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THE NEURAL AND BEHAVIORAL CORRELATES OF RELATED LURE INTERFERENCE
ON CORRECT RECOGNITION AND FALSE MEMORY SUPPRESSION

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ABSTRACT

Successful memory retrieval requires one to distinguish between old and new information. This is often difficult when new information is closely related to old information and thus causes interference at the time of the retrieval decision. In order to investigate the neural basis of these interference effects, we presented individuals with a retrieval test in which lures were perceptually similar to targets and counterbalanced the order in which the target and corresponding related lure were presented. Results showed that when the related lure came first (as opposed to when the related lure was preceded by the target), the lure caused interference in both recollection hit and recollection correct rejection trial types. Specifically, when the related lure was presented prior to the target, increased activity was observed in frontal and parietal regions (reflecting increased evaluation) as well as inferior and middle occipital gyri and fusiform gyrus (reflecting increased visual inspection necessary to resolve interference) for both items. When the target preceded the lure, results revealed a much more limited neural network for both target acceptance and lure rejection. These results suggest that the presentation of a related lure generates interference that then requires heightened attentional processing and evaluation of item details for both the current and future memory decisions. In contrast, when the target is presented first, and interference from the related lure is diminished, correct recognition and correct rejection processing operates much more efficiently.

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Chapter 1

Introduction

False memory retrieval has become a significant point of discussion within the field of memory psychology. Understanding the behavioral and neural mechanisms associated with true and false memories can help science more broadly understand the systems by which the human brain stores and retrieves information. False memory studies also have several applications outside of science, especially with respect to the criminal justice system. Cases of mistaken identity and incorrect eyewitness testimony have been attributed not to purposely falsified information, but rather inaccurate information being recalled by the witness after a crime (Loftus 1979). Understanding the nature of true and false memory has the potential to decrease the likelihood of false convictions. The present study examines neural networks and behavioral patterns associated with true memory recollection as well as correct rejection of lure information, thus the avoidance of false memories.

In order to avoid false memories, one must correctly identify information never before encountered as new, resulting in a correct rejection. The process of correctly rejecting false items presented at retrieval (lures) can be explained through dual process theory. Dual process theory arose from a study done on amnesic subjects who were shown to be able to recall information subconsciously, though they were unable to make correct conscious memory decisions (Warrington & Weiskrantz 1970). In its early years, dual process theory attempted to dissociate “intentional” from “automatic” processes, based on the idea that the two were separate (Jacoby 1991). Today, dual process theory holds that the two separate processes are familiarity and

recollection, with both processes working to either correctly identify an old memory or correctly reject false memories. When a participant views a target at retrieval, they first operate on a feeling of general familiarity, then accumulate recollected details over time which match with the target they saw at retrieval. When a participant views a lure at retrieval, they again accumulate familiarity at first, but given time will recall details from the target at encoding which do not match with the lure they are currently viewing, leading to correct rejection. Thus, recollection is a slower process than familiarity (Matzen, Taylor, & Benjamin, 2011). Because recollection of encoding details happens more slowly than the general sense of familiarity which may cause participants to false alarm to lures, there is an inverted-U relationship between false alarm rates and time (Brainerd, et. al. 2003). The time difference between the recollection and familiarity processes provide evidence to support the theory that the two are separate. Dual process theory thus provides a possible cognitive mechanism for both recollection acceptance and recollection of target information that is necessary to reject lures (i.e., recollection rejection).

Previous studies have shown that relatedness of a lure to its target is proportional to incidences of false alarm. Increased relatedness causes feelings of familiarity at retrieval in response to lures, in turn producing false acceptance of the lure as old (Fazendeiro et. al. 2005; Arndt & Reder 2003). Fuzzy-trace theory states that false memories are a result of a shared gist between two items, causing familiarity which is either accepted as valid or suppressed by detail recognition (verbatim trace) (Brainerd & Reyna 2002). An increase in false alarms for related lures is evidence for a shared gist trace between the target and lure, which causes difficulty in deciding between false acceptance and correct rejection of related lures at retrieval. The order in which a target is presented with respect to its lure during retrieval may therefore affect the difficulty of correct recognitions and rejections. Whether attempting to correctly accept a target

or correctly reject a lure, details from encoding are needed at retrieval. If a related lure is presented before the target, the gist traces shared by the lure and target may cause the lure to be falsely accepted as old. However, if the target is presented before the related lure at retrieval, it may act as a reminder of item details shown at encoding, aiding in false memory suppression when the lure is shown, and allowing the lure to be correctly rejected.

The current study analyzes data for recollection hits (correctly identifying a target at retrieval as old, in this paper called RecH) and recollection correct rejection (correctly identifying a lure at retrieval as new, in this paper called RecCR). This thesis takes both behavioral and neural data into account. Behaviorally, correct recognition of a target at retrieval as old relies on retrieval of details of the target from encoding. Participants compare these details with the target they view at retrieval, and accept the details of this target as old, leading to a recognition response (Henson et. al., 1999). If this recognition response is correct, the trial is categorized as a RecH. The neural networks for RecH include the prefrontal cortex, which works to regulate memory accuracy (Gallo, Kensinger & Schachter, 2006). Recognition judgements, especially when consciously made, have also been associated with the parietal lobe (Henson et. al., 1999). Correctly recognizing a target at retrieval also involves the medial temporal lobes (MTL). Higher MTL activation has been associated with correct memory retrieval, compared to lower MTL activity for incorrect memory retrieval (Nyberg, et. al. 1996). Visual detail retrieval is important for correctly retrieving details of visual stimuli and correctly recognizing the target as old, and visual areas such as the occipital cortex are also part of the neural network involved in correct recognition (Courtney et. al., 1996, 1997).

Correct rejection of lures at retrieval uses a cognitive process known as recollection rejection, which also relies on retrieval of details of the target at encoding. According to dual

process theory, initial recollection relies first on gist traces to the target at encoding, which is only possible if the lure bears some resemblance to the target (also known as related lures, used in this study). After initial gist traces have reminded the participant of the target, more specific details of the target are recalled which may be different from the details of the presented lure (Brainerd et. al., 2003). Thus the two processes of dual process theory (familiarity and recollection) work together to present the participant with a mental image of the target. They then compare these old details with the details of the lure (Odegard & Lampinen, 2005), recognize the differences between the two images, and correctly identify the lure as a new image leading to a RecCR trial type.

Several areas of the brain have been shown to be related to RecCR memory decisions. The process of recollection-rejection, like RecH, should recruit the MTL to retrieve memories of the original target in order to correctly identify the lure as different from the target (Brainerd & Reyna 2003; Daselaar et. al., 2006). The dorsolateral prefrontal cortex is a region involved in working memory (Petrides, 2000) and post-retrieval memory regulation (monitoring) (Fletcher & Henson, 2001), and literature has shown that it is involved in suppression and correct rejection of false memories (Achim & Lepage 2005).

The cognitive processes and neural networks associated with RecH and RecCR have been well researched. The novel contribution of this thesis is to consider RecH and RecCR analyses together with the presentation order of related lures and targets during retrieval. During the retrieval phase of the study, targets and lures were presented in semi-randomized order such that 50% of the time the target was presented first and the other 50% of the time the lure was presented first. This thesis aims to analyze whether presenting the target before the lure, or vice versa, has any effect on behavioral and neural RecH and RecCR data.

During encoding, participants were shown images of objects. At retrieval, objects were shown which were presented at encoding (targets), as well as objects which were related to targets in that they were new exemplars of categories presented at encoding (for example, a green apple lure where the target at encoding was a red apple; see Figure 1). According to our hypothesis, if the related lure came first during retrieval (as opposed to when the related lure is preceded by the target), the lure would cause interference that persists over the entire set, whether identifying the target or rejecting the lure. In the case of RecH, presentation of the target first (before the lure during retrieval) is identified as T1, and presentation of the target after the lure is identified as T2.

Hypothesis 1: RecH behavioral Recognizing a target as old should be less demanding if the target is presented at retrieval before the related lure is presented due to a lack of interference from the lure. Therefore we expect to see more recollection-based hits for the T1 condition than the T2 condition.

Hypothesis 2: RecH neural If the target is presented after the lure (T2 condition), the lure has already been presented and, most likely, rejected. The process of recalling details of the target in order to reject the lure should strengthen MTL signals tracing back to the target, leading to a stronger MTL signal at target recognition due to previous repetition of the target's features upon viewing the lure (Song, Jeneson & Squire 2011). Therefore, MTL activity should be seen in T2>T1 fMRI analyses.

In the case of RecCR, presentation of the lure first (before the target during retrieval) is identified as L1, and the presentation of the lure after the target is identified as L2.

Hypothesis 3: RecCR behavioral Familiarity traces can lead to false acceptance of related lures (Fazendeiro et. al. 2005). Therefore, L1 may be influenced by shared gist traces

between target and lure, leading to higher false acceptances and lower correct rejections.

However, in the case of L2, the target presented before the lure may act as a memory refresher of target-specific details, providing tools for false memory suppression and more correct rejections.

Therefore L2 should have a higher rate of correct rejections than L1, which has no target memory refresher before the lure is presented.

Hypothesis 4: RecCR neural We would expect an increase in MTL activity in L2 because of strengthened MTL connection from target refresher. In the L1 condition, we would expect to see increased PFC and parietal activity because more attentional processing is needed to recall details from encoding in order to reject the lure. Also, we may expect visual (occipital lobe) activity in the L1 condition as visual details are retrieved from the study phase.

Chapter 2

Method

Participants

Participants included 27 young adults. Data from all participants (19 females, mean age = 22.19 years, SD = 3.21 year, range = 18-31 years) are presented for behavioral analyses. Data from 5 young adults were excluded from imaging analyses due to insufficient trials in a regressor of interest, leaving data from 22 young adults presented in all neuroimaging analyses (mean age = 21.9 years, SD = 3.29 years). All participants were right-handed, native English speakers. All participants were screened for contraindications for functional magnetic resonance imaging (fMRI), including screening for health issues affecting blood flow, previous brain trauma, and medications that are known to affect neural functioning.

Materials

Stimuli consisted of 316 images of common objects collected from the Band of Standardized Stimuli (BOSS) database (Brodeur, Dionne-Dostie, Montreuil, & Lepage, 2010) as well as an internet image search. Images were cropped and resized to an approximate size of 400 x 400 pixels and equated for resolution. Images were displayed at a screen resolution of 1024 (H) x 768 (V) at 75 Hz. At the viewing distance of 143 cm, the display area was 20 deg (H) x 16 deg (V) with experimental stimuli subtending 5 (H) x 4 (V) deg.

Encoding items included 96 images, each an exemplar from a distinct category or conceptual theme (see Appendix B for full listing of categories). This was to ensure that recalling

the target item when a lure is presented would provide sufficient information to reject the lure.

For example, as long as there is only one backpack presented during encoding, recalling the features of the backpack will allow participants to reject a similar, yet distinct lure backpack shown at retrieval. This distinctiveness has been shown to be an important factor in eliciting the recall-to-reject strategy (Gallo, 2004; Lampinen, Watkins, & Odegard, 2006). At retrieval, these targets were re-presented in addition to three types of lures (see Figure 1 for example). The first type of lures was 'item lures' which were an alternative exemplar of the same item presented at encoding. For example, if a backpack were presented during encoding, a backpack of another color or design would be an item lure. The second type of lures was 'thematic lures' which were a new item within the same general category or theme of an item presented at encoding. In the above example, a duffle bag would be a thematic lure as it is also a bag, but is not the same type of exemplar presented during encoding. The third type of lures was 'unrelated lures' taken from categories not presented during encoding.

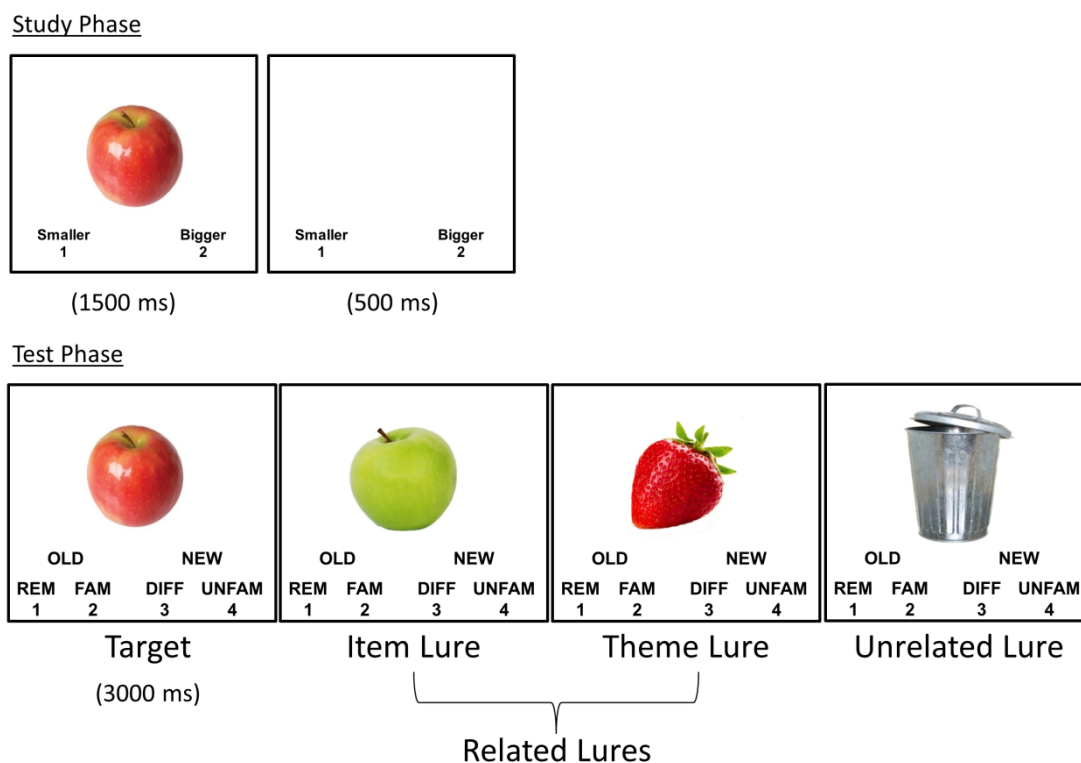


Figure 1. Stimulus presentation during the encoding and retrieval phases. During encoding, participants saw individual images presented on the computer screen for 1500 milliseconds followed by a 500 millisecond fixation cross. During that time, they decided whether the item presented would fit inside a shoebox. During the retrieval phase, participants were presented with targets, item lures, thematic lures, and unrelated lures for 3 seconds each. During that time they were asked to make a recognition judgment using the adaptation of the ‘remember-know-new’ paradigm.

To ensure that participants perceived target and items lures to be more related to one another than targets and thematic lures, a norming study was conducted with 15 Penn State undergraduates (11 females; mean age = 19.7, $SD = 1.6$) as well as 5 older adults (3 females; mean age = 74.2, $SD = 8.64$) from Centre County, PA. Participants were shown two images from each category at a time and had 4 seconds to make a relatedness rating on a 5 point scale (1 = not related, 2 = slightly related, 3 = moderately related, 4 = strongly related, and 5 = nearly identical). Participants were told that items could be considered related if they 1) looked similar 2) belonged to a similar category 3) could be used for a similar purpose or 4) were similar in any other important way that they could think of. Participants were presented with 104 categories and

made 3 relatedness judgments for each category, corresponding to the three types of item comparisons possible for each category (i.e., target – item lure; target – thematic lure; item lure – thematic lure). Once participants completed all relatedness judgments for all categories, participants made relatedness judgments for each unrelated lure. These items were presented individually on the computer screen and participants were asked to make relatedness judgments on the previously described 5-point scale based on each item's relatedness to any item presented previously in the experiment. That is, participants were asked for each item to try and think of an item from the experiment that was related to the currently presented item. If they could not think of such an item, participants were instructed to rate that item as a 1 (not related). If participants could think of one or more related items, they were instructed to make their rating based on the single most related item that they could think of. Participants were presented with 30 unrelated items and were given 7 seconds to make each rating.

Based on the results from this norming study, 8 categories were not included in the final experimental task and 2 unrelated lures were eliminated. Results from this norming study are presented as part of Appendix A, including the mean rating and standard deviation for each type of comparison. Means and standard deviations are presented for each age group separately. Although the sample was small, a 2 (Age: young, older) x 2 (Comparison Type: target – item lure, target – category lure) ANOVA was conducted to test for age differences in the perceived relatedness between items. Given that older adults tend to show higher rates of false recognition, it was necessary to ensure that any effect of aging in false memory would not be a result of older adults perceiving the stimuli as more related than young adults perceive them. This analysis revealed a main effect of Comparison Type [$F(1,18) = 173.83, p < 0.001$]. Post-hoc comparisons revealed that targets and item lures were viewed as more related to one another than

targets and thematic lures. Regarding age differences, there was no significant main effect of age [$F(1,18) = 0.32, p > 0.5$] nor was there a significant interaction [$F(1,18) = 1.41, p > 0.9$]. Thus, the norming study shows that item lures are perceived as more related to targets than category lures are and that this effect did not vary by age, suggesting that any behavioral age differences in memory responses are in fact memory related and not merely due to differential perceptions of the stimuli themselves.

Experimental Procedure

Participants completed the encoding and retrieval phases in a single session. The encoding phase took place inside the scanner and will be used for a separate analysis. Encoding was incidental and participants were instructed to make a size judgment about each of 96 items (i.e., is this item bigger or smaller than a shoebox?). Each image was presented for 1500 ms followed by 500 ms additional responding time before automatically advancing to the next item. Each item was followed by a variable inter-trial fixation ($M = 2470$ ms, $SD = 1760$ ms). Images were displayed by COGENT in MATLAB (MathWorks).

Following the encoding phase, participants underwent structural scans before beginning the retrieval task. After the structural scans, participants were given instructions for retrieval and completed several practice trials. Altogether, there were approximately 10 minutes in between the end of the encoding phase and the beginning of retrieval. During retrieval, participants completed four runs of the task, each lasting approximately 7 minutes. Images were projected onto a screen that participants viewed through a mirror attached to the head coil. Participants were presented with all 96 studied items (targets), both the item and thematic lures from each of

the encoding categories (96 of each), and 28 unrelated lures. Half of the categories presented the target first, and half of the categories presented the item lure first. For each run, there were an equal number of categories in each type (either target – first or item lure – first). The minimum distance between two items of the same category was 10 trials. Behavioral responses were recorded using a response box. Scanner noise was reduced with headphones and cushioning was used to reduce head motion. All stimulus categories were presented in an intermixed fashion during each run, pseudo-randomly ordered to ensure that no more than three stimuli of the same category were presented sequentially. Each stimulus was displayed for 3 seconds while participants made their responses in the adapted ‘Remember-Know-New’ paradigm. Each trial was followed by a variable inter-trial interval (jitter; $M= 2340$ ms, $SD= 1440$ ms) to aid in deconvolving the hemodynamic response (Dale, 1999). In accord with typical instructions for the remember-know-new paradigm, participants were asked to respond ‘Remember’ if they believed that the item was presented during the first phase of the experiment, and they remembered specific, vivid details of its prior presentation. Participants were instructed to respond ‘Know’ if they believed the item was presented during the first phase but they could not recall specific details about its prior presentation. However, instead of the typical ‘New’ response, participants were asked to respond with two distinct ‘new’ options - ‘Unfamiliar’ or ‘Different.’ They were instructed to respond ‘unfamiliar’ if they believed an item was not presented during the first phase of the experiment because it did not resemble or bring to mind anything from the previous encoding phase. Participants were instructed to respond ‘Different’ if they believe the item was not previously presented and they could recall aspects of truly presented items that provided evidence that this item was not presented (for full instructions, see Appendix A). After

completing the retrieval task, participants completed a debriefing questionnaire that asked about their strategies during the task.

Image processing

Functional data were preprocessed and analyzed with SPM8 (Statistical Parametric Mapping; Wellcome Department of Cognitive Neurology, <http://www.fil.ion.ucl.ac.uk/spm>). Images were first checked for movement and scanner artifacts using a time series diagnostic function TSDiffAana (Freiburg Brain Imaging) in MATLAB (MathWorks). Data were then spatially realigned in order to correct for motion artifacts and co-registered to each individual's high resolution anatomical image. Functional images were spatially normalized to a standard stereotaxic space using the Montreal Neurological Institute templates implemented in SPM8. Finally, the volumes were spatially smoothed using a 6-mm isotropic Gaussian kernel.

fMRI analyses

Trial-related activity was modeled in the General Linear Model with a stick function corresponding to trial onsets convolved with a canonical hemodynamic response function (hrf). Statistical parametric maps for each participant were identified by applying linear contrasts to the beta weights for the events of interest. Regressors were defined by crossing response options (remember, know, different, unfamiliar) with stimuli types (target, related lure, unrelated lure). Individual regressors were defined for each response to targets, leading to four regressors associated with target items (true recollection, true familiarity, misses based on recollection

rejection, and misses based on lack of familiarity). Within true recollection, two regressors of interest were defined for target recollection based on presentation order: recollection hit T1 (recollection hits for which the target was presented first during retrieval, identified as RecH T1) and recollection hit T2 (recollection hits for which the target was presented after its category lure, identified as RecH T2). True familiarity and misses were coded, but were treated as regressors of no interest as they were not used in analyses for the current study. For related lures, two regressors were defined for ‘different’ (recollection rejection) based on presentation order. Recollection rejection for which the lure had been presented before the target was defined as recollection rejection L1, or RecCR L1. Recollection rejection for which the lure had been presented after the target was defined as recollection rejection L2, or RecCR L2.

Also for related lures, individual regressors were defined for ‘unfamiliar’ (lack of familiarity) responses while ‘remember’ and ‘know’ responses were collapsed into a single regressor due to low power (related false alarms). Lastly, two regressors were defined for unrelated lures: ‘different’ and ‘unfamiliar’ responses (unrelated correct rejection) and ‘remember’ and ‘know’ responses (unrelated false alarm). While these regressors were coded, they were treated as regressors of no interest because they were not analyzed in the current study. For further information regarding the average number of trials included in each regressor of interest, see Table 1. Information about the definition of contrasts is presented below.

Table 1. Range and number of responses for each regressor in imaging analyses

	YA (n = 22)
	Range (M)
Recollection hits, T1	16-48 (34.44)
Recollection hits, T2	13-48 (24.36)
Recollection rejection L1	18-48 (33.95)
Recollection rejection L2	12-48 (25)

Trial types (in this paper, Recollection hits and Recollection rejection, or RecH and RecCR) were further specified by presentation order. Each condition (RecH T1, RecH T2, RecCR L1, RecCR L2) was contrasted with baseline activation to determine which areas of activation were unique to each condition. Further contrast analyses were completed to identify neural differences between presentation order conditions. All contrasts were conducted at a threshold of $p < .005$ and 10 voxels.

RecH analyses. Two analyses were completed using Recollection Hit trial types in order to determine neural differences between responses to the target-first and target-second conditions. One of the contrasts, RecH T1 > RecH T2, specifies areas in which greater activation was seen in RecH T1 vs. baseline than RecH T2 vs. baseline. This analysis shows brain activation which is greater in the T1 condition than the T2 condition. The other contrast, RecH T2 > RecHT1, shows brain activation which is greater for the T2 condition than the T1 condition.

RecCR analyses. Similarly, two analyses were completed using Recollection rejection trial types in order to determine neural differences between responses to the target-first and

target-second conditions. RecCR L1 > RecCR L2 specifies areas in which greater activation was seen in RecCR L1 vs. baseline than RecCR L2 vs baseline. This analysis shows brain activation which is greater in the L1 condition than the L2 condition. The other contrast done for this trial type, RecCR L2 > RecCR L1, shows areas which were more activated in the L2 condition than the L1 condition.

Methods relating to the current study were taken from Bowman, C. R. (2015). Recall-to-reject: Aging effects on the neural correlates of recollection rejection (Unpublished doctoral dissertation). The Pennsylvania State University. Only those pertaining to the current analysis are unique to the current paper.

Chapter 3

Results

Behavioral

For N=27 subjects, RecH trial types had a mean hit rate of .7198 if the target was presented before its related lure (that is, items were correctly accepted an average of 71.98% of the time if the item was presented first). RecH trial types had a mean hit rate of only .4793 if the target had been preceded by its related lure. The two means are significantly different ($p < .001$).

RecCR trial types also showed significant differences in mean due to presentation order. If the target was presented before the lure, the mean correct reject rate of RecCR trial types was .6620, while the mean correct rejection rate of RecCR trial types in the case of the lure being presented before the target was .4744. The two means are significant different ($p < .001$).

Additional behavioral analyses were carried out to determine differences in reaction times between the target –first and item lure –first conditions. RecH T1 reaction times, with a mean of 1282.9 ms, were faster than RecH T2 reaction times with a mean of 1372.1 ms ($p < .05$). RecCR L2 reaction times, with a mean of 1519.11 ms, were faster than RecCR L1 reaction times with a mean of 1767.49 ms.

RecH fMRI Results

Neural activity during retrieval was observed using fMRI. In order to reveal differences in recognition activity due to presentation order, RecH activity in the T1 condition was compared to RecH activity in the T2 condition. Neural activity which was greater for the T1 condition than for the T2 condition is shown in Table 1. Results showed activation of areas associated with gist and semantic processing, especially in the left hemisphere, as well as some prefrontal cortex and occipital activation.

Table 2. Areas of neural activity during RecH responses for which T1 > T2

Region	BA	H	Tal			Voxels
Cingulate gyrus	32	L	-3	34	-8	344
Inferior frontal gyrus	47	L	-39	21	-18	19
Middle temporal gyrus	21	R	56	-1	-9	28
Middle temporal gyrus	21	L	-59	-13	-11	51
Superior temporal gyrus	22	R	48	-1	4	47
Precentral gyrus	4	L	-53	5	6	26
Superior occipital gyrus	19	L	-42	-69	29	10
Cingulate gyrus	24	L	-3	29	13	13
Middle occipital gyrus	39	L	-50	-67	26	17
Superior frontal gyrus	9/8	L	-21	33	38	12
Cuneus	17/18	L	-15	-94	1	19
Inferior frontal gyrus	47	R	45	11	6	11

Neural activity at RecH was also evaluated for areas showing greater activity in the T2 condition compared to T1. Results showed activity in the occipital lobe, an area commonly associated with visual processing, as well as activity in cortical areas used for attentional processing.

Table 3. Areas of neural activity during RecH responses for which T2>T1

Region	BA	H	Tal			Voxels
Inferior occipital gyrus	19	R	42	-85	11	1072
Middle occipital gyrus	18	L	-33	-91	11	564
Middle frontal gyrus	46/9	R	48	41	21	291
Middle frontal gyrus	6	R	30	13	44	69
Inferior parietal lobule	40	L	-42	-39	50	73
Lingual gyrus	18	M	0	-71	4	68
Middle frontal gyrus	6	L	-27	-5	45	15
Postcentral gyrus	2/40	L	-59	-25	41	27
Middle frontal gyrus	6	L	-39	-2	37	41
Precuneus	7	R	9	-63	34	28

Similarly, fMRI data during correct rejections was compared between the L1 and L2 conditions. Results in the L2>L1 analysis are shown in Table 3 below. This analysis showed bilateral angular gyrus activation to be greater during RecCR when the lure came after the target. The angular gyrus is implicated in attentional processing.

Table 4. Areas of neural activity during RecCR responses for which L2>L1

Region	BA	H	Tal			Voxels
Angular gyrus	39/40	R	50	-52	37	99
Angular gyrus	39/40	L	-45	-55	29	26

Finally, RecCR fMRI data for which L1>L2 is shown in Table 4. These results show increased activation of multiple areas involved in attentional processing, including the prefrontal cortex, when the lure is presented before the target.

Table 5. Areas of neural activity during RecCR responses for which L1>L2

Region	BA	H	Tal			Voxels
Cuneus	18	L	-18	-94	14	395
Anterior cingulate	24/32/6	L	-6	7	48	828
Cerebellum	-	R	36	-49	-19	22
Fusiform gyrus	37	L	-33	-48	-17	167
Middle frontal gyrus	6/8	L	-48	6	28	108
Fusiform gyrus	37	L	-45	-65	-3	100
Posterior cingulate	31/1/2/3	R	15	-37	41	109
Fusiform gyrus	19	R	24	-66	-9	44
Postcentral gyrus	3/1/2	R	33	-14	32	35
Middle frontal gyrus	6/8	R	48	6	31	22
Caudate nucleus	-	L	-6	16	-3	18
Inferior frontal gyrus	47	R	36	22	-5	50
Inferior frontal gyrus	47	L	-42	29	13	28
Inferior frontal gyrus	47	L	-33	22	-5	50
Postcentral gyrus	3/2/1	L	-48	-20	30	23
Frontal medial gyrus	9/8	L	-27	33	35	10
Frontal medial gyrus	9	R	39	44	29	13
Posterior cingulate	31	L	-18	-34	39	17
Occipital cortex	18	M	3	-64	15	17
Occipitoparietal cortex	7/19	L	-24	-57	37	12

Chapter 4

Discussion

Cognitive and neural mechanisms of RecH

RecH behavioral results showed that participants made more hits when the target preceded the lure than if it followed the lure. This finding may be due to a lack of interference from the related lure. For example, if participants had been shown a red apple during the study phase, and later saw the same red apple at retrieval before being shown a similar object (i.e., green apple), dual process theory suggests that participants who correctly accept the target as old either 1) use a general feeling of familiarity to accept the target, thus matching the target at retrieval to the studied item at encoding based on gist 2) make a cognitive effort to retrieve details from the study phase, to identify details of the apple which match details of the apple currently being shown. By analyzing reaction times at retrieval, it may be possible to investigate the extent to which subjects correctly identified targets as old using feelings of familiarity as opposed to effortful recollection in the T1 condition (see “Future directions: Further investigations of the T1 condition”).

Cognitive mechanisms of the T2 condition may depend on participant reaction to the category lure before seeing the target (see “Future directions: Further investigations of the T2 condition”). However, whether mistakenly accepted or correctly rejected, behavioral data provides evidence that the category lure interferes with cognitive mechanisms required for target

acceptance. Identifying a target as old after seeing a category lure would require identification of verbatim details from encoding; interference from the lure would not allow for acceptance based on familiarity. Interference thus increases the cognitive effort required to accept targets and influences target hit rates, leading to the observed lower hit rate in the T2 condition.

Results of reaction time analyses also support the proposed cognitive mechanism and fuzzy-trace theory. Lure interference (as would occur in the T2 condition) may cause participants to rely on verbatim details at target identification. Verbatim detail recall is a slower process than familiarity (Brainerd & Reyna 2003), therefore recognizing a target in the T2 condition (when detail recall is necessary) requires more time than it would in the T1 condition (when familiarity, a faster process, may be involved in target acceptance).

Along with behavioral results, neural results support the claim that RecH is less demanding in the T1 condition. As discussed, fuzzy-trace theory would suggest that accepting a target as old without first seeing an interfering lure may operate on gist traces and acceptance based on familiarity.

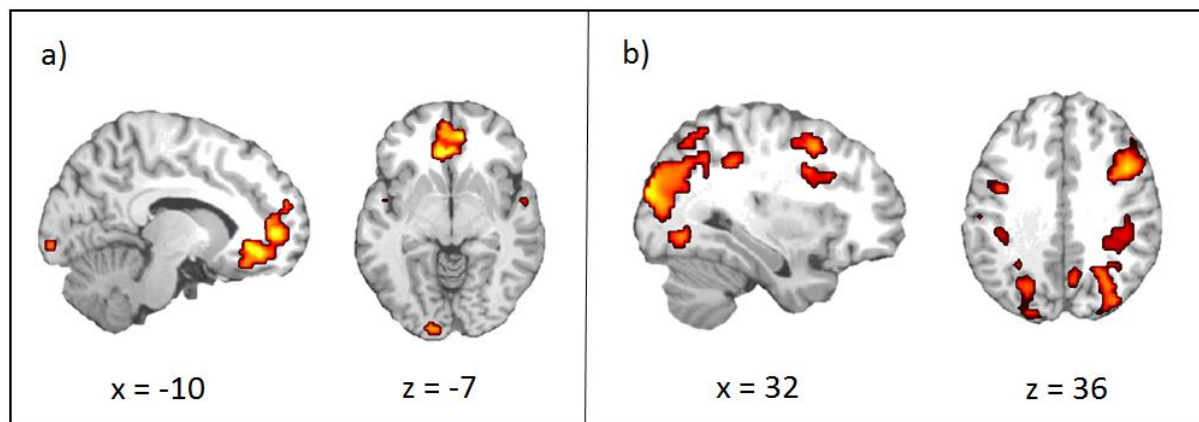


Figure 2. Neural activity for recollection hits in the a) T1 > T2 and the b) T2 > T1 contrasts. The T1 > T2 contrast shows increased activation in the cingulate gyrus and middle temporal gyrus, as well as other areas indicative of semantic processing network activation. The T2 > T1 contrast shows activation in visual and parietal areas associated with attentional networks.

T1 > T2 results showed activity in a different neural network than T2 > T1. In the target-first condition, greater activity was observed in the cingulate gyrus, middle temporal gyrus, and other fronto-temporal regions, suggesting a network of internal monitoring and semantic processing (Binder, et.al. 2009), which may be due to familiarity-based acceptance of the target. Some occipital regions also showed activity, which may be evidence of explained by the necessity for visual cue retrieval from the study phase in order to confirm the target as old (for a discussion on familiarity- versus detail-based acceptance of the target in the T1 condition, see “Future directions”).

Also consistent with behavioral data, fMRI data suggests an increase in visual and attentional processing in the T2 condition. Occipital activity, over 1000 voxels in size, was seen in this T2>T1 contrast. This heavy visual demand would suggest that extra effort was needed to overcome lure interference and retrieve details from encoding in order to correctly identify the

target as old, even after seeing (and possibly accepting) the related lure (Courtney et.al., 1996, 1997). Frontoparietal regions also showed activation in this contrast, suggesting an increased monitoring and control demand due to lure interference (Gallo, Kensinger & Schacter 2006; Henson, et. al. 1999).

Cognitive and neural mechanisms of RecCR

Behavioral RecCR data supported the hypothesis that the L2 condition would have a higher success rate than the L1 condition. Dual process theory would hold that, during retrieval, rejecting a related lure as old first operates on feelings of familiarity, then details are retrieved which differentiate the lure from the target, allowing the lure to be rejected as old. Behavioral data suggests that retrieving details from target presentation earlier in retrieval is less cognitively demanding than retrieving details from the study phase. Behavioral data shows a significant ($p < .001$) difference between lure rejection rates in the L1 and L2 conditions, with the L2 condition showing significantly higher correct rejection rates. These behavioral results are consistent with our hypothesis and dual process theory, both of which suggest that L2 is less cognitively demanding than L1.

In false memory studies, related lures are often falsely identified as old at retrieval due to a shared gist or category with a studied target item (Koutstaal & Schacter 1997). However, we found that correct rejections of lures increased if targets had been previously presented at retrieval (i.e., in the L2 condition). This decrease in false alarms and increase in correct

rejections suggests that the act of viewing the target helps to distinguish the lure as new, possibly because gist-based acceptance is less likely if participants have already accepted the target based on gist. For example, if a participant studied a red apple at encoding, they may accept the red apple at retrieval based on familiarity or gist. Upon later seeing the green apple related lure, they may refrain from using gist to falsely identify the lure as old because they have already accepted a related item based on gist traces or feelings of familiarity.

An analysis of reaction times for correct rejections of related lures also provides evidence that the L2 condition is less cognitively demanding than L1. Recollection rejection of related lures requires detail retrieval from targets; upon retrieval of details from the target, participants can compare targets and related lures and correctly identify related lures as different from the target items studied at encoding. These reaction time differences suggest that detail recall from earlier in retrieval (as would be necessary in L2) is less difficult than detail recall from the study phase (as would be necessary in L1). Faster reaction times, taken together with higher correct rejection rates, suggest that the L2 condition allows participants to complete this recall-to-reject process with more ease and accuracy than the L1 condition.

Neural activity is consistent with the proposed cognitive processes and behavioral data, showing considerably increased and more widespread activation in the L1 > L2 contrast as compared to the L2 > L1 contrast. L1 > L2 fMRI data shows activation in regions associated with visual and attentional processing, including frontal, parietal, and occipital regions, including the fusiform gyrus. The fusiform gyrus has been identified as an important area of activity during true recognition of targets (Atkins & Reuter-Lorenz 2011) and object identification (Okada, et. al., 2000). In the L1 condition there is no target refresher, so fusiform gyrus activation suggests

an increased need for specific item identification as lures are correctly rejected (as compared to the L2 condition, which does contain a target primer). Overall, RecCR L1 > L2 data suggests that there is greater demand for processing details in the L1 condition as participants retrieve details from encoding to correctly reject the lure.

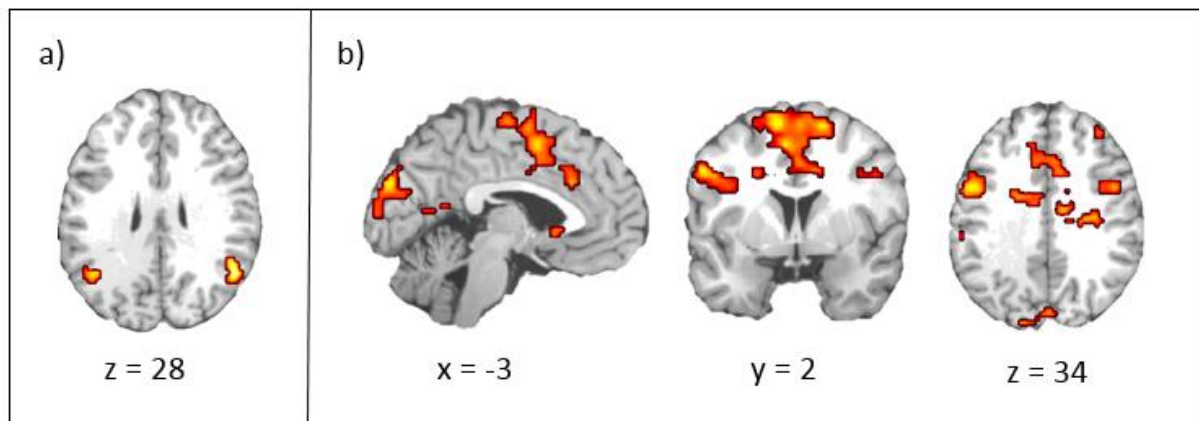


Figure 3. Neural activity for recollection correct rejections in the a) L2 > L1 and the b) L1 > L2 contrasts. L2 > L1 showed bilateral supramarginal gyrus activity, while L1 > L2 showed activity in visual processing, parietal, and prefrontal regions suggestive of attention network activation due to increased demands from lack of target facilitation.

Although the L2>L1 condition contains a target reinforcement during retrieval, cognitive mechanisms must still work to recognize details from the target and suppress false memories. Neural results showed bilateral activation in the angular gyrus. The angular gyrus is implicated in semantic processing (Noonan et. al. 2013; Humphries et. al., 2006; Davey et. al. 2015), as well as attention to internal states (Wicker et. al., 2003; Fransson 2005). These areas may have worked to direct attention to memories of the semantically similar target from earlier in the retrieval phase in order to retrieve recently observed details. This cognitive mechanism may be less demanding than the L2 condition which would require participants to retrieve details from the study phase. Thus, L2 > L1 shows less activation overall due to a decreased need for

attentional processing, but bilateral angular gyrus activation suggests directional processing as participants retrieve details from a relatively recently shown target.

The prediction that there would be MTL activation in the L2 condition due to repeated exposure to the target was not supported. An earlier analysis of the data collapsing across L1 and L2 also found no evidence of MTL activation during correct rejection (Bowman & Dennis, in print). Data from the current study expands this finding, showing that there is no MTL activity during correct rejection in either the L1 or L2 condition. Lack of MTL during correct rejections was also shown in a recent meta-analysis (Kurkela & Dennis, 2016). Though we had hypothesized MTL activity during correct rejection due to the MTL's role in memory retrieval, neural data from the current study instead suggests a network of internal state monitoring in the L2 condition.

Taken together, results suggest that presentation order of targets and related lures during the retrieval phase of memory studies impacts participant responses and corresponding cognitive mechanisms. Lure presentation before target acceptance may cause interference due to relatedness, causing the T2 condition to be more cognitively demanding than T1. Target presentation before correct rejection of related lures may facilitate detail recall, an important part of recollection-rejection, allowing L2 to be a less cognitively demanding condition than L1. Thus, presentation order has significant effects on both behavioral responses and neural correlates in correct memory recognition as well as false memory suppression.

Future directions

In the RecH T1 condition, participants have not yet seen the target at retrieval, and may therefore be accepting targets based on either verbatim detail recall or familiarity. For example, upon seeing a red apple (target) at retrieval, subjects may identify the red apple as old simply because they recall seeing an apple, and the red apple is the first they see at retrieval. However, they may identify the red apple as old because they trace feelings of familiarity back to the study phase, recalling specific details (ex. color) and correctly identifying the target as old. By definition, RecH trial types only include strong confidence ratings (compared to FamH, in which subjects correctly identified the target as familiar), suggesting more verbatim tracing than familiarity acceptance. However, it still may be possible to identify the extent to which T1 participants were operating on familiarity vs. detail recall by investigating reaction times. Brainerd & Reyna (2003) have shown that recollection is a slower process than familiarity. Therefore, analyzing reaction times may provide an indication as to how many instances of RecH occurred due to recollection and how many occurred due to familiarity.

In the T2 condition, participants see the related lure before they are shown the target. Participant response to the lure may have affected the cognitive mechanisms used to produce a RecH response when the target is later shown. If they had correctly rejected the lure, according to the fuzzy trace and dual-process theories, they would have first operated on a feeling of familiarity between the encoding item and category lure (for example, using a general feeling of familiarity between the red and green apples), then used details retrieved from the encoding phase in order to differentiate between the target and lure (i.e., recalling that the apple at

encoding had been red) subsequently rejecting the lure and identifying it as new. Retrieving details from encoding during lure presentation may strengthen cognitive traces to the target, and may result in a higher hit rate if the lure had been correctly rejected versus incorrectly identified as old.

Though subjects correctly rejected lures 68 percent of the time, 32 percent of the time the lure was falsely identified as the target. If the lure was mistakenly identified as old (for example, a green apple falsely being identified as old), participants may experience confusion upon later seeing the true target, possibly being more likely to rely on previous identification of the wrong item as old and subsequently falsely identify the true target as new (i.e., when seeing a red apple, participants may falsely reject it because they have already accepted the green apple as old). Thus, there may be a lower hit rate for T2 targets whose related lures had been falsely identified as old. One future direction, therefore, would be to compare T2 RecH rates based on participant response to the previously shown lure in order to independently analyze these two possible subsequent cognitive processes.

Appendix A

Task Instructions

General Procedure:

1. Consent and demographics
2. Encoding practice
3. Incidental Encoding
4. Matrix Reasoning
5. Retrieval practice
6. Retrieval
7. Debriefing Questions

Encoding Instructions

Thank you for participating in today's study. In the first part of the study, you will see images presented on the screen. For each image, you will decide if the item presented would fit inside a shoebox. If the item is a similar size or smaller than a typical shoebox, press the button with your index finger to indicate that the item is smaller than a shoebox. If the item is bigger than a typical shoebox, press the button with your middle finger to indicate that it is bigger than a shoebox. Each image will be presented for 1 second. You will have an additional half second after the picture goes off the screen to make your response.

Please make these judgments as quickly and accurately as you can. Do your best to answer for each item, but if you miss one, simply move your attention to the next item.

Now I have several practice trials for you so you can see what the task will be like and ask me questions if you have any before starting the actual task.

Participant completes practice trials.

There will be two blocks of this task, each lasting approximately 3 minutes. I will check in with you between blocks.

Participant completes two runs of encoding.

Matrix Reasoning Instructions

This next task is a measure of your logical reasoning skills using visuospatial stimuli. For each trial, a series of 3 images will be presented. Your job will be to decide which image would

most logically continue the pattern established with the first 3 items. You will have 4 items to choose from and will indicate your response with all four keys.

In making your decision, please be as accurate as possible. There is not a time limit for each item, so please take your time and think about each item carefully. They will also get progressively more difficult as you continue. I may come in and stop you at some point, but don't worry about that, just take your time.

Participant completes Matrix Reasoning during structural scans.

Retrieval Instructions

Now you will perform a memory test for the images that you saw in the first part of the study. During this phase, images will be presented one at a time on the screen. Some of these images will be from the first phase while some images will be new. Your task is to decide which of the images are from the first phase (old images) and which have not been presented before (new images). Importantly, there will be some new items presented that are very similar to old items. However, you should only endorse an item as old if it is exactly the same image you saw in the first phase.

As each image is presented, you will make one of 4 responses:

REMEMBER (REM) – If you think that the item is old and you have a vivid memory for its presentation during the first phase, including remembering specific details about your previous encounter with the item, press the button with your index finger.

FAMILIAR (FAM) - If you think that the item is old but it only seems familiar – you cannot remember vivid details from the encoding phase, press the button with your middle finger.

DIFFERENT (DIFF) – If you think that the item is new and you can remember details of old items that are inconsistent with the current item, press the button with your ring finger. For example, you might remember that the item presented in the first phase was a different color or shape than the item currently presented. You also may remember associations you made with the old item that are not relevant to the current item.

UNFAMILIAR (UNFAM) – If you think that the item is new because it seems unfamiliar to you, completely new and unlike what you've seen before, press the button with your pinky.

Just to make sure that everything is clear, can you please tell me how you are going to make your memory decisions for each of the 4 responses?

You will have 3 seconds to make your decision before the computer will automatically advance to the next screen. Do your best to answer for each item, but if you miss one, simply move your attention to the next item.

Now we have a couple of practice trials so you can get used to the task. First there will be three self-paced trials. During these trials, although it may feel a little odd, I would like you to look at the item and think out loud through your thought process for deciding why the item is old or new and which response option you would choose. However, please wait to press the key until I give you the go-ahead.

Participant completes self-paced practice trials with experimenter ensuring correct reasoning assigned to each key.

Great, now here are three practice trials at the pace of the actual task. You don't need to say your thought process aloud, just go ahead and make your decisions.

Participant completes practice trials at normal pace of the task.

There will be 4 blocks of this task, each of which will be approximately 5 minutes. Come and get me when you are done. Any questions?

Participant completes retrieval task.

Debriefing Questions

We have one last form for you to fill out before you leave. This form asks you about your effort and strategies during the task. It's really important to answer as honestly as possible. Your responses will not affect your credit for the experiment and is just for us to have a better idea of how you were performing in the experiment.

Appendix B

Results from stimulus norming study

Mean similarity ratings for targets and lures

Category	Young Adults (N= 15)		Older Adults ¹ (N= 5)	
	Target & Item Lure	Target & Thematic Lure	Target & Item Lure	Target & Thematic Lure
Alcohol	4.33	3.69	4.8	3.8
Art Supplies	4.83	4	5	3
Baby	4.91	3.69	5	4
Bags	4.43	3.55	4.4	3.4
Balls	5	3.5	4.8	3.4
Bedding	4.71	3.2	5	3.4
Birds	4.53	3.57	5	3.2
Boats	4.75	3.79	4.8	3.25
Body parts	4.91	3	5	3.5
Bowling	4.85	3.79	4.75	2.8
Brass instruments	4.77	3.86	4.6	3.2
Bread	4.86	3.71	4.8	4
Breakfast	5	3.33	5	3.4

¹ Older adult norming data was collected on a slightly non-overlapping stimulus set. After behavioral piloting of the memory task, several item lures were switched for slightly less similar images in order to reduce false recognitions. The stimulus set was then re-normed in young, but not older adults.

Cameras	4.8	4.31	4.8	4.4
Camping	4.67	3.46	4.2	4
Candy	4.79	3.57	4.2	3.2
Cars	4.36	3.6	4.6	3.6
Cats	4.8	4.21	5	4
Cereals	4.79	3.67	4.8	3.6
Cheeses	4.46	4	4.6	3.6
Chips	4.25	3.46	4.2	4
Christmas	4.53	3.36	4.4	3.2
Church	4.87	3.64	5	3.4
Classroom	4.93	4	5	3.4
Cleaning	5	3.53	5	3.6
Clocks	4.93	3.33	4.5	3.6
Clothing	4.62	3.38	4.6	3.6
Computers	4.86	4.27	4.4	4.8
Condiments	4.67	3.36	4.6	3.4
Cookies	4.85	3.86	4.6	3.6
Cooking tools	4.87	2.8	4.6	3
Crackers	4.85	4	5	4
Cycles	4.85	3.62	4.8	2.75
Dishes	4.33	3.8	4.2	3.4
Doctor	4.93	3.87	4.75	3
Dogs	4.85	3.86	5	3.8

Doors	4.23	4	4.6	3.8
Farm	4.82	3.14	4.8	3.2
Fishing	4.15	3.31	4.4	3.2
Flags	4.69	3.15	4.8	3.6
Flowers	4.46	3.57	5	4
Fruit	4.64	3.53	5	3.4
Games	5	3.54	5	3
Geometry	4.85	3.43	4.8	3.8
Ghouls	4.93	3.62	5	3.8
Golf	4.93	3.86	5	2.8
Gym	4.6	3.87	4.67	4
Hair clips	4.42	3.69	4.4	3.75
Hair tools	4.42	3.69	3	3
Hanukkah	4.71	3.6	5	3.2
Hats	4.79	3.42	5	3.4
Herbs	4.4	3.87	4	3
Ice cream	4.47	4.08	4.4	4.2
Insects	4.73	3.79	4.4	3.6
Jewelry	4.57	3.33	3.8	3.4
Juice	4.69	3.85	4.6	4
Jungle cats	4.92	3.31	5	3.6
Kitchen appliances	4.92	3	5	3.6
Leaves	4.69	4.13	4.4	3.6

Makeup	4.85	4.08	5	4.2
Manicure	4.92	3.69	4.8	3.6
Meats	4.62	3.36	4.5	3.2
Melons	4.93	3.46	4.8	3.4
Money	5	3.93	4.8	3.25
Nuts	4.79	3.29	4.4	3.6
Office	4.93	3.57	4.8	3
Party	4.93	3.54	4.8	2.8
Pasta	4.69	3.79	5	4.2
Percussion	4.86	3.43	4.4	3.8
Phone	4.4	3.64	4.4	3
Pie	4.75	3.73	5	4
Playground	4.86	3.54	4	2.8
Poker	5	3.62	5	3
Pretzels	4.93	3.92	4.8	4.4
Primates	4.57	3.6	4.5	3.2
Raquets	4.79	4.07	4.6	4.4
Sandwiches	5	3.27	3.8	3.5
Sewing	4.93	3.86	4.8	3.5
Shells	4.64	3.72	4.8	3
Shoes	4.27	3.27	4	3.4
Signs	4.93	2.73	4.8	3.2
Skates	4.64	3.6	4.4	3.2

Ski	4.92	3.69	5	2.8
Smoking	4.67	3.85	3.8	3.8
Soap	4.67	4	4.8	4
Star Wars	4.86	3.54	4.6	3.2
String instruments	4.64	3.85	5	3.4
Swim wear	4.36	3.64	4.6	3.4
Toys	4.93	3	4.4	2.75
Transport	4.67	3.36	4.8	3
Travel	4.75	3.5	4.2	3.4
Underwear	4.75	3.23	4.2	3.6
Vegetables	4.69	3.84	5	3.4
Woodwind instruments	4.69	3.67	5	3.8
Writing	4.83	3.71	4.8	3.75
Yogurt	4.62	4.08	4.8	4.2

BIBLIOGRAPHY

- Achim, A. M., & Lepage, M. (2005). Dorsolateral prefrontal cortex involvement in memory post-retrieval monitoring revealed in both item and associative recognition tests. *NeuroImage*, 24(4), 1113-1121. doi:10.1016/j.neuroimage.2004.10.036
- Arndt, J., & Reder, L. M. (2003). The effect of distinctive visual information on false recognition. *Journal of Memory and Language*, 48(1), 1-15. doi:10.1016/s0749-596x(02)00518-1
- Arndt, J., & Reder, L. M. (2003). The effect of distinctive visual information on false recognition. *Journal of Memory and Language*, 48(1), 1-15. doi:10.1016/s0749-596x(02)00518-1
- Atkins, A. S., & Reuter-Lorenz, P. A. (2011). Neural mechanisms of semantic interference and false recognition in short-term memory. *NeuroImage*, 56(3), 1726-1734. doi:10.1016/j.neuroimage.2011.02.048
- Binder, J. R., Desai, R. H., Graves, W. W., & Conant, L. L. (2009). Where Is the Semantic System? A Critical Review and Meta-Analysis of 120 Functional Neuroimaging Studies. *Cerebral Cortex*, 19(12), 2767-2796. doi:10.1093/cercor/bhp055
- Bowman, C. R., & Dennis, N. A. (2015). The neural correlates of correctly rejecting lures during memory retrieval: The role of item relatedness. *Exp Brain Res Experimental Brain Research*, 233(6), 1963-1975. doi:10.1007/s00221-015-4268-y
- Bowman, C. R., & Dennis, N. A. (in print). The Neural Basis of Recollection Rejection: Increases in Hippocampal–Prefrontal Connectivity in the Absence of a Shared Recall-to-

- Reject and Target Recollection Network. *Journal of Cognitive Neuroscience*, 1-16.
doi:10.1162/jocn_a_00961
- Bowman, C. R. (2015). *Recall-to-reject: Aging effects on the neural correlates of recollection rejection* (Unpublished doctoral dissertation). The Pennsylvania State University.
- Brainerd, C. J., & Reyna, V. F. (2002). Fuzzy-Trace Theory and False Memory. *Current Directions in Psychological Science Current Directions in Psychol Sci*, 11(5), 164-169.
doi:10.1111/1467-8721.00192
- Brainerd, C. J., Reyna, V. F., Wright, R., & Mojardin, A. H. (2003). Recollection rejection: False-memory editing in children and adults. *Psychological Review*, 110(4), 762-784.
doi:10.1037/0033-295x.110.4.762
- Courtney, S. M., Ungerleider, L. G., Keil, K., & Haxby, J. V. (1996). Object and Spatial Visual Working Memory Activate Separate Neural Systems in Human Cortex. *Cerebral Cortex*, 6(1), 39-49. doi:10.1093/cercor/6.1.39
- Courtney, S. M., Ungerleider, L. G., Keil, K., & Haxby, J. V. (1997). Transient and sustained activity in a distributed neural system for human working memory. *Nature*, 386(6625), 608-611. doi:10.1038/386608a0
- Dale, A. M. (1999). Optimal experimental design for event-related fMRI. *Human Brain Mapping Hum. Brain Mapp.*, 8(2-3), 109-114. doi:10.1002/(sici)1097-0193(1999)8:2/33.0.co;2-w
- Daselaar, S. M. (2006). Triple Dissociation in the Medial Temporal Lobes: Recollection, Familiarity, and Novelty. *Journal of Neurophysiology*, 96(4), 1902-1911.
doi:10.1152/jn.01029.2005
- Davey, J., Cornelissen, P. L., Thompson, H. E., Sonkusare, S., Hallam, G., Smallwood, J., & Jefferies, E. (2015). Automatic and Controlled Semantic Retrieval: TMS Reveals Distinct

- Contributions of Posterior Middle Temporal Gyrus and Angular Gyrus. *Journal of Neuroscience*, 35(46), 15230-15239. doi:10.1523/jneurosci.4705-14.2015
- Deese, J. (1959). Influence Of Inter-Item Associative Strength Upon Immediate Free Recall. *Psychological Reports PR*, 5(3), 305. doi:10.2466/pr0.5.3.305-312
- Eldridge, L. L., Knowlton, B. J., Furmanski, C. S., Bookheimer, S. Y., & Engel, S. A. (2000). Remembering episodes: A selective role for the hippocampus during retrieval. *Nature Neuroscience*, 3, 1149-1152.
- Fazendeiro, T., Winkielman, P., Luo, C., & Lorah, C. (2005). False recognition across meaning, language, and stimulus format: Conceptual relatedness and the feeling of familiarity. *Mem Cogn Memory & Cognition*, 33(2), 249-260. doi:10.3758/bf03195314
- Fazendeiro, T., Winkielman, P., Luo, C., & Lorah, C. (2005). False recognition across meaning, language, and stimulus format: Conceptual relatedness and the feeling of familiarity. *Mem Cogn Memory & Cognition*, 33(2), 249-260. doi:10.3758/bf03195314
- Fletcher, P. C., & Henson, R. N. (2001). Frontal lobes and human memory: Insights from functional neuroimaging. *Brain*, 124(5), 849-881. doi:10.1093/brain/124.5.849
- Fransson, P. (2005). Spontaneous low-frequency BOLD signal fluctuations: An fMRI investigation of the resting-state default mode of brain function hypothesis. *Human Brain Mapping Hum. Brain Mapp.*, 26(1), 15-29. doi:10.1002/hbm.20113
- Gallo, D. A., Kensinger, E. A., & Schacter, D. L. (2006). Prefrontal Activity and Diagnostic Monitoring of Memory Retrieval: FMRI of the Criterial Recollection Task. *Journal of Cognitive Neuroscience*, 18(1), 135-148. doi:10.1162/089892906775250049

- Henson, R. A., Rugg, M. D., Shallice, T., Josephs, O., & Dolan, R. J. (1999). Recollection and familiarity in recognition memory: An event-related functional magnetic resonance imaging study. *The Journal of Neuroscience*, *19*(10), 3962-3972.
- Humphries, C., Binder, J. R., Medler, D. A., & Liebenthal, E. (2006). Syntactic and Semantic Modulation of Neural Activity during Auditory Sentence Comprehension. *Journal of Cognitive Neuroscience*, *18*(4), 665-679. doi:10.1162/jocn.2006.18.4.665
- Jacoby, L. L. (1991). A process dissociation framework: Separating automatic from intentional uses of memory. *Journal of Memory and Language*, *30*(5), 513-541. doi:10.1016/0749-596x(91)90025-f
- Koutstaal, W., & Schacter, D. L. (1997). Gist-based false recognition of pictures in older and younger adults. *Journal of Memory and Language*, *37*(4), 555-583. doi:10.1006/jmla.1997.2529
- Kurkela, K. A., & Dennis, N. A. (2016). Event-related fMRI studies of false memory: An Activation Likelihood Estimation meta-analysis. *Neuropsychologia*, *81*, 149-167. doi:10.1016/j.neuropsychologia.2015.12.006
- Loftus, E. (1979). Eyewitness Reliability. *Science*, *205*(4404), 386-387. doi:10.1126/science.205.4404.386
- Matzen, L. E., Taylor, E. G., & Benjamin, A. S. (2011). Contributions of familiarity and recollection rejection to recognition: Evidence from the time course of false recognition for semantic and conjunction lures. *Memory*, *19*(1), 1-16. doi:10.1080/09658211.2010.530271
- Noonan, K. A., Jefferies, E., Visser, M., & Ralph, M. A. (2013). Going beyond Inferior Prefrontal Involvement in Semantic Control: Evidence for the Additional Contribution of

- Dorsal Angular Gyrus and Posterior Middle Temporal Cortex. *Journal of Cognitive Neuroscience*, 25(11), 1824-1850. doi:10.1162/jocn_a_00442
- Nyberg, L., McIntosh, A. R., Houle, S., Nilsson, L., & Tulving, E. (1996). Activation of medial temporal structures during episodic memory retrieval. *Nature*, 380(6576), 715-717. doi:10.1038/380715a0
- Odegard, T. N., & Lampinen, J. M. (2005). Recollection rejection: Gist cuing of verbatim memory. *Memory & Cognition*, 33(8), 1422-1430. doi:10.3758/bf03193375
- Okada, T., Tanaka, S., Nakai, T., Nishizawa, S., Inui, T., Sadato, N., . . . Konishi, J. (2000). Naming of animals and tools: A functional magnetic resonance imaging study of categorical differences in the human brain areas commonly used for naming visually presented objects. *Neuroscience Letters*, 296(1), 33-36. doi:10.1016/s0304-3940(00)01612-8
- Petrides, M. (2000). Dissociable roles of mid-dorsolateral prefrontal and anterior inferotemporal cortex in visual working memory. *The Journal of Neuroscience*, 20(19), 7496-7503.
- Reagh, Z. M., & Yassa, M. A. (2014). Repetition strengthens target recognition but impairs similar lure discrimination: Evidence for trace competition. *Learning & Memory*, 21(7), 342-346. doi:10.1101/lm.034546.114
- Song, Z., Jeneson, A., & Squire, L. R. (2011). Medial Temporal Lobe Function and Recognition Memory: A Novel Approach to Separating the Contribution of Recollection and Familiarity. *Journal of Neuroscience*, 31(44), 16026-16032. doi:10.1523/jneurosci.3012-11.2011
- Warrington, E. K., & Weiskrantz, L. (1970). Amnesic Syndrome: Consolidation or Retrieval? *Nature*, 228(5272), 628-630. doi:10.1038/228628a0

Wicker, B., Ruby, P., Royet, J., & Fonlupt, P. (2003). A relation between rest and the self in the brain? *Brain Research Reviews*, 43(2), 224-230. doi:10.1016/j.brainresrev.2003.08.003

ACADEMIC VITA

Academic Vita of Shalome Sine slsine24@gmail.com

Education

- ◆ Undergraduate education: The Pennsylvania State University
Expected graduation date: May 2016
- ◆ Major: Biology with an option in Neuroscience
- ◆ Minors: Psychology, German

Undergraduate Awards

- ◆ Braddock Scholarship for students in science
- ◆ Student in the Schreyer Honors College
- ◆ Honors in psychology

Research Experience

◆ **Research Assistant at The Dennis Cognitive Aging and Neuroimaging Lab**

February 2014-May 2016

- Collected data from subjects during behavioral studies; analyzed this data using Matlab, Excel, and SPSS
- Trained in fMRI neuroimaging and fMRI data analysis using SPM
- Completed an honors thesis (as required by the Schreyer Honors College) based on original research completed in this lab
- Presented thesis findings at the Cognitive Neuroscience Society conference in April 2016

Teambuilding Experience

◆ **Resident Assistant (RA)**

August 2014-May 2016

- Built inclusive communities by hosting weekly floor events
- Provided emotional support in crises
- Acted as a primary resource for reporting distress, wrongdoing, and personal crises
- Carried out duty nights, wherein RAs walk the halls and check for disturbances
- Carried out administrative tasks such as updating flyers and bulletin boards, sending floor emails, creating resident name tags

◆ **Public Relations Chair of Writers Organizing to Represent Diverse Stories (W.O.R.D.S.)**

September 2015-May 2016

- Reached out to other on-campus organizations to promote campus-wide awareness of our organization
- Promoted poetry slams and open mic nights through online social media
- Designed promotional flyers for poetry slams; promoted these slams through flyer distribution

◆ **Booking Chair of W.O.R.D.S.**

May 2015– September 2015

- Completed all forms required for room reservations, including reservations for general body meetings, performance team meetings, and larger events
- Managed event funding applications
- Worked with prospective outside performers and outside hosts to find collaborative opportunities