Title

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I Remember Me The Best, Always? Evidence For Self-Prioritization In Working Memory Binding Using A Visuo-Spatial Working Memory Task.

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Abstract

Research has demonstrated an advantage for the processing of self-associated stimuli for various mental functions (Sui & Humphreys, 2017). However, relatively little is known about whether prioritization exists for internal representations (Yin et al., 2019). In the current study, we first asked participants to associate social – labels ('self', 'friend', 'stranger') with arbitrary geometrical shapes (triangle, quadrilateral, and pentagon) (Sui et al., 2012) and then tested them for the maintenance of one or more features (shape, location, or a combination) of the target stimuli during a delayed match – to – sample task. In line with our expectations, our participants indeed showed a distinct advantage for self-associated stimuli for maintaining single features (identity, location) and a combination (shape & location). Our findings align with the proposal that self-reference may aid in binding information in working memory (Sui & Humphreys, 2015).

Keywords: self-association, working–memory binding, working memory, spatial working memory, identity, location.

Introduction

Prioritized processing for self-related information compared to information associated with others has now been well documented across a wide range of mental functions and different types of stimuli, such as self-face, self-name, self-owned objects, Etc. (Brédart, 2016; Cunningham, Turk, Macdonald & Macrae, 2008; Ma & Han, 2010). With such evidence of self-prioritization extending its preferential advantages for information related to oneself has been recorded across a range of cognitive processes, some of those studies have also been criticized because of the longtime training and familiarity effects that are possible with such stimuli (Sheets, 1987; Prentice, 1990). More recently, however, Sui, He & Humphreys (2012) demonstrated that similar and robust advantages of self-association can be obtained by momentarily associating socially salient labels (self/you, friend, stranger/other, etc.) with arbitrary geometric shapes (such as triangle, circle, square, etc.). The paradigm has been referred to as the associative learning paradigm. It has yielded replicable results across cultures and demonstrated significantly preferential processing for 'self-associated' stimuli compared to stimuli associated with others (Sui & Humphreys, 2015; 2017).

Moving further, while it has been established that 'self-associated' stimuli capture exogenous attention and preferential processing as reflected in faster responses for self-faces (Keyes & Brady, 2010), self-names (Devue & Bredart, 2008) etc., the influence of such stimuli on facets of endogenous attention and internal representations have only been sparingly investigated (Yin, Sui, Chiu, Chen & Egner, 2019).

As a cognitive function, Working Memory presents an opportunity to understand how these internal representations may be maintained or manipulated in real-time. Baddeley (2003) defines *working memory* as the capacity to temporarily retain and manipulate information internally, which then functions as a critical component of our cognitive processing system in general and our decision-making systems in particular. Working Memory has already been established as a critical factor interrelated with the modulation and manifestation of a self-prioritization effect. Neurobiologically, brain regions like Dorsolateral Prefrontal Cortex (DLPFC) which is active for working memory, have also been involved in the processing and the subsequent prioritization of self-referential information. (Kelley et al., 2002; Koster-Hale & Saxe, 2013). It is not surprising, thus, that even early studies have attributed WM with self-prioritization in that the greater relevance of self-related information to the individual may be increasing their encoding and retrieval strength (Klein & Kihlstrom, 1986) in memory. Other studies have also recorded how subjects better recall self-relevant words than those not, even when controlled for frequency or valence (Symons & Johnson, 1997; Rogers et al., 1977). Moreover, research like Bower & Gilligan, 1979 has also posited how self-prioritization can be attributed to the ease of processing self-related information that makes such data more accessible and facilitate its integration with other information in working memory.

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Extending from the evidence of self-bias influencing exogenous attention, it becomes natural to ask whether self-referential representations would modulate internal attentional prioritization in WM maintenance compared to less socially salient stimuli (Verma, Jain & Srinivasan, 2021). Yin et al. (2019) used a location probe task to check for self-bias. They demonstrated that participants consistently responded faster to WM probes at previously occupied locations by the self-associated stimulus. The authors concluded that automatic internal attentional prioritization is being extended for self-associated stimuli and proposed that the same may form the basis of egocentric biases in decision-making.

Another vital aspect of Working Memory is its ability to bind aspects of information into a single representation, an important function taken care of by the *episodic buffer* (Baddeley, 2000; Burglen et al., 2004; Johnson & Chalfonte, 1994). Consequently, researchers have been interested in investigating the potential of working memory as a storage space for combinations of features such as object identities and their locations (Prabhakaran et al., 2000) associatively embody a coherent representation of any stimuli or event. Thus, besides retaining information about different features, 'binding' or the characteristic capacity of establishing associations between different features becomes a critical component of working memory. (Burglen et al., 2004; Johnson & Chalfonte, 1994).

Considering these observations, our current study has looked to extend upon the findings presented by Yin et al. (2019) towards newer insights into self-referential prioritization interacting with the facets of Working Memory. Using the associative-learning paradigm that was first introduced by (Sui et al., 2012), we asked our participants to associate geometric shapes (i.e., a triangle, a quadrilateral, and a pentagon) with socially salient labels (e.g., you, friend, or stranger). Once the associations were ascertained, we asked the participants to engage in a delayed match-to-sample task (like in Yin et al. 2019, Burglen et al., 2004, Oberauer and Kliegl 2006) wherein their ability to maintain single features (identity, location) and also for the bounded condition (combination of identity & location) of the stimulus information was tested.

On the lines of previous research (Sui & Humphreys, 2015; Yin et al., 2019), we expected to find evidence indicating a prioritization in responses for the purported more salient self-referenced stimuli compared to more distant salience of others, both in terms of single features as well as any condition of binding information.

Experiment

Method

Participants: 36 students with normal or corrected-to-normal vision from IIT Kanpur (mean age= 26.77 SD=3.78; 6F, 30M) performed all five task blocks. Participants gave informed consent and received monetary compensation in return for their participation. The institute's ethics committee approved the protocol of the study.

Stimuli and Apparatus: The stimuli in the main task comprised two unique exemplars from three shape categories, i.e., triangle, quadrilateral and pentagon. For the association stage, 2 random instances of the three categories were initially used to create an association between the shapes and either 'Self', 'Friend' or 'Stranger' labels. For the Working Memory Task (Figure 1), a 3x3 grid was used with a fixation cross in the center of the grid. Instances from any two of the associated shape exemplars (belonging to different categories) were shown in the blocks around the center block. Each shape category had a set of 8 exemplars (8 unique triangles, quadrilaterals, pentagons) to choose from randomly. A *-shaped distracter appeared in the remaining blocks of the grid.

The grid presentation was followed by a math problem (to disallow for maintenance rehearsal), and the conditional matching and label matching task followed (the last two blocks in Figure 1).

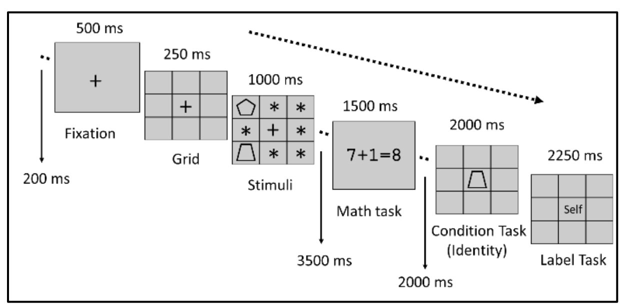

Figure 1: A single trial of the Working Memory Task for identity condition (double dots → blank screen).

The experiment was conducted on a Windows PC using Psychopy, where stimuli were presented at the centre of a 24" screen at a resolution of 1920 x 1080 in a dark and quiet room. All stimuli were presented on a white background.

Procedure: The experiment was carried out in two stages, i.e., the association-learning stage, followed by the working memory maintenance and response stage.

In the associative learning stage, participants were asked to associate the shape exemplars (e.g., 2 triangles, 2 quadrilaterals and 2 pentagons) to their respective social labels (i.e., 'you', 'friend', 'stranger'). This mapping of shapes to labels is counterbalanced across participants. They were subjected to a match-judgement task to ascertain whether the associations were formed and the participants remembered them. They had to respond to whether the presented shape-label combinations were correct. After 8 consecutively correct answers, we assumed that associations were made, and then the participants moved on to the working memory maintenance stage.

In the working memory maintenance stage, as in Figure 1, a blank screen is presented for 200 ms, followed by a fixation cross lasting for 500 ms; after this, an empty grid with the fixation cross at the center cell appears. After the empty grid (with a fixation cross at the center) has stayed on the screen for 250 ms, then two target stimuli appeared in any of the other cells of the grid and stayed for 1000 ms, while the rest of the cells were filled with stars "*" as distractors. After this, there was a blank screen for 3500 ms. The participants were then prompted with a basic one-digit arithmetic equation for 1500 ms, within which participants had to indicate its correctness. This was to disrupt maintenance and was followed by another blank of 2000 ms. In different blocks, participants were asked to remember features of the exemplar shapes (identity, location, or combination) of the presented stimuli.

For the *identity condition*, participants were instructed to remember the identity of two exemplars shown as target stimuli (Figure 1). Once the grid with the target stimuli had disappeared and the math problem had been solved (~after a delay of about 7000 ms), the same grid re-appeared but this time with a shape in the center cell, which the participants were required to match with either of the two previously presented target within 2000 ms. If the participants responded correctly at this stage, they were prompted to tell us the label associated with the target shape within 2250 ms.

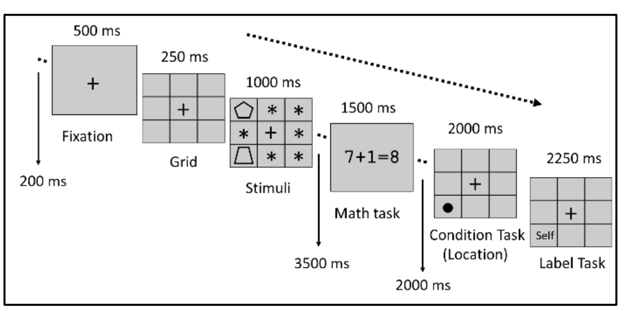

Figure 2: A single trial of the Working Memory Task for location condition (double dots → blank screen).

For the *location condition* (Figure 2), participants were instructed to remember just the location occupied by the target shapes in the grid. As opposed to the identity condition, this time, the participants were prompted with a black dot probe at any location (except the center) in the grid. The participants were expected to indicate whether the location of the dot probe was occupied by either of the target shapes within 2000ms. If the participants returned a correct response for the location, as earlier, they were prompted to indicate the label of the target shape, again within 2250 ms.

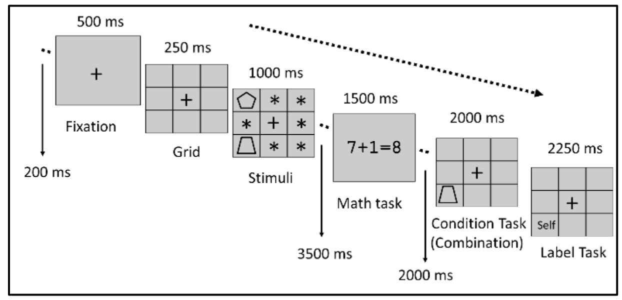

Figure 3: A single trial of the Working Memory Task for combination conditions (double dots → blank screen).

For the *combination condition*, participants were instructed to remember the identity and the associated locations of the target stimuli in the grid (see Figure 3). In this condition, participants were again prompted with a reference grid with a shape presented at any location (except the center) in the grid, and the participants were to match both the identity of the shape as well as its location with that of the previously presented target stimuli, within 2000 ms. If the participants responded correctly to identity and location, they were prompted to match the indicated label associated with the target shape within 2250 ms.

The order of presentation of the identity and location condition blocks was counterbalanced, while the combination block (binding condition) was always the final. Also, each experimental block had 96 trials preceded by a set of practice sessions consisting of 18 trials to familiarise the participants with the task. On presentation of each probe, they had to respond with corresponding yes/no keypress (which is also counterbalanced across participants and tasks) using "m/z" keys from the keyboard to indicate whether the probe matched the location or the identity or the combination of location and identity of the target shapes.

Results and Analysis

The dependent measures were Reaction Times (RTs) and Accuracy. Also, we only included the RTs of the correct trials in the analyses.

First, we cleaned RTs beyond mean ±2.5 SD for each participant, and condition, to eliminate accidental responses.

Reaction Time Data

First, we carried out a 3 (Label: Self, Friend, Stranger) x 3 (Condition: identity, location, combination) within–subjects repeated measures ANOVA for the entire data for accuracy and RTs.

For the RT data (as can be seen in Table 1), there was a significant main effect of Label, $F(2, 70) = 8.235$, $p < 0.001$, $\eta_p^2 = 0.190$ and the main effect of condition $(2,70) = 35.445$, $p < 0.001$, $\eta_p^2 = 0.503$ (see Figure 4). Interestingly, the interaction between Label x Condition was not found to be significant. However, we looked at the planned comparisons for the RT data to understand the data better.

We found that the participants were significantly faster for self-associated exemplars than the friend–associated exemplars, $t = -2.508$, $p_{holm} = 0.029$ & Cohen's $d = -0.204$; and stranger–associated exemplars, $t = -4.017$, $p_{holm} < 0.001$ & Cohen's $d = -0.328$. However, there was no difference between the friend and stranger-associated exemplars, $t = -1.509$, $p_{holm} = 0.136$ & $d = -0.123$.

Across conditions, we found that participants were faster for the location condition than the identity condition, $t = -8.220$, $p_{holm} < 0.001$ & Cohen's $d = -0.997$, and in comparison, to the combination condition. Also, participants were faster for the combination condition than the identity condition, $t = 5.688$, $p_{holm} < 0.001$ & Cohen's $d = 0.690$.

Moving further, to understand the pattern of performances of the participants across the three conditions of the WM task, i.e., identity, location, and combination for the different labels, i.e., self, friend & stranger, we carried out 3 within-subject repeated measures 1 (condition) x 3 (labels) ANOVAs. The following are presented below:

WM Location Task: There was a significant main effect of the label, i.e., $F(2, 70) = 4.722$, $p = 0.012$, $\boldsymbol{\eta_p^2} = 0.119$. Participants were faster for self than the stranger label, $t = -2.951$, $p_{holm} = 0.013$ & Cohen's $d = -0.278$; but not the friend label, $t = -2.218$, $p_{holm} = 0.060$ & Cohen's $d = -0.209$. They were also not significantly faster for friends than the stranger label, $t = -0.733$, $p_{holm} = 0.466$, & Cohen's $d = -0.069$.

WM Identity Task: There was again a significant main effect of the label, $F(2,70) = 3.373$, $p = 0.040$, $\boldsymbol{\eta_p^2} = 0.088$. On looking closely, participants were significantly faster for the self than stranger match condition, $t = -2.554$, $p_{holm} = 0.038$ & $d = -0.281$. Although, there was again no significant difference between response times to self-matched, compared to a friend–matched trials, $t = -0.867$, $p_{holm} = 0.389$, Cohen's $d = -0.095$; and for friend compared to stranger match condition, $t = -1.687$, $p_{holm} = 0.192$, Cohen's $d = -0.185$.

Table 1: Mean & SD for Reaction Time data for location, identity, and binding conditions.

Condition	Label	Mean (ms)	SD (ms)
Location	Self	0.748	0.116
	Friend	0.772	0.113
	Stranger	0.780	0.118
Identity	Self	0.884	0.156
	Friend	0.899	0.147
	Stranger	0.929	0.180
Combination	Self	0.774	0.124
	Friend	0.820	0.130
	Stranger	0.833	0.144

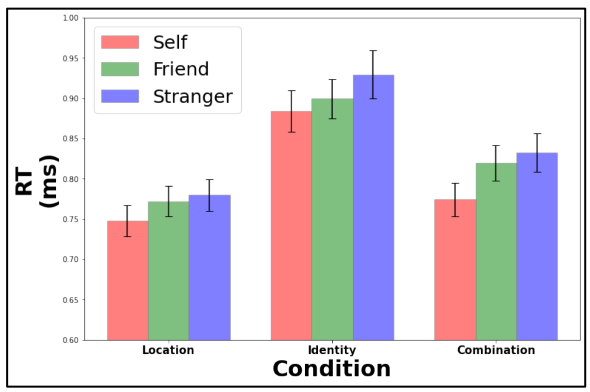

Figure 4: Reaction time for location, identity, and combination, conditions; error bars depict 'standard error'.

WM Combination (binding) task: For the location + identity combination or the binding task, there was again a significant main effect of the label, $F(2,70) = 6.043$, $p < 0.01$, $\eta_p^2 = 0.147$. Here, participants were faster for self than the stranger, $t = -3.312$, $p_{holm} = 0.004$ & Cohen's $d = -0.437$ and to the friend, $t = -2.570$, $p_{holm} = 0.025$ & Cohen's $d = -0.339$. However, the difference between the friend and stranger conditions was insignificant, $t = -0.743$, $p_{holm} = 0.46$ & Cohen's $d = -0.098$.

Accuracy Data

When performing a 3 (Label: Self, Friend, Stranger) x 3 (Condition: identity, location, combination) within–subjects, repeated measures ANOVA for accuracies (see Figure 5 and Table 2). There was a significant main effect of Condition, $F(2, 70) = 6.167$, $p = 0.003$, $\eta_p^2 = 0.150$; but there was no main effect of Label (2,70) = 3.103, p = 0.051, $\eta_p^2 = 0.081$; and interaction between Label x Condition (4,140) = 0.769, p = 0.547, $\eta_p^2 = 0.021$.

Looking at the planned comparisons for the accuracy data, we found that the participants were slightly more accurate for self-associated exemplars as compared to the friend–associated exemplars, t = -0.815, p_{holm}= 0.418 & Cohen's d = -0.105; and stranger – associated exemplars, t = 1.631, p_{holm} = 0.215 & Cohen's d = 0.210; although these differences were not significant. We also did not find a significant difference between the accuracies for the friend and stranger-associated exemplars, t = 2.446, p_{holm} = 0.051 & d = 0.314.

Participants were found to be more accurate for the location condition in comparison to the identity condition, t = 3.512, p_{holm} = 0.002 & Cohen's d = 0.471, and the combination condition, t = 1.784, p_{holm} = 0.158 & Cohen's d = 0.239, although the difference was not significant. Also, participants were relatively more accurate for the combination condition than the identity condition, t = -1.728, p_{holm} = 0.158 & Cohen's d = -0.232; the difference was insignificant.

To understand the pattern of performances of the participants across the three conditions of the WM task, i.e., identity, location, and combination for the different labels, i.e., self, friend & stranger, we also carried out 3 within-subject repeated measures 1 (condition) x 3 (labels) ANOVAs for accuracy data as well. However, we did not find any significant differences across the different conditions.

Table 2: Mean & SD Accuracy for location, identity, and combination conditions.

Condition	Label	Mean	SD
Location	Self	0.962	0.048
	Friend	0.960	0.058
	Stranger	0.950	0.056
Identity	Self	0.924	0.090
	Friend	0.943	0.078
	Stranger	0.896	0.120
Combination	Self	0.939	0.069
	Friend	0.946	0.067
	Stranger	0.931	0.086

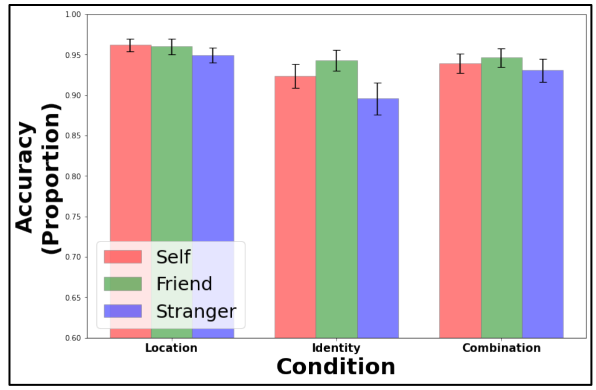

Figure 5: Accuracies for location, identity, and combination; error bars depict SE (standard error).

Discussion

In the current study, we investigated whether the prioritization of self-associated stimuli persists in maintaining single features (identity or location) and the binding of features (combination of identity and location) of stimuli in our working memory. As per the proposal from Yin et al. (2019), the maintenance of items in working memory involves the endogenous capture of attention by the internal representations associated with the stimuli in question. Further, suppose an advantage is registered for the self-associated stimuli. In that case, one may extrapolate the influence of the self-associated representations in both endogenous attentional capture and the organization of internal representations.

In line with our expectations and previous research (Sui & Humphreys, 2015; Yin et al., 2019), we found a clear advantage in faster RTs for self-associated shape exemplars across the three conditions of the working memory task, albeit not for accuracies.

The findings of no consistent significant difference or improvement for self-associated exemplar vs that of others for accuracy, even though a bit surprising, is totally in line with other research that has adopted a similar paradigm. Yin et al. 2019 also reported differences in RT to demonstrate self-prioritization, while their accuracies were not reported to be of such significant difference, with all reaching ceiling effects. Among studies with other non-social contexts, Zokaei et al. 2011's visual working memory task had participants remember the locations of several coloured circles and then later identify if a probe circle appeared in the same location as one of the circles in memory. Here, even though the accuracies were not significantly improved, the RTs were faster for probes that appeared in the same location as one of the circles in memory. The authors noted a selective prioritization of relevant information in working memory. Another study by Oberauer & Kliegl (2006) used a delayed match-to-sample task where participants had to remember a set of coloured squares and then indicate if the probe square matched one of the squares in their memory. Here, the participants responded faster to probes matching one of the relevant squares, even when accuracy was not improved. The author then argued that this effect reflected a prioritization of relevant information in working memory, which led to faster processing of that information.

Returning to our own RT findings, we found that the advantages for the self-associated stimuli are strongest compared to the stranger-associated stimuli; but relatively lesser against that of the friend-associated stimuli. Such a pattern of results is not new. It has been reported in previous studies that the advantage of self-association is most reliably demonstrated in comparison to the least socially salient category, i.e., the stranger in this case, and appears slightly attenuated for the intermediate categories (Verma et al. 2021; Roy et al., 2023). Such a finding indicates that preferential processing seems to be allocated along a gradation or continuum of social saliency and manifests as such, especially when the task at hand is slightly difficult (e.g., current study; see Roy et al., 2023 for more on this).

An interesting caveat from the current study is that participants found the identity condition of the WM task to be more difficult than the others. While, one could attribute such a pattern to a higher degree of response uncertainty for the identity task, given that there were 3 social labels and 2 shape exemplars associated with each of these labels, and hence remembering the exact identities would have been difficult; a more detailed investigation is needed to be certain for that.

Moving on, our findings provide a logical extension of the work by Yin et al. (2019), given that the latter demonstrated the advantages of self-association (faster responses) during the maintenance of location information. However, our current study adds important evidence of preferential prioritization in maintaining isolated information when considering precise visuospatial identification of stimuli, including tending location and identity information. It facilitates holistically remembering the other bounded attributes for stimuli.

Indeed, binding aspects of information about stimuli together has been attributed to the episodic buffer (Baddeley, 2000; Johnson & Chalfonte, 1994), and the fact that self-association facilitates the same indicates the pervasive influence of self-representations in the organization of information in the working memory and its exchange with episodic long-term memory (Burglen et al., 2004). This is in line with Leshikar, Dulas & Duarte (2015), whose participants, both young and older adults, were found to retain more episodic detail about self-associated stimuli (adjectives) relative to their semantic details.

Moreover, our results further corroborate the proposal from Sui & Humphreys (2015) that self-reference may enhance the binding of different forms of information about stimuli. Indeed, our participants were faster for the self-associated exemplars than the friend- and stranger-associated exemplars in the combination condition. Self-reference aids in putting together information about the identity and the location of stimuli in the grid, better than the categories with relatively lower social salience.

Previous studies that have demonstrated similar advantages for self-associated stimuli in binding have done so using faces (Sui & Zhu, 2005; Cunningham, 2014). Our results, therefore, not only corroborate their findings but at the same time extend the same to demonstrate that the self-referential advantage in binding does not stem from overlearning a certain class of stimuli (e.g., self-face, self-name) or participants' familiarity with them, but can be extended to neutral instances of socially salient associations, as extensible from the first findings of Sui et al., 2012.

Finally, a limitation of the current study could be that these experiments do not explicitly investigate the mechanisms responsible for the observed prioritization of self-referenced information in binding different aspects of information. Future studies should focus on the mechanisms behind the binding of information and how associating the information with the self creates an advantage over information associated with others or non-socially salient information.

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