their best friend, a stranger). Here, participants were verbally instructed that, for example, "a stranger is a circle, Katrin [*the participant's best friend*] is a triangle and you are a square." These new associations were then tested in a match–non-match task, where participants were presented with either pairings that matched the instructions (e.g., you–square) or pairings that did not match the instructions (e.g., stranger–triangle). Using this paradigm, the researchers found faster and more accurate responses for the self-associated shape than for pairings between others and shapes. Further, they found that a reduction in luminance contrast of the shapes had less influence on task performance when the presented shape was related to the self, than when the shapes were related to others. They concluded that self-reference influences the perceptual processing of stimuli associated with the self. This study also suggests that new shape–identity associations can be established quickly and are therefore an efficient way to study effects of self-reference, while ruling out familiarity as a factor.

Further evidence that newly established associations with the self can influence perception comes from a follow-up study using shape–identity associations in a global–local task (Sui et al., 2015). A global–local task involves stimuli that have two levels: a global shape (say a triangle) made up of local shapes (in congruent trials the strokes of the global shape would be made up of several smaller triangles and in incongruent trials it would be made up of some other shape, such as several smaller circles); participants in this experiment are asked to quickly name either the global shape ("triangle") or the local shape ("circle"). In such a task, the shape associated with the self interfered with shape naming in incongruent trials. For example, if the self-related shape was presented at the local level, it would interfere with the naming of the global level shape, and vice versa. However, the shapes associated with others did not influence shape naming performance. It was argued that the self-related shape yielded response patterns similar to an object with higher physical salience. This suggests that social salience can influence attention in a way similar to physical salience and that newly established self-referential stimuli are able to grab attention as well as established ones do.

However, some recent experiments have failed to find an effect of self-reference on the perceptual system. For example, Siebold, Weaver, Donk, and van Zoest (2015) used a similar associative learning paradigm in several oculomotor visual search tasks. Here, associations were formed between the self, a stranger and two orthogonally tilted lines (45° left and right). Participants were asked to make an eye movement to one of two tilted lines, which were presented in opposite hemi-fields at about 8° eccentricity, embedded in a grid of vertical lines. In this paradigm, differences in eye movement latencies would indicate that self-reference can influence overt attention. However, no such effect of self-reference was found in the visual search task. Nevertheless, the study was able to replicate the original findings of Sui et al. (2012), finding shorter reaction times for the self-related line in a match–non-match task. These findings suggest that self-reference does not affect voluntary overt visual selection, even if it affects responses in a match–non-match task.

Additionally, it has been well established that associations with the self not only influence attention but also affect memory. What has been termed the self-reference effect (SRE) is the facilitation of memory for nouns, traits and incidents that have been related to the self compared to those that were not considered in relation to the self (e.g., Bower & Gilligan, 1979; Rogers et al., 1977; Turk et al., 2008). In studies investigating the SRE, memory is usually tested in a surprise recall task at the end of a range of judgment tasks (Symons & Johnson, 1997). Rogers et al. (1977) compared memory for trait words when participants judged their relatedness to the self versus when they judged aspects of the word's appearance (i.e., "were the letters capitalized?"), phonetics, semantics and meaning, and found that more trait words were recalled when the task was to judge their relation to the self than for any of the other judgments. In a meta-analysis of 129 studies, Symons and Johnson (1997) identified factors that influence the size of the SRE. They found that the SRE was more pronounced when self-reference was compared to semantic encoding, than when it was compared to encoding the relation to another person (e.g., Does the attribute describe your mother?). Further, when comparing self-reference with reference to another person, intimacy (not familiarity) was shown to modulate the size of the SRE. That is, the more intimate the relationship to the other person the smaller the benefit for self-reference in memory.

Most of these findings come from studies where self-reference is used explicitly in judgment tasks. Although people might be using self-reference actively as a technique to form memories, self-reference might also be able to influence memory unintentionally. Turk et al. (2008) compared the influence of self-reference when reference to the self was made explicit compared to when it was implicit. Following either a self-referential stimulus (e.g., own face or name) or non-self-referential stimulus (e.g., face or name of a gender-matched celebrity), participants were shown trait adjectives and either asked to judge if the traits describe the person shown before (explicit) or if the trait adjective was presented above or below the fixation mark (implicit). In a surprise memory task, memory was found to be better for attributes presented following the self-related stimulus compared to the other-related stimulus, and better when traits were judged in relation to the person compared to its position. Although the memory effect was bigger in the explicit judgment task, it was shown that memory can also be automatically influenced by self-reference. That is, presenting a stimulus in close proximity with self-referential information seems to be enough to make it more memorable than when it is presented alongside other-referential information.

A number of theories have been brought forward to explain how considering information in relation to the self might facilitate memory for this information. Of particular importance are four proposals: depth of processing, elaboration, connectivity and organization. First, according to the depth of processing theory (Craik & Lockhart, 1972), evaluating the physical appearance of a descriptive attribute word (e.g., "confident') leads to shallow processing of the word and hence to a weaker memory trace than when evaluating if the attribute is descriptive of one's personality (deeper processing) (Eysenck & Eysenck, 1979). Second, elaboration is thought to facilitate memory (Craik & Tulving, 1975; Eysenck & Eysenck, 1979) and self-reference might lead to increased elaboration. For example, when asked to judge if an attribute is descriptive of oneself, we might consider the self in a range of situations to reach a conclusion, whereas when asked if the first letter of the attribute is a "c" we are unlikely to consider anything but the first letter of the word. This difference in elaboration leads to substantial differences in memory for such words. Third, the self as a memory construct can be involved in a large number of possible connections, based on the large amount of pre-existing information already connected to it (Ingram, Smith, & Brehm, 1983; Keenan & Baillet, 1980; Markus, 1977). Strength of connectivity can lead to improved memory for such words. Fourth, facilitation effects based on self-reference can also be attributed to better organization of information. That is, when evaluating if attributes are descriptive of oneself, they will likely be organized into those that are and those that are not and therefore can be better recalled (Klein & Kihlstrom, 1986). Therefore, self-referencing likely leads to deeper processing of stimuli, with increased elaboration, increased conceptual connectivity and better structured information, thereby leading to more stable memory traces (Kihlstrom, 1993; Symons & Johnson, 1997).

It is clear that the evidence outlined above suggests that both attention and memory are influenced by self-reference or self-prioritization, even with novel self-associations (perhaps with the exception of overt attention; Siebold et al., 2015). This should not come as a surprise considering that attentional and memory processes are closely intertwined (Awh, Vogel, & Oh, 2006; Baddeley, Lewis, Eldridge, & Thomson, 1984). With attention working as a gatekeeper for memory, self-prioritization is likely to influence the probability of memory formation in addition to the above-mentioned factors that modulate memory encoding and consolidation. Therefore, self-association could lead to increased engagement of attention compared to other-association or evaluating an item's semantics. This in turn might increase the likelihood with which this attribute is made available to memory and thereby the likelihood with which it is later recalled. However, the interaction between attention and memory is not a one-way street; attention can also be influenced by memory. When activated (e.g., through an associated retrieval cue), information that is stored in long-term memory is made temporarily available to working memory (Baddeley, 2000; Cantor & Engle, 1993; Ericsson & Kintsch, 1995; Ranganath, Johnson, & D'Esposito, 2003). For items as different as faces (Downing, 2000) and colour and shape singletons (Olivers, Meijer, & Theeuwes, 2006; Soto, Heinke, Humphreys, & Blanco, 2005; but see Woodman & Luck, 2007), it has been shown that actively holding them in working memory can capture attention. This the case for both visually and verbally presented items (Soto & Humphreys, 2007). This suggests that, when investigating the effect of self-reference, attention might be drawn to a stimulus not because of its relation to the self, but because it is *more active or stable in memory*. We plan to test this possibility in the current study.

Furthermore, when attention is assessed in terms of reaction times, discrepancies can arise from differences in the certainty with which a response is made. Reaction times were shown to be faster when memory was more stable (Dewhurst, Holmes, Brandt, & Dean, 2006). Therefore, differences in reaction times could be incorrectly attributed to changes in attention allocation to or perceptual salience of self-referential stimuli when they in fact originate from differences in memory-based certainty and accuracy. Anecdotal evidence suggests that three shape–identity pairs can be learnt quickly. From this it has been implicitly inferred that memory processes are the same for all pairings (such as those in the Sui et al. studies). Hence reaction time differences have been ascribed to attentional and/or perceptual processing. However, introducing time pressure by terminating trials after a short response period can also reveal differences in the stability of the formed associations that might otherwise not be obvious, producing the same results.

Due to the close relationship between attention and memory the effect of self-reference might not be attributable exclusively to one or the other, and could even be based on an interaction between attention and memory. Therefore, when trying to disentangle the effects of self-reference on attention and on memory, one of them has to be carefully controlled while the other is studied. It is hard to control for these differences using established referential stimuli like one's own or others' names and faces. Even when the stimuli representing the other are chosen to be well known, they are still likely to be less familiar (e.g., own face compared to that of a celebrity). Using newly established stimulus–identity references can overcome this problem. However, since the associations between stimuli and identities need to be learnt first, these associations are also susceptible to differences in memory processes when they are not controlled for. As is evident from the literature on the SRE for memory, relating something to the self leads to a more stable memory representation than when relating it to others (Symons & Johnson, 1997).

The associative learning procedure typically used in such studies (e.g., Siebold et al., 2015; Sui et al., 2012) relies on the fact that participants can learn the associations between shapes and identities rapidly by listening to a statement (once or a few times at most) about their connections. Here, the associated shapes and identities are usually presented aurally (e.g., the sentence "Kevin [*the participant's best friend*] is a square, you are a triangle and a stranger is a circle" is uttered through a headphone). In such a situation, given the well-documented SRE advantage in memory processes, it is possible that self-related associations are represented in a stronger and more stable manner than are non-self-related associations, leading to poor performance on non-self-related trials in subsequent tasks. In this reading, the perceptual and attentional systems do not differentially process the subsequently presented pairings, but it is the differences in the stability of their memory, or in other words the strength of the shape–identity binding, that translates to the observed behavioural differences. This explanation can also account for the so-called perceptual effects of the self on behaviour, such as the lack of reduction in performance for self-associations when stimuli have lower luminance contrast (Sui et al., 2012). Here, it is possible that the self-association is strong and hence leads to quicker and more accurate responses, even when the stimulus itself is weakly perceived, whereas the other representations are weakly represented and cannot drive high performance even at higher contrasts. Thus, the results do not unambiguously suggest that self-related stimuli are perceived or attended differently than non-self-related stimuli (e.g., a low contrast self-stimulus is not perceived as having higher contrast). The results could be attributed to memory differences. Similarly, the interference induced by self-associated shapes in the global–local task (Sui et al., 2015) can also be explained as due to stronger representations for self-associations, which can influence responses, and not necessarily due to perceptual differences. Therefore, in the studies using such short and uncontrolled associative learning paradigms, it is unclear whether the results are driven by perceptual or memory differences.

The current study was designed to test the hypothesis that the observed performance differences as a function of the kind of associations made with novel stimuli were due to differences in the strength of memory representations for the newly formed associations rather than perceptual or attentional effects. In two experiments, we hoped to disentangle the effect self-association has on attention and on memory. In Experiment 1, we used the original associative learning paradigm introduced by Sui et al. (2012, Experiment 1) and attempted to replicate their findings. Additionally, we introduced an extended learning paradigm. In this paradigm, participants were not only told which shapes represented which identities, but they also practiced on these associations until they reached error-free performance. This should eliminate any memory based differences among all shape–label pairings; we then tested if the effects of self-reference remained when possible differences in memory were controlled for. The second experiment approached the same question from the opposite direction: it was designed to test if differences observed by Siebold et al. (2015) and Sui et al. (2012) could be produced when differences in memory were artificially induced, even without any involvement of the self. Here, associations were formed between shapes and *meaningless* word-like non-words. Exposure to these associations during learning was manipulated to explicitly produce differences in memory representations. That is, we sought to introduce a difference in memory between the different shape–non-word association by manipulating the frequency with which a shape–non-word pair was presented during training. We then tested if the behavioural performance resulting from such memory differences matched those ascribed to perceptual effects in the literature. If it is the case that the effect of self-prioritization is based on differences in memory, and is not due to changes in the perceptual domain, we would expect that extended associative learning will eliminate the effect of self-prioritization. Further, introducing memory differences for non-identity related information should evoke response patterns that resemble those of self-prioritization. These findings should allow us to arbitrate the debate between perceptual and cognitive origins of the self-prioritization effect.

## Methods: Experiment 1

This experiment pursued two goals. First, it attempted to replicate the findings of Sui et al. (2012). Second, it tested an alternative explanation for the effect of self-prioritization in match–non-match tasks. Towards these ends, we implemented the same paradigm as Sui et al. (2012) and added two further conditions that investigated the role of memory in the reported self-reference effects. In the latter conditions, we eliminated potential differences in memory across different shape–identity associations using extended associative learning; we then tested if the advantage for self-related associations over non-self-related associations in terms of reaction times and accuracy persisted.

### *Participants*

Seventy-two participants (24 per learning condition, 51 female, 22.2 $\pm$ 4.8 years) were recruited from the student population at the University of Aberdeen. They were compensated for their participation with either course credit (year 1 and 2 Psychology undergraduate students) or £5 (all other students). Participants had normal or corrected-to-normal vision. Participants who had previously taken part in experiments where they were asked to form associations between shapes and identities were excluded from the study. Informed written consent was obtained. The study was approved by the ethics committee of the University of Aberdeen.

The number of participants was based on power analysis conducted for the main effect of association type (e.g., to self, friend or other) in a within-subjects design using the G*Power3 application (Faul, Erdfelder, Lang, & Buchner, 2007). The effect size used for this calculation was the smallest reported effect size ($\eta^2 = 0.41$) in Sui et al. (2012) for the comparison of interest (Experiments 1 and 2a). For a recommended power of 0.95 (Open Science Collaboration, 2012), 14 participants were considered necessary to uncover an effect at an α-level of 0.05 and 19 participants at an α-level of 0.01. We recruited 24 in order to allow for complete counterbalancing.

### *Material and stimuli*

The visual stimuli were designed to match those described by Sui et al. (2012) and were generated in MATLAB using Psychophysics toolbox extensions (Brainard, 1997; Kleiner et al., 2007; Pelli, 1997). All stimuli were displayed in black on a white background on a 19-inch Dell TFT Screen (1280 x 1024, 60 Hz). Viewing distance was approximately 57 cm.

Three identity words (*you, friend, stranger*), three geometric shapes (*circle, triangle, square*) and three geometric labels (the words *circle, triangle, square*) were used as stimuli in an associative learning task and in a match–non-match task. Line drawings of geometric shapes had a size of approximately 3.8 × 3.8 degrees. Words were presented in Geneva font and had a height of approximately 1.6 degrees. Participants wore headphones to receive auditory instructions and feedback. All spoken instructions were generated using a computer voice.

## *Procedure*

The experiment consisted of two tasks: an associative learning task and a match–non-match judgement task.

### *Associative learning task*

To learn associations between shapes and identities, all participants were told which identity was represented by which shape. For example, a participant was told: "you are a circle, Kevin [the participant's best friend], your friend, is a square, and a stranger is a triangle." This association was learned by the participant in one of three ways:

(1) Standard learning procedure (as used by Sui et al., 2012): participants were given verbal instructions indicating which identity was represented by which shape. They received this instruction once via the headphones.
(2) Shape–identity learning procedure: after receiving verbal instructions, as in the standard learning procedure, participants performed an extended shape–identity matching. This learning took place over multiple blocks of six trials each. In half of the trials (three trials), a shape was presented and the participant was asked to pick its identity among all three options using a mouse. In the other half (remaining three trials), an identity word was presented and the participant was asked to pick the appropriate shape. All shapes and identities were tested within a block. We describe below (see Figure 1a) the procedure when a shape was presented and its identity was to be reported; the procedure is similar when an identity was presented and the corresponding shape was to be reported – the respective stimuli are flipped: 500 ms after a fixation mark was centrally presented, one of the three shapes appeared above the fixation mark (~3.5 deg eccentricity on the vertical meridian) and the three identity words were presented in a row as response options below the fixation mark (~3.5 deg, in random order). Participants were asked to click on the identity that matched the presented shape. Trials were terminated either when a response was made or when 1500 ms

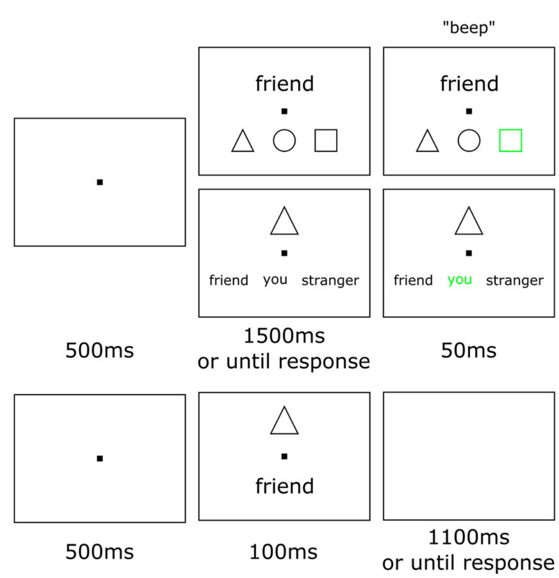


**Figure 1.** Sequence of a trial for a) the shape identity learning procedure and b) the match non-match task.

had passed from stimulus onset, whichever was earlier, in order to encourage rapid responses and hence to improve memory strength. Subsequently, the correct response option was highlighted and auditory feedback was provided indicating if the response was correct, too slow or wrong. Participants performed the shape–identity matching task until performance (accuracy) was error-free for each association (no error or time out for three consecutive blocks, with training being mandatory for a minimum of six blocks).

(3) Shape–label–identity learning procedure: This procedure was exactly the same as the shape–identity learning procedure described above (#2) except that the line drawings of shapes were replaced by their label words (for example, the word "circle" instead of an actual circle). Thus, any effects on self-prioritization in this group of participants cannot be attributed to any sort of perceptual or stimulus–response learning/associations (since testing on the match–non-match task involves shapes and not shape-labels; see below). Participants were randomly assigned to one of these three learning conditions.

### *Match–non-match judgement task*

This task (Figure 1b) was an exact replication of Sui et al. (2012). A fixation mark was presented centrally; 500 ms after trial onset one of the symbols was presented approximately 3.5 degrees (centre to fixation distance) above the fixation mark along the vertical meridian and one of the identity words was presented below the fixation mark (~3.5 deg centre to fixation) along the vertical meridian. Stimuli were presented for 100 ms followed by a blank screen, which lasted until response or for 1100 ms, whichever was earlier. Participants were asked to report, as quickly and accurately as possible, if the displayed shape–identity pairs matched one of the learned associations (match trial) or if they did not match any of the learned associations (non-match trial). Response was given by pressing one of two keys with the two index fingers. The assignment of the keys (match or non-match) was counterbalanced between participants. Auditory feedback was provided after each trial. Trials with response times shorter than 200 ms (anticipatory responses) and trials where no response was made before it was terminated were reinserted at random locations among the remaining sequence of trials. The participant's behavioural performance in the form of average accuracy was displayed on screen after each block.

The session started with 12 practice trials allowing the participant to become familiar with the task, followed by nine blocks of 60 trials each. Match and non-match trials appeared equally often per condition (self-match, self-non-match, friend-match, friend-non-match, stranger-match and stranger-non-match).

For participants in one of the extended learning conditions (the shape–identity and shape–label–identity learning groups) match–non-match judgement blocks were interleaved with further learning blocks. These top-up learning blocks were presented to counteract possible memory decay for the different shape–identity associations and to ensure that the memory associations for each identity were equally strong (in terms of accuracy). Top-up learning blocks had the same structure as the learning blocks presented at the beginning. Blocks were repeated until performance was error-free (no error or time out) for three consecutive blocks.

## *Results*

In Experiment 1, participants formed three shape–identity associations in one of three learning conditions before performing the match–non-match task: (1) the standard learning condition (replication of Sui et al., 2012), (2) shape–identity learning, or (3) shape–label–identity learning. Figure 2 shows the median number of learning blocks participants completed before reaching error-free performance in learning conditions 2 and 3 over the course of the experiment. Block "0" refers to training before the first match–non-match task block. Overall, participants needed several blocks of training before they could accurately remember and report the identity of a shape (and vice versa). During the initial training period, participants needed a median of 30 blocks (~180 trials) in the shape–label–identity condition and 18 blocks (~108 trials) in the shape–identity condition before they could accurately report all three identity–shape associations. That is, auditory presentation of assigned associations was not sufficient for ensuring that memory strength was equal across the three associations (as implicitly assumed in previous studies), especially under time-limited conditions like

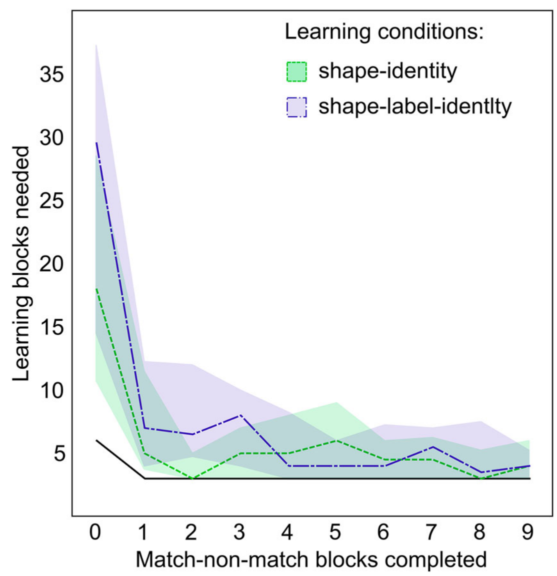


**Figure 2.** Median number of training blocks needed to reach error-free performance for both extended learning conditions (green dashed line: shape-identity learning; blue dashed-dotted line: shape-label-identity learning) compared to the minimum number of blocks (black solid line). Shaded areas show the 25th and 75th percentiles.

those used in the match–non-match task. Thereafter, top-up training blocks were reasonably close to the minimum number of blocks that we imposed for continuing onto the match–non-match task. These findings emphasize the need for caution regarding the implicit assumptions made about memory requirements in such tasks.

We tested the effect of the different learning conditions on the self-prioritization effects by analysing accuracy and reaction times (RT) in the match–non-match task. Trials with RTs shorter than 200 ms were excluded from the analysis, eliminating less than 1% of the trials. Median reaction times for each condition and participant were then submitted for analysis. *d′* values were calculated for each of the three associations (you, friend and stranger) to assess accuracy. Following Sui et al. (2012), a trial where a matched association (e.g., circle = you) was correctly recognized as a matched pair was called a hit. A trial was considered a false alarm for the same association when the shape (here, circle) was presented with a different label (e.g., friend) and was reported as a match. Figure 3 shows the RT and *d′* for each of the three learning conditions.

We conducted a two-way (3 x 3) mixed design ANOVA with shape–label association (self, friend and stranger) as the within-subjects factor and learning condition (standard learning, shape–identity learning, and shape–label–identity learning procedures) as the between-subjects factor, with *d′* values as the dependent variable. We found that learning conditions modulated performance ($F_{(2,69)} = 12.73$, $p < .001$, $\eta_p^2 = .270$) and so did the type of shape–label association ($F_{(1.62,112)} = 24.03$, $p < .001$, $\eta_p^2 = .258$). *d′* was higher in both extended learning conditions compared to the original learning condition,

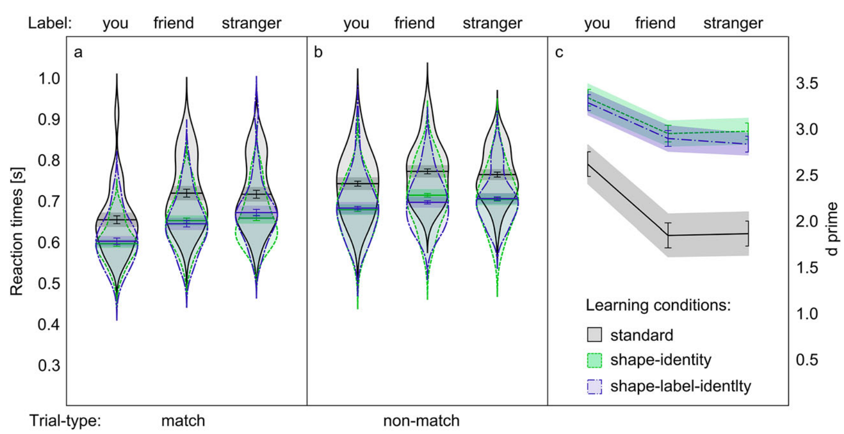


**Figure 3.** Median reaction times (left y-axis) and mean d′ (right y-axis) for experiment 1 for each of the three learning conditions (black solid line: standard; green dashed line: shape-identity; blue dashed-dotted line: shape-label-identity learning). Panel (a) shows violin plots ($n$ = 24) of reaction times for the match trials, panel (b) plots RT for the non-match trials, and panel (c) shows mean d′ across participants. Shaded areas are ±1 SEM (between subjects, to allow comparison across the learning conditions, which were tested in separate participants). Error bars show ±1 SEML&M (within subjects, to allow comparison within a learning condition across the three associations, which were tested on the same participants). Performance (both RT and d′) was better for self-associations than friend or stranger associations. This was found in all three training conditions. Further, overall performance was better in the two extended learning conditions, relative to the standard condition.

**Table 1.** Pairwise comparisons between $d'$ values for shape–identity associations.

| Association | Learning condition | $t_{(23)}$ | $p$ | Cohen's $d$ |
|---|---|---|---|---|
| You – Friend | standard | 3.274 | **.023** | .668 |
| | shape–identity | 3.115 | **.024** | .636 |
| | shape–label–identity | 2.594 | .065 | .529 |
| You – Stranger | standard | 3.685 | **.011** | .752 |
| | shape–identity | 3.566 | **.013** | .728 |
| | shape–label–identity | 3.235 | **.022** | .660 |
| Friend – Stranger | standard | −0.190 | .851 | .039 |
| | shape–identity | 0.519 | >.999 | .104 |
| | shape–label–identity | −0.219 | >.999 | .045 |

Note: Significant differences are indicated in bold. Bonferroni-Holm correction was used to correct for multiple comparisons.

respectively ($p_s < .001$). However, there was no difference between the two extended procedures ($p = .607$). $d'$ was higher for self-association than for other associations ($t_{71} = 5.01$, $p < .0001$, $d = .591$; $t_{71} = 5.84$, $p < .0001$, $d = .688$); however, there was no difference between the latter ($t_{(71)} = .074$, $p = .941$, $d = .009$). An interaction between learning condition and shape–label association was not observed ($F_{(3.24,112)} = 1.41$, $p = .242$, $\eta_p^2 = .039$).

We investigated the effect of self-prioritization further with planned pairwise comparisons between pairs of the three shape–label associations for each learning condition. In all learning conditions, $d'$ was higher for self-association compared to the other associations ($p_s < .050$); the difference between self and friend associations was only marginally significant ($p = .065$) in the shape–label–identity condition. There was no difference between the other associations ($p_s > .851$). Results of all pairwise comparisons are displayed in Table 1.

Median RT data was analysed using a 3 x 2 x 3 mixed-design ANOVA with shape–label association (self, friend, stranger) and trial type (match, non-match) as the within subject factors and the learning method (standard learning, shape–identity learning, shape–label–identity learning procedures) as the between subject factor. Main effects were observed for association type ($F_{(2,138)} = 64.8$, $p < .0001$, $\eta_p^2 = .484$), trial type ($F_{(1,69)} = 306$, $p < .0001$, $\eta_p^2 = .816$) and learning condition ($F_{(2,69)} = 7.85$, $p = .001$, $\eta_p^2 = .185$). Median reaction times were lower for the self-association than for the other associations ($p_s < .0001$), with no difference between the other (friend vs stranger) associations ($p = .535$). Further, RTs were lower for the match trials, than for the non-match trials. RTs were also higher for the standard learning procedure compared to both extended learning procedures ($p_s < .010$), with no difference between the latter ($p = .756$). Only the interaction between association and trial type yielded a significant result ($F_{(2,138)} = 22.3$, $p < .0001$, $\eta_p^2 = .244$). No other interactions were observed [three-way interaction ($F_{(4,138)} = .222$, $p = .926$, $\eta_p^2 = .006$), two-way interactions between association type and learning condition ($F_{(4,138)} = 1.88$, $p = .117$, $\eta_p^2 = .052$) and trial type and learning condition ($F_{(2,138)} = .534$, $p = .589$, $\eta_p^2 = .015$)].

To analyse the two-way interaction between association type and trial type further, planned pairwise comparisons were conducted between pairs of the three identities for the two trial types (match, non-match) separately, in each of the three learning conditions. All results are summarized in Table 2 and are corrected for multiple comparisons using the Bonferroni-Holm method. In all learning conditions, RTs in the match trials were faster for the self-association than for the other associations ($p_s < .01$). Differences were less consistent in the non-match trials; self-association RTs were faster than those for the friend association in the standard and shape–identity learning conditions ($p_s < 0.05$); responses were faster for self association than for stranger association in the shape–identity and the shape–label–identity learning conditions ($p_s < 0.05$). No difference was noticeable between friend and stranger associations in any of the learning conditions (all $p_s > 0.116$).

We will discuss the implications of these results after presenting the details and results of Experiment 2.

## Methods: Experiment 2

In the second experiment, we approached the question of whether memory-based differences could explain the observed self-related effects from a different angle. Here, we tested the hypothesis that differences in the stability of memories for shape–label (e.g., identity) associations can produce the performance patterns reported by Sui et al. (2012). That is,

**Table 2.** Planned pairwise comparisons for the reaction time data of Experiment 1.

| Trial type | Association | Learning condition | $t_{(23)}$ | $p$ | Cohen's $d$ |
|---|---|---|---|---|---|
| Match | You – Friend | standard | −5.876 | **<.001** | 1.199 |
| | | shape–identity | −6.297 | **<.001** | 1.285 |
| | | shape–label–identity | −3.870 | **.009** | 0.790 |
| | You – Stranger | standard | −3.947 | **.008** | 0.806 |
| | | shape–identity | −7.187 | **<.001** | 1.467 |
| | | shape–label–identity | −7.937 | **<.001** | 1.620 |
| | Friend – Stranger | standard | 0.199 | .844 | 0.041 |
| | | shape–identity | −0.679 | >.999 | 0.139 |
| | | shape–label–identity | −2.103 | .233 | 0.429 |
| Non-match | You – Friend | standard | −3.589 | **.015** | 0.733 |
| | | shape–identity | −4.789 | **.001** | 0.978 |
| | | shape–label–identity | −2.236 | .212 | 0.456 |
| | You – Stranger | standard | −2.643 | .116 | 0.539 |
| | | shape–identity | −4.046 | **.007** | 0.826 |
| | | shape–label–identity | −3.534 | **.016** | 0.721 |
| | Friend – Stranger | standard | 0.885 | >.999 | 0.181 |
| | | shape–identity | 2.019 | .221 | 0.412 |
| | | shape–label–identity | −2.442 | .159 | 0.498 |

Note: Significant differences are indicated in bold.

we tested if the observed behavioural patterns can be reproduced if memory differences were intentionally introduced, even in the absence of any self-related associations.

### Participants

Twenty-four participants (19 female, 22.3 ± 4.7 years) were recruited from the student population of the University of Aberdeen and received either course credits (year 1 and 2 Psychology undergraduate students) or monetary reimbursement of £5 (all other students) for their time. Students that had been asked to form associations between labels and shapes in previous experiments were excluded from the study. Participants had normal or corrected-to-normal vision. Written informed consent was obtained. The study has been approved by the ethics committee of the University of Aberdeen.

### Material and stimuli

The material and stimuli were the same as in Experiment 1 with one exception. Instead of the identity words *you, friend and stranger,* and "stranger", three meaningless non-words *fline, gyple and umry* were used. These words were chosen from a list of non-words supplied by a language expert (Dr Alexandra Cleland, personal communication). We then tested if the words had any meaning in English or other languages, including slang, by checking against google translate (http://translate.google.com) and the urban dictionary (http://www.urbandictionary.com). We selected three words that did not have any meaning.

### Procedure

The procedure for Experiment 2 was the same as that of the second (shape–identity extended learning) condition in Experiment 1, apart from two changes. First, instead of associating identities with shapes, participants learned to associate non-words with shapes and, second, memory differences between the newly associated shape–non-word pairs were introduced intentionally.

First, participants were presented with (counterbalanced) associations between geometric shapes and the non-words. For example, a participant was told: "Flyne is a triangle, umry is a square and gyple is a circle." The verbal instruction was then followed by a shape–non-word training task, which was designed to consolidate the three associations to varying degrees. As in Experiment 1, in half of the trials a shape was presented above the fixation mark and the three non-words were presented below the fixation mark as response options. In the other half of the trials, one of the non-words was presented above the fixation mark and the shapes were shown as response options. Participants were presented with 104 training trials split over four blocks. Memory differences were introduced by manipulating the exposure to the three shape–non-word pairs: 8 (low exposure), 24 (medium exposure) or 72 (high exposure) times respectively. The timing sequence of the trials during the learning part and the procedure of the match–non-match task were identical to Experiment 1.

### Results

In the second experiment, participants formed associations of varying strengths between geometric shapes and non-words. Participants were then tested on a match–non-match task to determine if the same pattern of results as observed in Experiment 1 would also be observed here, in the absence of any reference to the self.

Figure 4 shows the accuracy of reporting the appropriate shape/non-word for a given non-word/shape for the different frequencies of exposure, during the training procedure. Performance was much higher, unsurprisingly, for the shape–non-word association with the highest exposure, suggesting that the manipulation of memory strength was successful. Note that the participants had been verbally informed about the appropriate association before undergoing this training session.

We then analysed performance in the match–non-match tasks. As in Experiment 1, trials with reaction times of less than 200 ms were excluded from the analysis. Excluded trials amounted to less than 1%.

A one-way (3 level) repeated-measures ANOVA was conducted to investigate the influence of exposure (low, medium and high). A main effect of exposure was found ($F_{(2,46)} = 9.07$ $p < .001$, $\eta_p^2 = .283$). Planned pairwise comparisons (Bonferroni-Holm corrected) revealed higher accuracy for the associations that were practiced for 72 trials compared to those practiced for 24 ($t_{(23)} = 2.61$, $p = .032$, $d = 0.532$) and 8 trials ($t_{(23)} = 4.27$, $p < .001$, $d = 0.871$), respectively. However, low and medium exposure conditions did not differ in accuracy ($t_{(23)} = 1.49$, $p = .151$, $d = .303$).

A two-way repeated measures ANOVA was conducted on median RT data, with exposure (low, medium, high) and trial type (match, non-match) as within-subject factors. Both exposure ($F_{(2,46)} = 16.0$, $p < .0001$, $\eta_p^2 = .410$) and trial type ($F_{(1,23)} = 103$, $p < .0001$, $\eta_p^2 = .818$) affected performance. An interaction between exposure and trial type ($F_{(2,46)} = 15.3$ $p < .0001$, $\eta_p^2 = .399$) was also observed. Overall, RTs were faster for associations that were practiced for 72 trials compared to those practiced for 24 and 8 trials ($p_s < .001$), respectively. No difference in RTs were found between associations practiced for 24 and 8 trials ($p = .737$). RTs were lower for match than for non-match trials ($p < .0001$). Planned pair-wise comparisons revealed that exposure influenced RTs only for the match trials. Results for all pairwise comparisons can be seen in Table 3. RT and $d'$ for each exposure condition are plotted in Figure 5. Data from the standard condition of Experiment 1 is plotted alongside for reference. The response pattern (shorter RTs and higher $d'$ for the self-related/high-exposure association compared to the other associations) is the same in both conditions. However, the performance in the exposure condition appears to be slightly better. This might be attributable to the training on associations in this, but not in the standard learning condition.

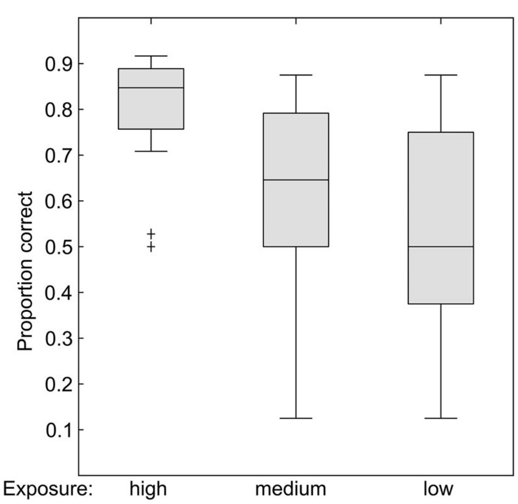


**Figure 4.** Box plots of accuracy ($n = 24$) for each exposure condition, during the learning part.

### Post hoc analysis

We had also planned to fit a hierarchical drift diffusion model (HDDM) (Wiecki, Sofer, & Frank, 2013) to the data of both experiments to be able to test if the behavioural

**Table 3.** Planned pairwise comparisons for the reaction time data of Experiment 2.

| Trial type | Exposures | $t(23)$ | $p$ | Cohen's $d$ |
|---|---|---|---|---|
| Match | 72 – 24 | −6.09 | **<.0001** | 1.24 |
| | 72 – 8 | −6.08 | **<.0001** | 1.24 |
| | 24 – 8 | −.717 | .973 | .144 |
| Non-match | 72 – 24 | −1.63 | .464 | .334 |
| | 72 – 8 | −1.22 | .707 | .249 |
| | 24 – 8 | 0.57 | .576 | .116 |

Note: Significant differences are indicated in bold. $p$-values are Bonferroni-Holm corrected.

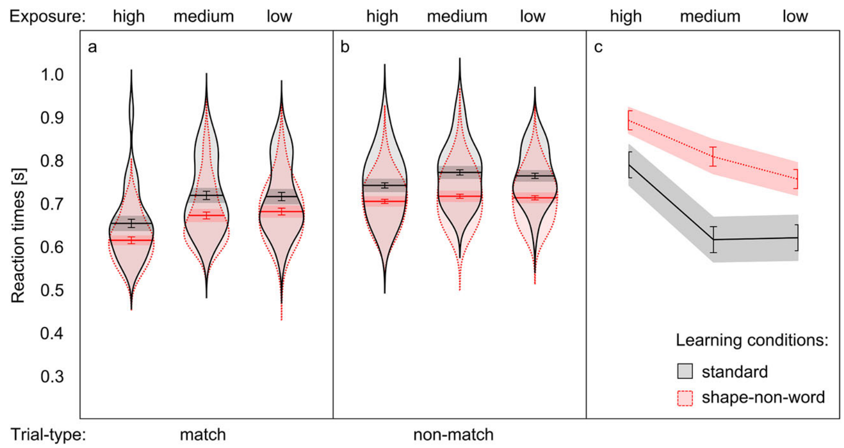


**Figure 5.** Median reaction times and mean $d'$ data for Experiment 2 as a function of exposure during learning (red dotted line). The standard condition of Experiment 1 (black solid line) is shown for reference (identities you, friend and stranger compared to exposures high, medium and low, respectively). Note that all pairs in Experiment 2 were presented equally often during the match-non-match task. Panel (a) shows violin plots ($n$ = 24) of reaction times in the match trials; panel (b) depicts violin plots of the reaction times in the non-match trials, and panel (c) plots the d' data. Shaded areas are ±1 SEM (between subjects, for comparisons between both experiments). Error bars are ±1 SEML&M (within-subjects, for comparisons between the different exposure conditions).

differences observed in the above experiments were based on perceptual or non-perceptual differences, and if those differences would be affected by extended learning. Although we did make sure that a high enough number of trials was submitted to the model overall (e.g., by repeating timed out trials), the models with the best fits did not converge for one or more of the learning conditions. Hence, we are not able to draw conclusions from these models.[1] However, we can tentatively conclude from these models (see Supplemental data) that, in the standard learning condition (replication of Sui et al., 2012), self-associations are more biased towards "match" responses, need less evidence for response and have faster evidence accumulation for decision making than other-associations, suggesting that both perceptual and non-perceptual processes are modulated by relating objects to the self.

Given that there is tentative evidence for differences in bias (which likely reflects a non-perceptual parameter, at least in paradigms such as the current one) across the different types of associations, according to the above model and some previous studies (e.g., Sui et al., 2012), we analysed (not planned in our pre-submission) the influence of learning and association on bias (or the response criterion c) using signal detection theory. That is, we tested if self-prioritization shifts the internal criterion, if this criterion is modulated by learning, and if differences in exposure to non-social stimuli lead to a similar pattern in bias as for social stimuli. The response criteria for all shape–label pairs and learning conditions are shown in Table 4.

One-sample $t$-tests were applied to assess the existence of biases for the different associations in the standard learning condition and independent samples $t$-tests were used to compare the criteria for the other learning conditions (shape–identity, shape–label–identity, shape–non-word learning) with the standard learning condition.

The response criterion for the self-related association did not differ between the standard learning condition and both extended learning conditions ($t_{(33.3)}$ = 1.23, p = .229, d = .354; $t_{(35.1)} = .894$, p = .229, $d$ = .038). Overall, no bias was observed for the self-related association ($c = .004 \pm .24$; $t_{(71)} = .131$, $p = .896$, $d = .015$). For the friend-related association, participants were conservative in the standard learning condition ($c = .301 \pm .40$; $t_{(23)} = 3.67$, $p = .001$, $d = 4.90$). For both extended learning conditions, this bias

**Table 4.** Response criteria for each of the learning conditions and identities/exposure.

| Learning condition | you/high exposure | friend/medium exposure | stranger/low exposure |
|---|---|---|---|
| standard | .03 (.34) | .30 (.40) | .30 (.25) |
| shape–identity | −.06 (.16) | .06 (.13) | .14 (.23) |
| shape–label–identity | .02 (.18) | .08 (.23) | .17 (.22) |
| shape–non-word | −.11 (.21) | .19 (.24) | .21 (.27) |

Note: Positive scores indicate a conservative response criterion and negative scores a liberal response criterion. The closer to zero the value is, the more balanced is the response criterion. The numbers in parentheses are standard deviations. Criterion = $-0.5*(Z[\text{Hit}] + Z[\text{false alarme}])$

was significantly reduced ($t_{(27.8)} = 2.77$, $p = .010$, $d = .800$; $t_{(46)} = 2.32$, $p = .025$; $d = .669$). For the stranger-related association, again a bias was found for the standard learning condition ($c = .298 \pm .25$; $t_{(23)} = 5.75$, $p < .001$, $d = 31.17$), and was again reduced for the shape–identity learning condition ($t_{(46)} = 2.19$, $p = .034, d = .632$) and marginally reduced for the shape–label–identity condition ($t_{(46)} = 1.83, p = .074$, $d = .528$).

We then compared the response criteria for the standard self-association and the high exposure condition of Experiment 2. We found no differences between them. There were no differences for the two other-associations as well ($t_{(37.9)} = 1.69$, $p$ = 0.099, $d = .489$; $t_{(37.3)} = 1.91$, $p$ = .241, $d$ = .344; $t_{(46)}$ = 1.15, $p$ = .257, $d = .331$).

These findings suggest that there is no response bias for self-associations in any of the learning conditions or for the high exposure condition. However, responses are conservative in the standard friend/medium exposure conditions and in the standard stranger/low exposure conditions. Thus, the response patterns and criteria are comparable between typical self-prioritization experiments and when memory differences are artificially introduced. However, these biases are eliminated when participants undergo extensive training aimed at equating memory differences across association types.

## Discussion

It has been well established that effects of self-prioritization facilitate memory acquisition (e.g., Bower & Gilligan, 1979; Rogers et al., 1977; Symons & Johnson, 1997; Turk et al., 2008). In two experiments, we tested if effects of self-prioritization that have been ascribed to differences in perception (e.g., salience) between self-related and non-self-related stimuli are instead due to underlying differences in memory. We approached this question from two sides. We tested if deliberately introduced differences in memory would lead to response patterns that resemble those based on self-prioritization. We found that this was indeed the case; newly introduced memory differences in novel stimuli lead to self-prioritization-like effects, even in the absence of any association with the self. Next, we tested if extended learning, which was aimed at overcoming possible memory differences between self- and other- stimuli, would eliminate effects of self-prioritization in the perceptual domain. Here, we found that extensive training did not eliminate self-prioritization effects.

### Perception or memory?

In the standard learning condition, where participants were only verbally informed about the associations between simple geometric shapes and identities, we found better performance for the self-shape association than for friend-shape or stranger-shape associations. This replicates the findings of Sui et al. (2012). However, this could have been due to differences in the stability of the associations between self and a shape, and others and corresponding shapes. Indeed, modulating exposure and thereby memory for different shape–non-word pairs in Experiment 2 resulted in better performance (higher $d'$ and faster RTs) for the pair that was most often presented (72 times) during the learning part, than for the pairs that were presented less frequently (24 or 8 times). In this experiment, there was no reference to the self. In fact, all stimuli were novel and had no social significance. Further, the internal criterion used for decision making, or bias, varied in the same way for the different association types in the two experiments. These results suggest that memory differences could lead to the documented pattern of behaviour. It is possible that such memory differences are introduced when associations between geometric shapes and different identities are formed.

However, if memory differences play a role, one might have expected that extensive practice with the different shape–label pairs would have eliminated or at least reduced differences in performance. Although we found that overall performance ($d'$ and RT) improved in the two extended learning procedures (shape–identity and shape–label–identity learning), differences among the different shape–identity associations remained. On the one hand, this could be interpreted as evidence that memory differences among association pairs does not explain the self-prioritization effects. That is, the observed effects of self-prioritization are not due to memory differences but in fact manifest in the perceptual domain. On the other hand, it might be the case that the learning procedures that we applied were unable to overcome the strong and persistent influence that self has on memory. The extent of training we used (averaging about 250 trials in 30 minutes) might not be sufficient to overcome the life-long preference for self-related information for memory consolidation. Another reason could be that, in our learning procedure, participants were exposed to all shape–label pairs equally often during the learning part. That is, not only were the participants trained on the other-related pairs, but also had similar exposure to the self-related pair. Our criterion for allowing participants to be tested on the match–non-match task was achieving error-free performance in the training task for at least three blocks. It could be that participants achieved ceiling performance for all three associations, but the strengths of memory associations might still have been different, given equal exposure to all pairs. This could be why we observed an overall increase in $d'$ rather than a convergence of $d'$ values between the different shape–identity pairs. Hence, we cannot conclude that memory has an influence, but we cannot exclude it either.

Another possibility for why the self-related effect was not eliminated by extended training might have to do with concreteness of the used labels. In a recent study examining the self-prioritization effect, Wade and Vickery (2017) found that labels that referred to concrete items such as "Snake," "Frog" or "Greg"[2] produced prioritization effects comparable to that of "Self". However, non-concrete labels such as "Friend" or "Stranger" did not do so, even when they were imbued with threat associations. Based on this, it was suggested that the labels used as controls in typical self-prioritization studies (e.g., friend, stranger, other), are not concrete and hence do not produce any prioritization effects, whereas "Self" is concrete and hence leads to a benefit. Our extended learning technique does not introduce any concrete associations for the control labels. This might be why the self-related benefit persisted despite training. In other words, the results of the first experiment might not suggest that self-prioritization effects are perceptual in nature, but reflect the continued concreteness of the "self" label, which is not shared by the control labels. Of course, the effect of concreteness might be mediated through perceptual processes (e.g., through visual mental imagery; Kosslyn, Thompson, & Ganis, 2006) or semantic processes (Binder, Westbury, McKiernan, Possing, & Medler, 2005; Kounios & Holcomb, 1994). However, these processes are not self-related and apply to all objects. Further, it is known that concreteness also affects memory encoding and retrieval. Concrete objects are more likely to be remembered and recalled than less concrete objects (Fliessbach, Weis, Klaver, Elger, & Weber, 2006). This concreteness benefit is also observed for novel associations between pairs of stimuli (Paivio, Walsh, & Bons, 1994).

Although extended learning did not reduce the differences in performance among the different shape–identity associations, post-hoc analysis of participants' internal criteria[3] revealed that learning does modulate processing of stimuli. This has implications for our hypothesis. In the standard learning condition, we found that participants' criterion was unbiased only for the self-related association. For the other related-associations, the response criteria were substantially conservative. However, extended learning reduced this bias.

In the second experiment, where memory stability was directly manipulated by differences in exposure to shape–non-word pairs, we found a pattern of the internal criterion reminiscent of the standard self-prioritization effect. There was no bias in the high exposure condition, but participants were more conservative in the medium and low exposure conditions. Further, the pattern of results was comparable in the standard learning and the memory manipulation conditions. This provides further evidence that the basis of self-prioritization might lie in memory differences. Nevertheless, we cannot exclude that self-prioritization leads to perceptual changes.

Further evidence against perceptual influences of self-prioritization comes from a recent study that investigated the influences of self-prioritization on detection thresholds for shapes presented under continuous flash suppression (CFS) (Macrae, Visokomogilski, Golubickis, Cunningham, & Sahraie, 2017; Stein, Siebold, & van Zoest, 2016). The association procedure in the Macrae et al. study was similar to the original procedure used by Sui et al. (2012) and our standard-learning condition. In this study, perceptual and non-perceptual influences for the three identity–shape associations were estimated using hierarchical drift diffusion modelling. Only non-perceptual parameters were found to differ between identities (you, friend, stranger). As in our study, a difference in bias between the self-related and the other-related associations was observed. Similarly, Stein et al. (2016) did not find a difference in breakthrough CFS duration (a measure of the extent of suppression during CFS) for self and other associations, indicating that the self-related benefit arises at a later stage of processing and not at the perceptual level.

We also found shorter reaction times in the match trials for the self-related shape–identity pair compared to the friend or stranger related pair, replicating the findings of Sui et al. (2012). However, we did not observe a distinction between the friend and stranger related shape–identity associations. The distinction between a familiar other and a non-familiar other seems not as robust as the difference between the self and others and is not consistently observed (Golubickis et al., in press). As with the accuracy results, extended learning led to an overall improvement in reaction times, but there was no reduction in the differences between self and other related shape–identity pairs. Reaction times for the shape–identity and shape–label–identity learning procedures were shorter than for the standard learning procedure. No differences were observed between the two extended learning procedures.

### *Perceptual learning*

Interestingly, the improvement in performance observed in the learning conditions cannot be attributed to perceptual learning. In the third (shape–label–identity) learning condition, we did not use any shapes; instead, we used shape words (such as the word "circle'). The participants, however, were tested with shapes in the match–non-match task. The pattern of results in this condition was the same as in the condition where participants were trained with shapes. This suggests that the benefits of learning (overall increase in *d′* and reduction in RT) were not due to increased exposure to shapes.

Artificially introduced memory differences (Experiment 2) led to a pattern of performance similar to that in the established self-prioritization effect (higher *d′* and faster RT for self-related objects). Here, responses were faster to the shape–non-word pair that was practiced most frequently during the learning part and slower for the less frequently practiced pairs. However, one potential confounding factor in Experiment 2 is perceptual learning. That is, the difference in exposure might not only have influenced the consolidation of memory, but also low-level perceptual processing. However, we do not think that this was the case. In the training session, the response options for a given target non-word included all shapes (or non-words, when the target object was a shape). Hence, the difference in perceptual exposure to the individual shapes and non-words in the three exposure conditions (low, medium, high) was actually much lower than what the names might suggest. The shapes and non-words were presented 56, 64 and 88 times, respectively, in the low, medium and high exposure conditions. However, note that the *association* was trained 8, 24 and 72 times, respectively. Further, much perceptual learning is location specific and reduced when different stimuli are presented at the same location (see Watanabe and Sasaki, 2015, for a recent review on visual perceptual learning). During learning, the shapes and non-words used for the responses were never presented at the same location. Further, all target objects were presented in the same location, making it unlikely that perceptual learning occurred. We believe that our learning procedure successfully manipulated memory as intended. The results of this experiment, therefore, show that memory differences can be one source for the pattern of results observed in typical self-prioritization tasks.

## Conclusion

Although extended learning improved overall performance, we found that differences between self-related and non-self-related shape–label associations remained. This could either indicate that memory has no influence on self-prioritization effects, which are mediated via perceptual differences, or that self-related memory is too powerful to be easily eliminated (at least with our procedure). Alternatively, it could reflect the concreteness of the labels used, which is not altered by extended training. However, we observed that memory differences for non-words can be quickly established and can reproduce response patterns closely resembling typical self-prioritization effects. We conclude that the same pattern of behavioural results can be established through a number of routes, which might include perceptual effects, differences in memory strengths, and reward incentive structures (de Greck et al., 2008; Northoff & Hayes, 2011; Sui et al., 2012). It can be argued that in paradigms that do not directly measure perceptual changes, but instead rely on reaction times as a measure, differences cannot be exclusively attributed to changes in perception, but are just as likely based on differences in memory.

## Notes

1. A description of the planned approaches and the performed analyses are presented in the Supplemental data.
2. For the participants, "Greg" was the name of the experimenter who ran the study.
3. Note that this analysis was performed since the planned analysis of perceptual and non-perceptual effects based on parameter estimation using hierarchical drift diffusion modelling (HDDM) was not successful. For a description of the planned analysis using HDDM see the Supplemental data.


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## Disclosure statement

No potential conflict of interest was reported by the authors.


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