Self-referential False Associations: A Self-enhanced Constructive Effect for Verbal but Not Pictorial Stimuli

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Authors' Note

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Abstract

Memory is considered to be a flexible and reconstructive system. However, there is little experimental evidence demonstrating how associations are falsely constructed in memory and even less is known about the role of the self in memory construction. We investigated whether false associations involving non-presented stimuli can be constructed in episodic memory and if the self plays a role in such memory construction. In two experiments, we paired participants' own names (i.e., self-reference) or the name "Adele" (i.e., other-reference) with words and pictures from Deese/Roediger–McDermott (DRM) lists. We found that (1) participants not only falsely remembered the non-presented lure words and pictures as having been presented, but also misremembered that they were paired with their own name or "Adele", depending on the referenced person of related DRM lists; and (2) there were more critical lure-self associations constructed in the self-reference condition than critical lure-other associations in the other-reference condition for word but not for picture stimuli. These results suggest a self-enhanced constructive effect that might be driven by both relational and item-specific processing. Our results support the spreading activation account for constructive episodic memory.

Keywords: false association, self, item-specific processing, relational processing, spreading activation

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A Self-enhanced Constructive Effect for Verbal but Not Pictorial Stimuli

Episodic memory enables individuals to bind different elements of an experience into a coherent and meaningful mental representation (Eichenbaum & Cohen, 2004; Tulving, 2002). However, during such memory encoding processes, and subsequently during retrieval, errors or distortions may occur, reflecting the constructive nature of memory (Schacter & Addis, 2007; Cheng, Werning, & Suddendorf, 2016). For example, the *constructive episodic simulation* hypothesis proposes that our memory system may flexibly recombine elements from different episodes to simulate future situations (Schacter & Addis, 2007). Although there is evidence showing this constructive combination in episodic memory (e.g., misattribution of true memory to a wrong source; Carpenter & Schacter, 2017), only limited knowledge exists on how false memories can be flexibly combined with episodes from past experiences. The general purpose of the current paper was to examine whether the memory system can falsely combine different elements from memory episodes and thus create false associations in episodic memory.

The self plays a critical role in episodic memory (Conway, 2005; Tulving, 2002). Indeed, the role of self in memory has extensively been investigated since the 1970s (e.g., Rogers, Kuiper, & Kirker, 1977; Symons & Johnson, 1997). The self has been found to facilitate perceptual processing of stimuli. For example, the self-reference recollection effect (SRRE, Conway & Dewhurst, 1995) refers to the phenomenon that people have more recollective experiences (e.g., more details, higher vividness) when encoding information with reference to oneself compared to encoding information with reference to others. Recently, studies have shown that the self can act as a binding mechanism that serves to aid in the combination of memories with sources (Sui & Humphry, 2015). For example, Cunningham, Brebner, Quinn, and Turk (2014) found that after seeing objects (e.g., an apple or a cup) paired with either their own face or other people's faces, children remembered the stimuli-self associations better than the stimuli-other associations. Leshikar and Duarte (2014) found similar results in young and older adults showing that object-scene bindings (e.g., saxophone–beach) were remembered better in a self-referenced manner than in an other-referenced manner. Thus, it has been shown that the self can facilitate (correct) binding between items as well as binding between the self and items in episodic memory (see also Durbin, Mitchell, & Johnson, 2017). As mentioned, because memory is constructive, the very process of encoding and storing information in memory can lead to distortions including source memory errors (e.g., Carpenter & Schacter, 2017). However, rarely has the role of self been examined in such constructive memory processes. Therefore, another aim of the current study was to investigate the role of self in constructing (false) associations in episodic memory.

To address this, we examined self-referential processing in a well-established false memory procedure, the Deese/Roediger–McDermott paradigm (DRM; Deese, 1959; Roediger & McDermott, 1995). In the DRM paradigm participants encode word lists that contain related items such as *butter, flour, dough, sandwich, jam, milk* and so on, which are all related to a non-presented critical lure (i.e., *bread*). After studying the list of related items, participants usually falsely remember the critical lure (i.e., *bread*) as also having been presented. Recently, Wang, Otgaar, Howe, and Zhou (2019) examined the impact of self-reference on false memory (see also Rosa, Deason, Budson, & Gutchess, 2015; Rosa & Gutchess, 2013; Wang et al., 2021). They paired the DRM items with participants' own names (i.e., to activate the self) and found that more false memories of the critical lures would be formed when the

DRM items were paired with one's own name. One possible mechanism for the self-enhanced false memory effect is that, when the self is paired with the DRM items, the self might enhance relational processing of the stimuli and thus strengthen the relatedness among the DRM items (Klein, 2012; Klein & Loftus, 1988), which in turn increases the activation of the critical lures (Wang et al., 2019). As critical lures are found to be activated at the encoding phase (e.g., Gallo, 2010), during which the self is presented/activated as well, we wondered whether people would also construct false associations between the critical lures and the self under self-referential processing.

More specifically, our questions concerned whether, when DRM items are paired with the self (e.g., the participant's own name) or with another person, would (1) false associations or binding between the referenced person and the critical lures be constructed and (2) the activation of the self, facilitate the false association construction between the self and the critical lure? Although recent research has shown that the self can enhance false memories of non-presented *items* (Rosa & Gutchess, 2013; Wang et al., 2019), no study has examined whether the self can impact false *associations* among items. False associations reflect incorrect binding between elements in episodic memory. Studying how false associations are formed can help uncover the (re)constructive mechanisms of episodic memory.

According to spreading activation accounts of memory (e.g., Anderson, 1983; Associative-Activation Theory, AAT, Howe, Wimmer, Gagnon, & Plumpton, 2009; Otgaar, Howe, Muris, & Merckelbach, 2019; Activation-Monitoring Theory, AMT, Roediger, Balota, & Watson, 2001), memory is a network consisting of different concepts/elements and associations between related concepts. A key proposition made by spreading activation accounts is that the activation of one concept can spread to nearby concepts automatically along memory associations. As a consequence, after people study items such as *butter, flour, dough, sandwich*, and *jam*, activations may spread to their related item *bread*, making people falsely remember it.

When the self is encoded along with the DRM items (i.e., presenting one's own name simultaneously with the DRM items), as Figure 1 shows, the concept of self, as well as the DRM items, would be activated in the memory network. Based on the spreading activation account, the critical lure that is related to the relevant DRM items may also become activated. Thus, the co-activation of the self and the critical lure may lead to a false recollection that the self has been presented together with the critical lure, resulting in a false association constructed between the self and the critical lure. Because the self can facilitate the binding of the self-stimuli associations (Cunningham et al., 2014; Sui & Humphreys, 2015), which can lead to higher levels of spreading activation, the self may facilitate the false association between the self and the critical lures.

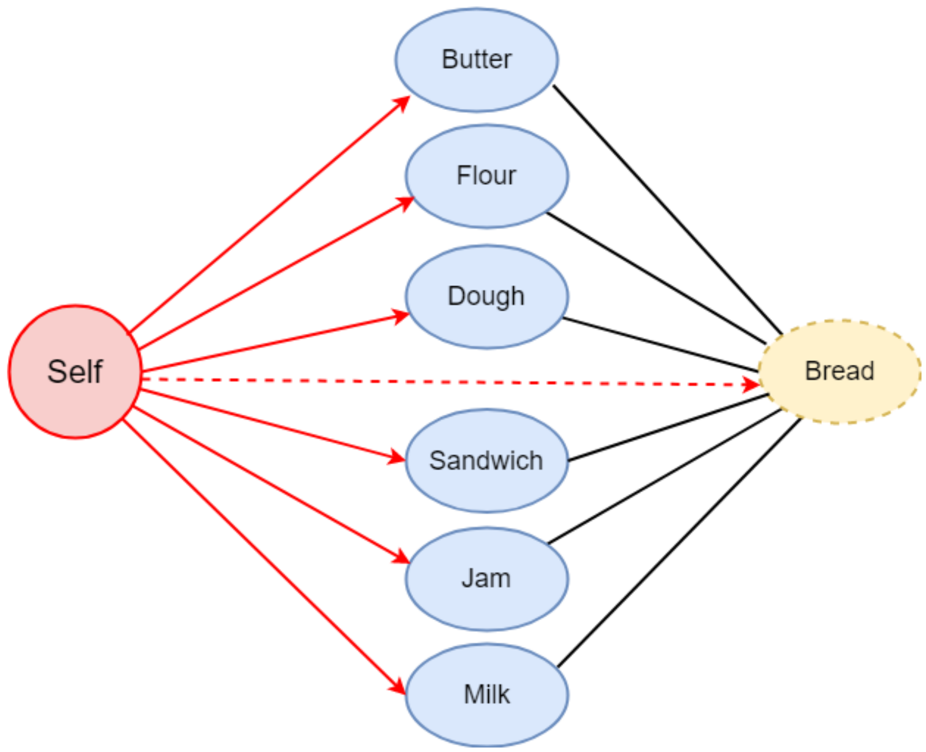

Figure 1. Hypothetical associative memory network when the self is encoded together with DRM items, based on spreading activation theories (Howe et al., 2009; Roediger et al., 2001) and the mechanisms of self (e.g., Sui & Humphreys, 2015). Blue circles represent DRM list items; yellow dashed circle represents the non-presented critical lure. Red lines with an arrow refer to the pairing of self and stimuli during study. Black solid lines represent existed semantic associations among items in the memory network and dashed red line represents the proposed false association.

Another mechanism underlying self-referencing is item-specific processing that involves the encoding of distinctive aspects of an item (Klein & Loftus, 1988; Klein, 2012; Symons & Johnson, 1997). That is, the self can promote the encoding of information specific to an individual item (e.g., color, shape, context) and thus promote recognition of that item by providing multiple retrieval routes. However, unlike the boosting effect of relational processing on false memory, item-specific processing or distinctive encoding has been found to reduce false memories (Huff & Bodner, 2019). For example, research showed that pictorial DRM lists, which contain more item-specific details, can suppress false memories of critical lures relative to their corresponding verbal DRM lists (Schacter, Israel, & Racine, 1999; Wang, Otgaar, Howe, Felix, & Smeets, 2018).

Research so far has found that false memory is boosted by self-referencing (Rosa & Gutchess, 2013; Wang et al., 2019). Researchers have argued that the self enhances false memory via relational processing because item-specific processing is mostly known to reduce false memory (e.g., Arndt & Reder, 2003; Huff & Bodner, 2019; Schacter et al., 1999). However, it is still unknown whether item-specific processing still plays a role in the self-reference effect on false memory. Pictures of items (e.g., picture of a car) contain more item-specific details such as color and shape than words (e.g., the word *car*), hence pictorial DRM lists have higher levels of item-specific information or distinctiveness than verbal DRM lists (Schacter et al., 1999). By using both pictorial and verbal DRM lists, we can determine whether the level of item-specific information can mediate the self-reference effect on false memory. If item-specific processing is indeed an underlying mechanism of self-referencing, manipulating pictorial vs. verbal stimuli should impact self-referential false memories. If item-specific processing is not involved, there should be no statistical difference in self-referential false memory for verbal and pictorial stimuli.

To our knowledge, no study has induced false associations related to non-presented lures and no study has investigated the role of the self in generating false associations. The present experiments aimed to examine whether false associations with critical lures can be constructed in episodic memory and whether the self would facilitate such constructive processes in verbal and pictorial DRM lists. Using both verbal and pictorial stimuli, we could examine the mechanisms underlying self-referential false memory.

The Current Experiments

In two experiments, we presented participants with DRM lists together with either their own name (self-referenced condition) or another person's names (e.g., the famous singer *Adele*; other-referenced condition). Experiments 1 and 2 followed similar procedures. During the study phase, participants were asked to remember DRM items shown to them as well as whom (self or other) the items appeared together with. In line with our previous study (Wang et al., 2019), after the study phase, participants were asked to recognize the items with Remember/Know judgements (Conway & Dewhurst, 1995; Yonelinas, 2002). Importantly, after the recognition test, participants were asked to remember whether the items had appeared together with their own or another person's name. Based on spreading-activation theories (Anderson, 1983; Howe et al., 2009; Roediger et al., 2001), we predicted that false associations between the referenced person and critical lures would be constructed in participants' memory. Based on the relational processing mechanism of the self (Cunningham et al., 2014; Sui & Humphreys, 2015), we predicted that the self-referenced condition would result in more false associations than the other-referenced condition. We also predicted that self-referencing would lead to higher accuracy rates for self-DRM item associations than other-referencing based on findings of previous studies (Cunningham et al., 2004; Durbin, Mitchell, & Johnson, 2017).

Experiment 1

Method

Participants

The experiment was pre-registered on the Open Science Framework (https://osf.io/zv342). As pre-registered, we calculated the required sample size using G. Power 3.1 (Faul, Erdfelder, Lang, & Buchner, 2007) prior to participant recruitment. We estimated a medium effect size (*d* = 0.5) based on related previous research (Wang et al., 2019). Power analysis showed that 34 participants were needed to reach a power of 0.8. Thirty-four participants from Maastricht University, the Netherlands were tested. The sample consisted of 14 males and 20 females (M_{age}= 22.14, *SD*= 2.79, min 19 – max 29 years old). All participants were fluent in English. The experiment was approved by the ethical board of Faculty of Psychology and Neuroscience, Maastricht University.

Materials

Eight DRM word lists and eight DRM picture lists with 8 items per list were used. The lists were taken from a previous study (Howe, Garner, & Patel, 2013). The picture lists were pictorial versions of DRM word lists that were normed for image and name agreement (i.e., to what extent the picture represents the DRM concept – see Snodgrass & Vanderwart, 1980; Wang et al., 2018). The picture lists have a mean image agreement rating of 4.22 (*SD* = 0.48) on a scale of 1 to 5 (see Wang et al., 2018). Word lists and picture lists were matched in backward associative strength (BAS). Word lists (M_{BAS} = 0.23, *SD* = 0.11) and picture lists (M_{BAS} = 0.25, *SD* = 0.09) did not differ in mean BAS, $t(14) = 0.36$, $p = .72$. For each stimulus type (word vs. picture), DRM lists were pseudo-randomly assigned to the self-reference (4 lists) and other-reference (4 lists) conditions and DRM lists were counterbalanced in a way that each list had an approximately equal chance of appearing in the self-reference or other-reference condition. For each material type, the recognition list included 8 critical lures (one critical lure per list), 8 related but non-presented items (i.e., these items used to be members of the DRM lists thus they were weakly related to the DRM lists), 24 studied items, and 32 unrelated new items. The studied items were from the 1^{st}, 3^{rd} and 7^{th} position of each list.

Design and Procedure

The experiment was a 2 (Reference: self vs. other) × 2 (Stimuli: word vs. picture) within-subject design. All participants went through a study-test round for verbal DRM lists and another study-test round for pictorial lists. Half of the participants studied word lists first and the other half studied the picture lists first. Each participant was tested individually in a quiet and isolated room.

Participants first filled in some information including their own name. They were instructed to enter the name that they were most frequently referred to. For each type of material, in the study phase, the DRM items were presented one by one together with either their own name (self-reference condition) or the name of a famous singer "Adele" (other-reference condition). Participants were asked to remember the items and whom the items appeared together with (self or Adele). The DRM words or pictures were shown list by list, and the items within a list always appeared with the same name (see Figure 2). For each type of materials, the study phase was separated in 4 blocks with each block containing two BAS matched lists (a self-referenced list and an other-referenced list).

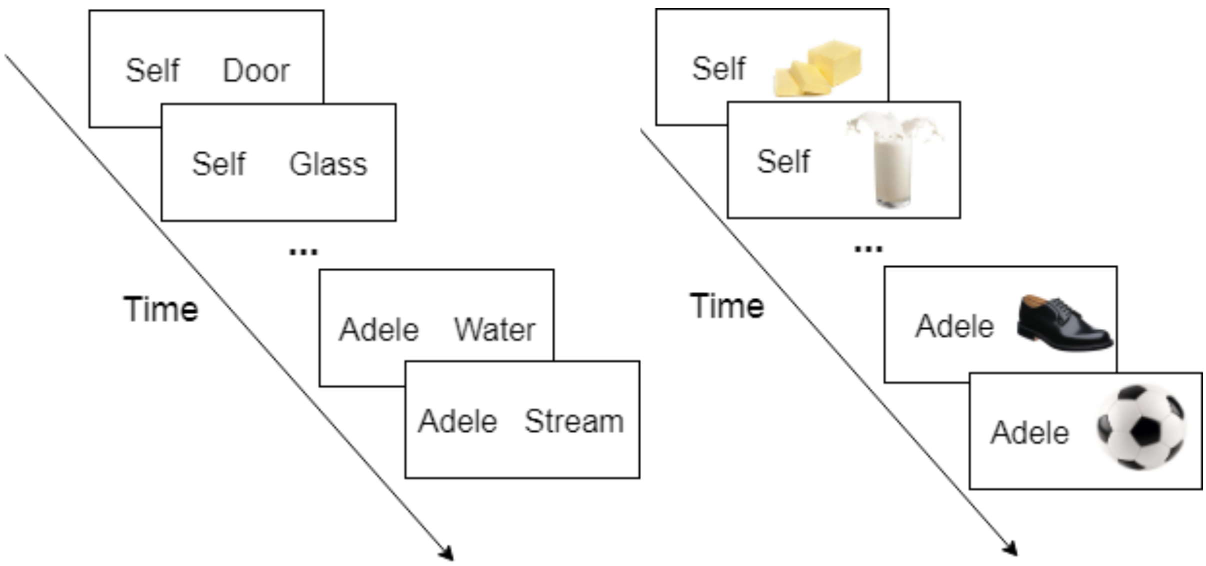

Figure 2. Illustration of the study phase for verbal stimuli (left) and pictorial stimuli (right). "Self" stands for participant's own name. Words and pictures shown in the above figure are sample items from DRM lists, e.g., *Door* and *Glass* are words from the list with critical lure "Window"; *Water* and *Stream* are words from the "River" list. Each DRM list contained 8 items. Each pair was presented for 1500 ms with 500 ms inter-stimulus interval.

After the study phase, participants performed a filler task (playing the "Bejeweled" game) for around 5 min. Then, in the test phase, they completed a recognition test and a separate memory association test. In the recognition test, words (or pictures) were shown at the center of the screen and participants responded by clicking the "Remember", "Know", or "New" button. If the item was new, they clicked the "New' button; if they remembered the word (or picture) as old and can recall specific details such as size, color, shape, etc., they clicked the "Old: Remember" button; and if they identified the item as old but could not recall specific details, they clicked the "Old: Know" button (Yonelinas & Jacoby, 1995; Yonelinas, 2002). After all items were recognized, in a subsequent memory association test, participants were asked which source the words (or pictures) appeared together with by clicking on one of the four buttons: name of oneself, "Adele", "Cannot remember", or "Not presented". Note that participants could choose "Not presented" if they thought the word (or picture) was not presented at all.

Results

Because we were most interested in examining the association data and the memory association test was independent from the recognition test, we first report the association data and then report the recognition results[1]. All data can be accessed at https://osf.io/k5sa8/.

True Association

A true association was defined as when participants correctly recalled the associated name when cued with a studied item. True association rate was calculated

[1] Note that the pre-registered data analyses plan included analyzing net accuracy data, but these data were not reported here because in retrospect they were not relevant to our main purpose.

as the proportion of the number of true associations out of all tested studied items. True association rates were corrected by subtracting relevant association rates of unrelated items to control for response bias. Consistent with previous findings (Cunningham et al., 2014; Durbin et al., 2017), a 2 (Reference: self vs. other) × 2 (Stimuli: word vs. picture) repeated measures ANOVA on corrected true associations revealed a main effect of Reference, $F(1,33) = 8.63$, $p = .006$, partial $\eta^2 = 0.21$, indicating that more stimuli-self associations ($M = 0.69$, 95% CI [0.63, 0.75]) were remembered than stimuli-other associations ($M = 0.59$, 95% CI [0.53, 0.66]). We also found a main effect of Stimuli such that more associations were correctly remembered for picture stimuli ($M = 0.77$, 95% CI [0.72, 0.83]) than for word stimuli ($M = 0.51$, 95% CI [0.44, 0.58]), $F(1,33) = 68.06$, $p < .001$, partial $\eta^2 = 0.67$. There was no statistically significant interaction effect between Reference and Stimuli, $F(1,33) = 3.06$, $p = .09$, partial $\eta^2 = 0.09$. These findings confirm that self-reference can enhance true associations for both words and pictures.

False Association

Of particular interest was whether false associations to critical lures could be created. False association was defined as participants misremembering the lure word/picture paired with a name (i.e., their own name or the name Adele). For non-presented unrelated words, participants recalled false associations for an average of 7.44% (95%CI [0.03, 0.12]) of them, but participants constructed false associations for an average of 66.54% (95%CI [0.59, 0.74]) of all the critical lures in DRM word lists. In pictorial DRM lists, average false association rate for unrelated pictures was 2.76% (95%CI [0.01, 0.04]), but participants developed false associations for 52.94% (95%CI [0.44, 0.61]) of all the critical lure pictures. Hence, although participants were given the chance to choose “Cannot remember” or “Not presented” for critical lures during the memory association test, a large proportion of critical lure words and pictures were falsely remembered as having appeared together with their own name or Adele.

False associations could be either critical lure-self associations (i.e., remembering critical lure paired with own name) or critical lure-other associations (i.e., remembering critical lure paired with Adele). Before making any further analysis, false association rates were corrected by subtracting the relevant false association rates for unrelated items to control for possible response bias. As Figure 3 shows, a 2 (Reference: self vs. other) × 2 (Stimuli: word vs. picture) × 2 (False association type: critical lure-self vs. critical lure-other) repeated measures ANOVA on corrected false association rates showed a statistically significant interaction between Reference and False association type, $F(1,33) = 207.16$, $p < .001$, partial $\eta^2 = 0.86$, suggesting that the reference condition impacted the false association types. No other interaction effects or main effects were found.

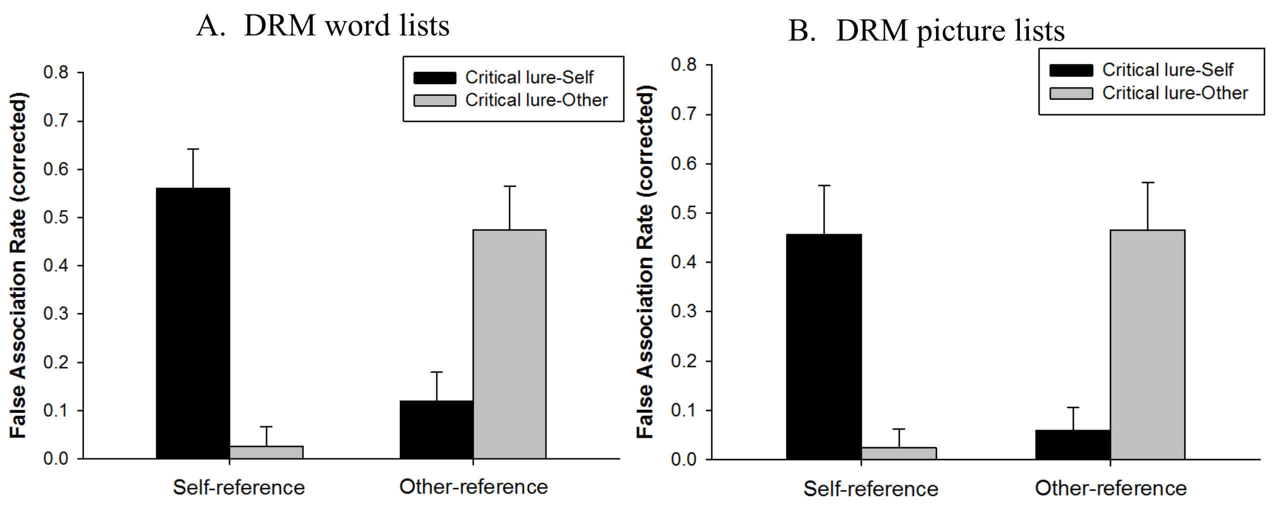

Figure 3. Corrected false association rates in self-reference and other-reference conditions (Experiment 1). Left (A): DRM word lists; right (B): DRM picture lists. Error bars denote 95%CIs.

To further illustrate the Reference × False association interaction, follow-up ANOVA analyses broken down by Reference were conducted. As Figure 3 shows, in self-referenced DRM lists, critical lures were more likely to be misremembered as having appeared together with one's own name than with the name "Adele", $F(1,33) = 166.22$, $p < .001$, partial $\eta^2 = 0.36$. However, in the other-reference condition, i.e., when DRM lists were paired with "Adele", critical lures were more likely to be misremembered as having appeared together with the name "Adele" rather than with their own name, $F(1,33) = 103.42$, $p < .001$, partial $\eta^2 = 0.47$. These results showed that critical lures were most frequently mis-associated with the referential name of their related DRM lists, what we term here as "congruent false associations".

Our second interest was to explore whether self-referencing would enhance the formation of congruent false associations relative to other-referencing. To this end, we compared the magnitude of the effects in the above analyses to contrast the binding effect of self vs. other. The magnitude of the binding effect was calculated as the net proportion of congruent false associations, e.g., subtracting the proportion of critical lure-other associations from proportion of critical lure-self associations in the self-reference condition. We did exploratory comparisons on the binding effect in word and picture stimuli. We found that, for word stimuli, the net proportion of congruent false associations was significantly higher in the self-reference condition ($M = 0.51$, 95%CI [0.41, 0.62]) than in the other-reference condition ($M = 0.36$, 95%CI [0.25, 0.46]), $t(33) = 2.21$, $p = 0.03$, Cohen's $d = 0.54$, suggesting the stronger binding effect of the self in forming congruent false associations. These results suggest that the self not only generates more congruent false associations, but also "clusters" the lure words attached to the self. For pictures, the net proportion of congruent false associations in the self-reference condition ($M = 0.43$, 95%CI [0.31, 0.55]) was similar to that in the other-reference condition ($M = 0.41$, 95%CI [0.29, 0.52]), $t(33) = 0.29$, $p = 0.78$, Cohen's $d = 0.05$.

Table 1. Response rates for critical lures in different reference and stimuli conditions during memory association test (Experiment 1; Means with 95%CIs).

Stimuli type & Reference	Response Rates			
	Critical lure-Self	Critical lure-Adele	Cannot Remember	Not Presented*
Word lists				
Self-reference	0.59 [0.51, 0.67]	0.07 [0.02, 0.12]	0.12 [0.05, 0.19]	0.22 [0.15, 0.29]
Other-reference	0.15 [0.08, 0.21]	0.52 [0.44, 0.61]	0.12 [0.05, 0.20]	0.21 [0.13, 0.28]
Picture lists				
Self-reference	0.47 [0.37, 0.58]	0.04 [0.00, 0.07]	0.10 [0.05, 0.15]	0.39 [0.29, 0.49]
Other-reference	0.07 [0.02, 0.12]	0.48 [0.38, 0.57]	0.08 [0.03, 0.13]	0.37 [0.26, 0.37]

*Note: "Not Presented" means that the critical lure was judged as not presented by the participants.

True Recognition

Based on the R/K paradigm, participants responded either "Remember" or "Know" when they judged an item as presented during the recognition test. A 2 (Reference: self vs. other) × 2 (Stimuli: word vs. picture) repeated measures ANOVA was conducted separately for proportions of remember responses and know responses to studied items. As Table 2 illustrates, for remember responses of studied items, we found a main effect of Reference, $F(1,33) = 15.85$, $p < .001$, partial $\eta^2 = 0.33$; that is, the self-reference condition had statistically more remember responses to studied items than the other-reference condition. We also found a main effect of Stimuli, where pictorial lists had statistically higher remember rates than word lists, $F(1,33) = 22.99$, $p < .001$, partial $\eta^2 = 0.41$. There was no statistically significant interaction effect, $F(1,33) = 0.06$, $p = .80$. For know response rates, there were neither main effects nor interaction effect of Reference and Stimuli.

Table 2. Remember and Know rates of studied items, critical lures and unrelated items in different reference and stimuli conditions (Experiment 1; Means with 95%CIs).

Item type & Reference	DRM word lists		DRM picture lists	
	Remember	Know	Remember	Know
Studied items				
Self-reference	0.55 [0.45, 0.65]	0.25 [0.16, 0.34]	0.76 [0.68, 0.84]	0.16 [0.09, 0.22]
Other-reference	0.45 [0.36, 0.54]	0.26 [0.18, 0.33]	0.68 [0.59, 0.76]	0.20 [0.14, 0.26]
Critical lures				
Self-reference	0.46 [0.34, 0.57]	0.24 [0.14, 0.33]	0.22 [0.13, 0.31]	0.29 [0.19, 0.38]
Other-reference	0.34 [0.24, 0.46]	0.35 [0.24, 0.46]	0.22 [0.14, 0.31]	0.24 [0.16, 0.33]
Unrelated items	0.03 [0.00, 0.05]	0.06 [0.03, 0.09]	0.01 [0.006, 0.02]	0.008 [-0.005, 0.02]

False Recognition

False recognition happened when participants responded “remember” or “know” to a non-presented critical lure. A 2 (Reference: self vs. other) × 2 (Stimuli: word vs. picture) × 2 (Recognition: remember vs. know) repeated measures ANOVA was conducted on false recognition rates of critical lures (see data on “critical lures” in Table 2). A statistically significant three-way interaction was found, $F(1,33) = 4.36$, $p = .045$, partial $\eta^2 = 0.12$. As Table 2 shows, for proportion of remember responses, self-reference increased false remembering recognitions of critical lures significantly compared to other-reference, $t(33) = 2.08$, $p = 0.045$, Cohen’s $d = 0.36$, which aligns well with previous research (Wang et al., 2019), but it did not increase remember recognitions for pictorial critical lures, $t(33) \approx 0.00$, $p \approx 1.00$. For proportions of know responses, self-reference did not have any impact on knowing rates to critical lures in either word or picture DRM lists. Table 2 includes specific remember and know rates in all conditions.

Discussion

Experiment 1 has replicated a number of findings from previous studies. First, we replicated the classical self-reference effect (Symons & Johnson, 1997; Wang et al., 2019). That is, self-reference increased remembering or recollection of studied items for both word and picture stimuli. Second, we replicated the finding that the self can enhance (true) stimuli-self associations for both word and picture stimuli (e.g., Cunningham et al., 2014). Third, we also replicated our previous results concerning the self-reference false memory effect that self-reference facilitates the false recollection of critical lures (Wang et al., 2019).

The novel findings are that when DRM word and picture lists were paired with one's own name or other's name, participants not only falsely remembered that critical lure words and pictures had been presented, but also falsely associated the lure words and pictures with their own name or the other name. This suggests that, without an actual learning experience, the memory system can spontaneously construct a false association for elements from different episodic memories, thus creating a new memory such as one's own name paired with a non-presented lure word/picture. Moreover, such constructive processes seem to be driven by semantic associations. When DRM lists were paired with the self, their semantically related lures were mostly associated with the self; and when DRM lists were paired with another person's name, corresponding lures were mostly associated with that name.

Critically, results from Experiment 1 also suggest that the self specifically facilitates the creation of congruent false associations, i.e., without increasing the overall rates of false associations. We found that, although both self- and other-referencing led to false associations formed between critical lures and the referenced person, the self-binding effect was larger than the other-binding effect, particularly in the word lists. That is, the net proportion of critical lure-self associations was significantly higher than the net proportion of critical lure-other associations. These results suggest that the self might enhance the binding of elements from different episodic memories (e.g., one's own name with a critical lure).

Regarding the effect of stimulus, the differences between self-reference and other-reference on false association rates were found only for word, not for picture, stimuli. Picture DRM lists have a higher level of distinctive information than verbal DRM lists and item-specific processing is more likely be engaged in pictorial than verbal stimuli. Such discrepancies support the hypothesis that item-specific processing might play a role in the self-reference effect on false memory. If self-referencing is not mediated by item-specific processing, there should be no statistical difference on the effect of self-referencing between verbal and pictorial DRM lists. However, we did not observe the impact of stimulus on the false association results. That is, when we compared false association rates in the word and picture lists, no statistically significant difference was found. Although our analyses on net proportions of congruent false associations found a self-binding effect in words and not in pictures, these analyses were merely exploratory and cannot convincingly lead to a conclusive stimulus distinction on false association. To further investigate whether stimulus can impact the formation of false associations, Experiment 2 was conducted. In Experiment 1, the word DRM lists and the picture DRM lists were different lists (because we were using a within-subjects design); and different lists might have different probabilities to induce false recognitions or false associations. To rule out this possibility, in Experiment 2, we used the same DRM lists for the word condition and the picture condition, which required a between-subjects design. That is, the word lists were matched with the picture lists such that each picture list was the pictorial form of a word list (see Wang et al., 2018). Another limitation of Experiment 1 was that each reference condition had only four lists, so four critical lures in total, which might reduce the power. Thus, in Experiment 2, we increased the number of DRM lists in each condition, matched the DRM word lists and picture lists, and used a between-subjects design.

Experiment 2

Method

Participants

A total of 68 participants were tested in Experiment 2 based on the sample size of Experiment 1. Half of the participants ($N = 34$) were randomly assigned to the word group (9 males and 25 females, $M_{\text{age}}= 22.44$, $SD= 2.96$) and the other half ($N = 34$) to the picture group (9 males and 25 females, $M_{\text{age}}= 23$, $SD= 2.90$). Participants were recruited from the online participant pool at Maastricht University and they received course credits for their participation in the experiment.

Materials

Ten word DRM lists (eight items per list) and their corresponding pictorial versions were used in Experiment 2. For example, a DRM word list that contained words such as *truck, bus, train* and *Jeep*, had a corresponding pictorial DRM list containing images of truck, bus, train and Jeep. The word group studied 10 verbal

DRM lists and the picture group studied 10 pictorial DRM lists with the exact same concepts. In this case, the lists were strictly matched in the two groups. The DRM word and picture lists were used in a previous study (Wang et al., 2018). Half of the lists for each group were assigned to the self-reference condition and the other half were assigned to the other-reference condition. Lists in the self-reference and other-reference conditions were counterbalanced in a way that each list has equal chance to be assigned to one of the reference conditions.

The recognition list for each type of stimulus contained 10 critical lures (one per list), 30 studied items (three items per list), 30 new unrelated items and 10 new related items. The studied items were from the 1^{st}, 3^{rd}, and 7^{th} position of each list. Thus, the word group received a verbal version of the recognition list and the picture group were tested with a pictorial version of the same recognition items.

Design and Procedure

The experiment used a 2 (Reference: self vs. other) × 2 (Stimuli: word vs. picture) mixed design, with Reference as a within-subject variable and Stimuli as a between-subjects variable. The procedure of Experiment 2 was identical as in Experiment 1.

Results

True Association

In line with Experiment 1, a 2 (Reference: self vs. other) × 2 (Stimuli: word vs. picture) repeated measures ANOVA on corrected true association rates showed a main effect of Reference, $F(1,66) = 29.23$, $p < .001$, partial $\eta^2 = 0.31$, with more stimuli-self associations being remembered ($M = 0.61$, 95% CI [0.55, 0.66]) than stimuli-other associations ($M = 0.47$, 95% CI [0.42, 0.52]). We also found a main effect of Stimuli such that more correct associations were remembered for picture stimuli (*M* = 0.64, 95% CI [0.57, 0.70]) than for word stimuli (*M* = 0.44, 95% CI [0.37, 0.50]), $F(1,66) = 18.25$, $p < .001$, partial $\eta^2 = 0.22$. No statistically significant interaction effect was found between Reference and Stimuli, $F(1,66) = 0.95$, $p = .33$, partial $\eta^2 = 0.01$.

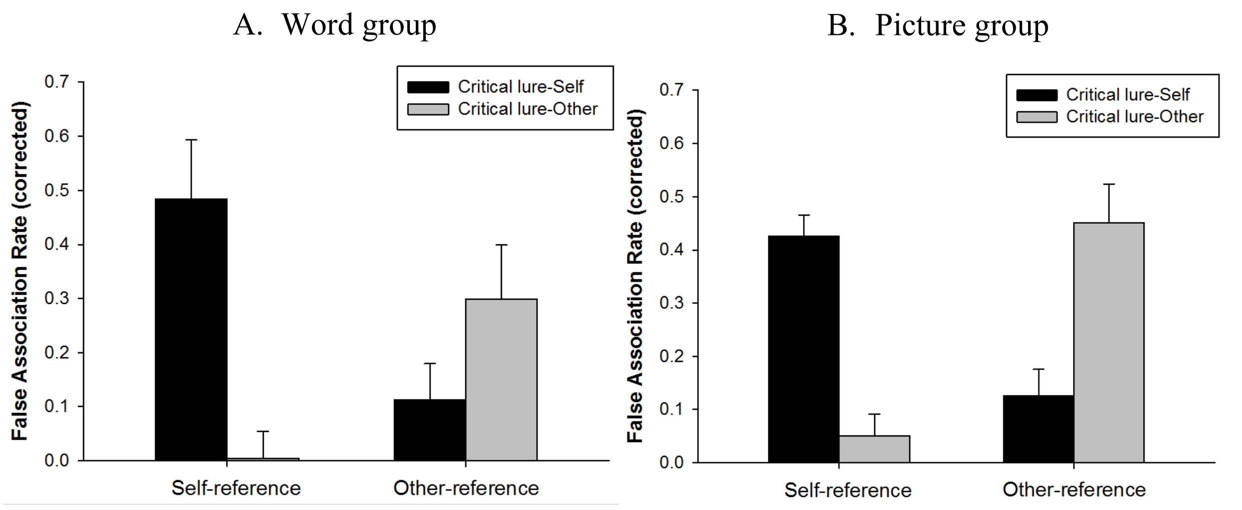

Figure 4. Corrected false association rates in self-reference and other-reference conditions (Experiment 2). Left (A): word group, $n = 34$; right (B): picture group, $n = 34$. Error bars denote 95%CIs.

False Association

As Figure 4 illustrates, a 2 (Reference: self vs. other) × 2 (Stimuli: word vs. picture) × 2 (False association type: critical lure-self vs. critical lure-other) repeated measures ANOVA was conducted on corrected false association rates. A main effect of False association type was found, $F(1,66) = 9.44$, $p = .003$, partial $\eta^2 = 0.13$, showing that there were more critical lure-self associations than critical lure-other associations in general. Similar to Experiment 1, a significant interaction effect between Reference and False association type was found, $F(1,66) = 138.96$, $p < .001$, partial $\eta^2 = 0.68$, suggesting false association types were impacted by the reference conditions. There was a significant interaction effect between Reference and Stimuli, $F(1,66) = 8.20$, $p = .006$, partial $\eta^2 = 0.11$, as well as a significant interaction between

False association type and Stimuli, $F(1,66) = 4.79$, $p = .03$, partial $\eta^2 = 0.07$. Interaction effects were broken down as described below.

Post-hoc analysis examining the Reference × False association interaction showed that, for both lure words and lure pictures of self-reference lists, they were mostly falsely associated with the self rather than with Adele, $F(1,66) = 118.72$, $p < .001$: for word stimuli, $t(33) = 7.39$, $p < 0.001$, Cohen's $d = 1.92$; for picture stimuli, $t(33) = 8.51$, $p < 0.001$, Cohen's $d = 2.20$. Equivalently, for lure words and lure pictures of other-reference lists, they were more likely to be falsely associated with Adele, $F(1,66) = 38.85$, $p < .001$: for word stimuli, $t(33) = -2.82$, $p = 0.008$, Cohen's $d = -0.75$; for picture stimuli, $t(33) = -6.69$, $p < 0.001$, Cohen's $d = -1.80$.

Since we found an interaction effect between False association type and Stimuli, separate analyses broken down by Stimuli (i.e., simple main effect analyses) were conducted. For word stimuli, there were statistically more false associations related to the self than false associations related to the other, $F(1,66) = 9.25$, $p = .005$, partial $\eta^2 = 0.05$; however, for picture stimuli, no statistical difference was found between self-related and other-related false associations, $F(1,66) = 0.77$, $p = .39$. This suggests that the self-enhanced binding effect for false associations was only observed in word stimuli. Moreover, to further investigate the Reference × Stimuli interaction, separate ANOVA analyses were broken down again by Stimuli. Self-referencing did not statistically increase the overall false association rates compared to other-referencing in word stimuli, $F(1,66) = 2.56$, $p = .12$, while in picture stimuli, other-referencing even had higher false association rates relative to self-referencing, $F(1,66) = 6.60$, $p = .02$, partial $\eta^2 = 0.02$.

To examine if self-reference facilitates the construction of congruent false associations, we conducted the following tests on false association scores as in

Experiment 1. We contrasted the magnitude of the binding effect of self vs. other. A 2 (Reference: self vs. other) × 2 (Stimuli: word vs. picture) repeated measures ANOVA on the net proportion of congruent false associations was conducted. We found no significant main effect of Stimuli, $F(1,66) = 0.09$, $p = .76$, partial $\eta^2 = 0.001$, but a significant main effect of Reference, $F(1,66) = 7.74$, $p = .007$, partial $\eta^2 = 0.11$, showing more congruent false associations in the self-reference than other-reference condition. We also observed a statistically significant interaction effect, $F(1,66) = 7.14$, $p = .01$, partial $\eta^2 = 0.10$. Similar to what we found in Experiment 1, in the word group (see Figure 4), net critical lure-self association proportion in the self-reference condition ($M = 0.48$, 95% CI [0.35, 0.60]) was significantly higher than the net critical lure-other association proportion in the other reference condition ($M = 0.19$, 95% CI [0.06, 0.32]), $t(33) = 3.33$, $p = 0.002$, Cohen's $d = 0.80$, indicating a stronger binding effect of the self in binding critical lures with itself. For picture stimuli, net critical lure-self association proportions did not differ in the self-reference ($M = 0.35$, 95% CI [0.26, 0.44]) and other-reference ($M = 0.35$, 95% CI [0.24, 0.45]) conditions, $t(33) = 0.10$, $p = 0.92$.

Table 3. Response rates for critical lures in different reference and stimuli conditions during memory association test (Experiment 2; Means with 95%CIs).

Stimuli type & Reference	Response Rates			
	Critical lure-Self	Critical lure-Adele	Cannot Remember	Not Presented*
Word group				
Self-reference	0.55 [0.44, 0.66]	0.07 [0.03, 0.11]	0.12 [0.05, 0.20]	0.26 [0.18, 0.33]
Other-reference	0.18 [0.10, 0.25]	0.36 [0.27, 0.46]	0.12 [0.05, 0.19]	0.33 [0.24, 0.42]
Picture group				
Self-reference	0.43 [0.35, 0.51]	0.08 [0.04, 0.11]	0.35 [0.27, 0.43]	0.14 [0.08, 0.20]
Other-reference	0.13 [0.08, 0.18]	0.48 [0.40, 0.56]	0.29 [0.21, 0.38]	0.10 [0.05, 0.15]

*Note: "Not Presented" means that the critical lure was judged as not presented at all.

True Recognition

Remember and Know rates of various items were reported in Table 4. We conducted a 2 (Reference: self vs. other) × 2 (Stimuli: word vs. picture) repeated measures ANOVA on remember and know rates of studied items respectively. For remember rates, there was a main effect of Reference, $F(1,66) = 8.75$, $p = .004$, partial $\eta^2 = 0.12$; that is, the self-reference condition had statistically more remember responses to studied items than the other-reference condition. We also found a main effect of Stimuli, with the picture group having significantly higher remember rates than the word group, $F(1,66) = 19.58$, $p < .001$, partial $\eta^2 = 0.23$. No statistically significant interaction effect was detected, $F(66) = 0.14$, $p = .71$. For the know response rates, only a main effect of Stimuli was found, $F(1,66) = 9.88$, $p = .003$, partial $\eta^2 = 0.13$, where the word group had higher know rates than the picture group.

False Recognition

Previous research (Wang et al., 2019) as well as results in Experiment 1 showed that self-referencing mainly impacts false remembering. 2 (Reference: self vs. other) × 2 (Stimuli: word vs. picture) repeated measures ANOVAs were conducted on remember rates as well as know rates of critical lures (see Table 4). For remember rates, there was neither a main effect of Reference, $F(1,66) = 1.19$, $p = .28$, nor a main effect of Stimuli, $F(1,66) = 0.003$, $p = .95$. When analyzing know rates of critical lures, we found no main effect of Reference, $F(1,66) = 0.19$, $p = .67$, no main effect of Stimuli, $F(1,66) = 1.59$, $p = .21$, and no significant interaction effect, $F(1,66) = 0.008$, $p = .93$. Table 4 shows remember and know rates of critical lures in each reference and stimuli condition.

Table 4. Remember and Know rates of studied items, critical lures and unrelated items in different reference and stimuli conditions (Experiment 2; Means with 95%CIs).

Item type & Reference	DRM word lists		DRM picture lists	
	Remember	Know	Remember	Know
Studied items				
Self-reference	0.48 [0.38, 0.58]	0.33 [0.24, 0.42]	0.69 [0.62, 0.76]	0.17 [0.12, 0.22]
Other-reference	0.39 [0.30, 0.48]	0.33 [0.24, 0.42]	0.62 [0.57, 0.68]	0.21 [0.16, 0.26]
Critical lures				
Self-reference	0.28 [0.19, 0.28]	0.34 [0.26, 0.42]	0.25 [0.18, 0.32]	0.28 [0.19, 0.36]
Other-reference	0.22 [0.14, 0.31]	0.32 [0.24, 0.41]	0.26 [0.20, 0.32]	0.26 [0.17, 0.36]
Unrelated items	0.10 [0.05, 0.14]	0.04 [0.02, 0.06]	0.03 [0.006, 0.05]	0.01 [0.001, 0.02]

However, when we combined remember and know responses and examined the overall recognition rates (i.e., summing up the remember and know rates), a 2 (Reference: self vs. other) × 2 (Stimuli: word vs. picture) × 2 (Recognition: true vs. false) repeated measures ANOVA showed a significant main effect of Reference, $F(1,66) = 6.44$, $p = .01$, partial $\eta^2 = 0.09$, with generally higher recognition rates in the self-reference than the other-reference condition. There was also a main effect of Recognition, $F(1,66) = 82.91$, $p < .001$, partial $\eta^2 = 0.56$, with more true recognitions than false recognitions on average. The only significant interaction effect was between Reference and Stimuli, $F(1,66) = 6.25$, $p = .01$, partial $\eta^2 = 0.09$. Recognition (true/false) neither interacted with Reference nor with Stimuli. Follow-up analyses (with Bonferroni correction) revealed that, for both true and false recognitions, self-reference led to higher recognition rates in word stimuli ($p = .005$) but not in picture stimuli ($p = .51$). Thus, Experiment 2 found the self-reference false memory effect for overall recognition rates in word stimuli.

Discussion

Experiment 2 has replicated the main findings of Experiment 1. Specifically, (1) false associations of critical lures can be robustly constructed for both word and picture stimuli. That is, 36% - 55% of the critical words were falsely associated with a reference name and 43% - 48% of the critical pictures were falsely associated with a reference name (see Table 3); (2) there were more critical lure-self associations formed than critical lure-other associations. With more DRM lists included per reference condition, the enhancing effect of the self on association construction has been robustly demonstrated.

Another interesting finding was a discrepancy on false recognition/association results for different stimuli. Consistent with results in Experiment 1, Experiment 2 found that self-reference only facilitated (overall) false recognition and false association formation for words but not for pictures, even with DRM word lists and DRM picture lists being the same lists. The picture lists and words lists share the same concepts and the same critical lures, hence a main difference between these two stimulus types should be the level of item-specific information (Schacter et al., 1999). When looking at the overall false recognition and false association rates of critical pictures in the self-reference and other-reference conditions respectively, we found that false memory rates of critical pictures did not differ in the self-reference and other-reference conditions, suggesting that item-specific processing impacts the self-reference false memory effect.

General Discussion

The current experiments examined whether false associations can be spontaneously created in episodic memory and how the self plays a role in forming false associations. For the first question, our two experiments consistently showed that false associations can be constructed even for non-presented words and pictures at a robust level (on average, 52% ~ 66%). When a list of related items (e.g., *truck, bus, train, keys, garage*, etc.) was paired with oneself or another person, participants later misremembered that a related but non-presented item (i.e., *car*) was also paired with themselves or the other person. Furthermore, these false associations seem to be directional in the sense that they may be guided by the semantic connectivity in the memory network. That is, we found that non-presented critical lures were most frequently associated with the referential person of their semantically related DRM lists (see Figure 1), even though participants could choose that they "Cannot Remember" the association or the critical lure was simply "Not Presented".

This is the first study to construct false associations between non-experienced stimuli and the self in episodic memory. Memory researchers have long speculated about the reconstructive nature of memory. For example, Bartlett (1932) first suggested that memory is reconstructive, i.e., that people can fill in missing elements while remembering, leading to false memories of the missing elements. Since then researchers have successfully induced false memories with different experimental paradigms (e.g., Loftus & Palmer, 1974; Roediger & McDermott, 1995), confirming the reconstructive nature of memory. However, little is known about how exactly memory is constructed. By focusing on associations between stimuli, the current experiments showed that our memory system can construct new associations (e.g., critical lure-self or critical lure-other) based on semantic relatedness.

Spreading Activation and Constructive False Memory

The constructive memory phenomenon in the current experiments can be readily explained by spreading activation accounts (Anderson, 1983; Howe et al., 2009; Roediger et al., 2001). In a memory network, concepts from DRM lists such as *butter, flour, dough, sandwich, jam* and *milk* are embedded and there are existing associations relating each concept to the critical lure *bread* due to, for example, personal experiences. When these DRM items (words or pictures) are incidentally paired with one's own name (or another person's name), stimuli concepts as well as the reference person are activated and therefore stimuli-self (or stimuli-other) associations can be formed in the memory network (see Figure 1). According to the spreading-activation principle, activations of the list items can spread automatically to their related concepts (e.g., *bread*), resulting in the activation of *bread* as well. Indeed, recent neuroimaging research has shown that critical lure concepts are probably activated during encoding (Zhu et al., 2019). Thus, critical lures and the self (or "Adele") are activated together and this co-activation could possibly lead to a false association being constructed between critical lures and the self (or other) in the memory network. Intriguingly, we indeed found that high levels of false associations were constructed spontaneously in participants' memory, which is consistent with the automaticity assumption of spreading activation.

What the current experiments cannot tell us is whether the false associations were created during encoding or retrieval. Since previous research showed that false memories of critical lures are probably formed during encoding (e.g., Gallo, Roediger, & McDermott, 2001; Zhu et al., 2019), in the current study, false associations between critical lures and the reference person could have been formed during encoding, too. However, that does not have to be the case, and the false associations could also have been formed at retrieval. Roediger et al. (2004) proposed that attribution of the critical lures might be the function of participants' knowledge about the structure of the memory test. Similarly, participants in the current study might reason that if they recollected that a word or picture was presented, it should have appeared together with either their own name or the other person's name. However, if false associations are constructed during retrieval, it is intriguing that participants made false associations even though they could have opted for not remembering the source or saying that the critical lure was not presented. Future research is needed to investigate at which phase false associations are formed.

Self-enhanced Constructive Effect and its Boundary

For our second question, whether the self plays a role in false association construction, the answer is yes. We looked at two indicators related to this question: the absolute number of congruent false associations created in the self-reference and other reference conditions, and the net proportion of congruent false associations within each reference condition. In both experiments, we found that (1) there were more critical lure-self associations constructed than critical lure-other associations and (2) in the self-reference condition, the net proportion of critical lure-self associations was significantly higher than the net proportion of critical lure-other associations in the other-reference condition. Although these results were only found with word stimuli, they suggest that when people process information related to themselves, they tend to construct more associations of non-experienced stimuli related to themselves, and this self-enhanced constructive effect may only work at the verbal or low item-specific level.

We term the phenomenon of enhancing both false recognition and false association by the self as the self-enhanced constructive effect. The reason for observing such an effect may be due to the relational processing of the self as well as spreading activation in the memory network. For true associations, Experiments 1 and 2 have replicated the previous finding that self-reference enhances learned stimuli-self associations; that is, the binding of stimuli to oneself for both words and pictures (Cunningham et al., 2014; Durbin, Mitchell, & Johnson, 2017). As Sui and Humphry (2015) proposed, the self can facilitate the binding of memory to source. When the self was paired with DRM items in our experiments, we indeed found that more stimuli-self associations were remembered. When more stimuli-self associations were encoded in memory, according to the spreading-activation account, more activation might spread to the critical lure and more indirect associations might be established between the self and the critical lure (see Figure 1), resulting in a higher chance of creating critical lure-self associations.

However, we found in our study that the self-enhanced constructive effect is limited to verbal stimuli and does not extend to picture stimuli. This difference might be accounted for by the amount of item-specific information in the stimuli. The main mechanisms underlying the self-reference effect have been suggested to be item-specific processing and relational processing (Klein, 2012; Symons & Johnson, 1997), for which the main evidence came from the experiment by Klein and Loftus (1988). Our results have extended the dual-processing account to self-referencing on false memory. For true recognition/association, both experiments found that self-reference simultaneously increased true recollection as well as stimuli-self relational binding for both words and pictures. This is because self-referencing can evoke both item-specific processing (i.e., recollection) and relational processing (i.e., association), and both of them benefit true memory (see Huff & Bodner, 2019), regardless of stimulus types. For false recognition/association, both experiments found that self-reference increased false recognition and false association in the word but not picture condition. The reason why we did not find a self-enhanced constructive effect in pictures might be due to the opposing effects of this dual processing on false memory: item-specific processing usually suppresses false memory (McCabe, Presmanes, Robertson, Smith, 2004) while relational processing can enhance false memory (Gallo & Roediger, 2002). In the picture condition where item-specific processing is naturally boosted, the opposing effects of self-referencing might have cancelled out in picture stimuli, resulting in a null effect. By contrast, words generally have low distinctive item-specific information, so the effect of relational processing might surpass the effect of item-specific processing, resulting in a larger false memory effect.

One might argue that what we found may be specifically due to an "Adele" effect as "Adele" was used in both experiments. However, previous research on the self-reference effect suggests that this is unlikely. First, many studies have used celebrity names (e.g., presidents, singers, actors) in the other-reference condition and found similar results when studying the effect of self vs. other on true memory (see a review by Symons & Johnson, 1997). Second, our previous research on self-reference and false memory used other names such as "Trump" and "Li Ming" in different cultural groups but found no difference between these names (Wang et al., 2019). Indeed, false recognition data from the current two experiments have replicated the same result pattern as in Wang et al. (2019). Thus, it is unlikely that the enhanced effect of self on false memory was particularly due to the name "Adele". The reason for using "Adele" as the other-reference name in both experiments is because we wanted to make the results comparable across the two experiments.

Taken together, we found that false associations of non-presented words and pictures can be constructed in episodic memory. More importantly, we found a self-enhanced constructive effect that self-reference enhances the formation of congruent false associations in verbal stimuli. We propose that spreading activation in the memory network leads to false association construction, and item-specific processing might inhibit the self-enhanced constructive effect.

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