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The impact of semantic versus perceptual attention on memory representation

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Abstract

Encoding new information in relation to existing knowledge benefits learning. However, integration into existing knowledge might also lead to false memories for similar—but never-studied—information. Here, we asked whether certain attentional encoding states promote the integration of new information into prior knowledge, thereby enhancing memory *and* elevating false alarms. We manipulated participants' attention to semantic versus perceptual features by cueing them to alternately make a judgment about the story (semantic) or artistic style (perceptual) of a series of pictures. We then used an old/new recognition test—which included new illustrations depicting studied stories or artistic styles (lures)—to assess whether story attention increased false alarms to story lures, representing integration into story knowledge. We found that semantic attention benefited memory. However, while integration into prior semantic knowledge was high overall, it was not impacted by attention. These findings suggest that while semantic attention improves memory, it does not do so by boosting integration of new memories into existing knowledge structures.

Keywords: memory integration; attention; episodic memory

Introduction

New memories can be encoded into the backdrop of our related existing memories (Bartlett, 1932), ultimately giving rise to flexible knowledge structures that can guide behaviour in new scenarios. Beyond this behavioural flexibility, integration of new memories into prior knowledge might also benefit memory for the newly learned information itself (Bransford & Johnson, 1972; Brewer & Treyens, 1981; Schlichting, Zeithamova, & Preston, 2014; van Kesteren, Brown, & Wagner, 2016). It has been proposed that enhancing shared themes across experiences through integration may bring both beneficial and harmful outcomes: For example, shared content may be better remembered, but idiosyncratic details of the individual experiences lost (for review see Schlichting & Preston, 2015).

Integration of new memories into existing knowledge is thought to occur through reactivation of the related memories during encoding. Such reactivation creates competition among contents of the related memories, resulting in not only encoding of the new trace but also "reconsolidation" of the previously stored memory (Nadel & Moscovitch, 1997; Nadel, Samsonovich, Ryan, & Moscovitch, 2006). In this way, multiple related memory traces may be formed when encoding a single experience, leading to memory errors during a later test (Anderson, 1981; Anderson, Goodmon, & Anderson, 2011; Kuhl, Rissman, Chun, & Wagner, 2011). In particular, false memories for similar—but importantly, not actually viewed—content may be formed, promoting memory errors to these highly related stimuli (i.e., false alarms; Castel, Mcgillivray, & Worden, 2013; Gershman, Schapiro, Hupbach, & Norman, 2013; Reyna, Holliday, & Marche, 2002).

We hypothesize that promoting the integration of new information into existing knowledge may enhance memory for common features while simultaneously resulting in the formation of false memories. One mechanism that could facilitate the integration of new information is attention towards features most related to prior knowledge. Attention to semantic information (e.g., narrative themes) has been shown to benefit memory across a wide range of stimulus types (Bransford & Johnson, 1972; Craik & Tulving, 1975; Lockhart, 2002). However, existing studies have not examined whether semantic attention at encoding also increases the likelihood of forming false memories due to integration into prior knowledge. Furthermore, it is unclear if the memory benefit seen for information attended in this way is related to the emphasis of semantic themes, or a consequence of the greater task engagement associated with deeper levels of processing (in comparison to shallow encoding strategies).

Our study will be the first to ask whether attention to familiar semantic themes will promote the reactivation of related existing knowledge and incorporation of new information into that existing knowledge—namely, by interrogating false alarms to new items that share features. We showed participants novel illustrations depicting famous children's stories (e.g., fairytales, fables), which offered an opportunity for new illustration memories to be integrated into this previous knowledge. Critically, we hypothesized that attention to the relevant type of information—namely, the story content—would promote such integration. In other

words, we anticipated elevated false alarms to those similar stories (as evidence of integration into story knowledge) when participants attended to the story in the first place, in which case it can serve as a retrieval cue for the related (story) knowledge. We contrasted attention to the story depicted in the illustration with attention to the surface, perceptual features (Challis, Velichkovsky, & Craik, 1996; Craik & Tulving, 1975) of the illustration—namely, the style of the artist creator—which we expected would offer less opportunity for integration.

Method

Participants

Seventy University of Toronto students participated in this experiment for course credit. Participants were excluded from the final sample if they did not meet the following criteria: age between 17-35 years, having normal or corrected-to-normal vision and hearing, having no prior diagnosis of mental illness or neurological disorder, and performing above 66% accuracy on the encoding task. We adopted an encoding task performance threshold that ultimately led to the exclusion of 26 participants because we reasoned that participants unable to identify repeated images on the story and artist dimensions might either (1) be unfamiliar with the stories in our stimulus set and/or (2) be unable to modulate their attentional state at encoding, both of which are necessary preconditions for observing our hypothesized memory effects. The threshold of 66% was chosen based on an independent group of participants (N=14) as being an achievable performance level for the majority of people (N=12) in the sampled population. Anecdotally, our criteria mainly excluded participants who were either unfamiliar with Western fairytales or who exhibited a general lack of motivation.

Our final sample included 44 young adults (mean age=19.02, SD=1.75 years; 36 females). This sample size was determined *a priori* based on a power calculation to achieve 80% power to detect an effect size of d=0.45 estimated based on prior work (Aly & Turk-Browne, 2015). The experimental protocol was approved by our Research Ethics Board.

Design and Procedure

Our paradigm consisted of an incidental memory encoding task followed by a recognition memory test. Further details on our design and procedure can be found in our pre-registration (https://osf.io/udvsg). During incidental encoding, we manipulated an ongoing distractor task to draw participants' attention to either semantic or perceptual features. We then tested participants' memory in a surprise old/new recognition memory test. The recognition memory test consisted of studied (old) images along with new images, which were selected to be highly similar to (i.e., lures for) a particular studied illustration. Lures were defined as illustrations that either shared semantic (i.e., same story) or perceptual (i.e., same artist) features with an illustration that was presented during encoding. The inclusion of semantic and perceptual lures at test allowed us to assess the impact of semantic and perceptual attention on memory integration along both of these dimensions.

Stimuli We curated a set of 576 storybook-style illustrations that varied in semantic (i.e., story content) and perceptual features (i.e., artist) to be used during the encoding and retrieval tasks. The illustrations were retrieved from a variety of online databases and image cataloguing sites (e.g., SurLaLune and DeviantArt). All illustrations were cropped to a 4:5 ratio, standardized for luminance, and cleared of identifying features (i.e., artist signatures, borders, and text).

Illustrations presented at encoding consisted of (1) pairs of illustrations drawn by the same artist but depicting different stories (hereafter, "artist repeats"), (2) pairs of illustrations portraying the same story drawn by different artists ("story repeats"), and (3) illustrations with unique stories and artists ("fillers"). Using these illustrations, we created 18 blocks of eight illustrations each (Figure 1A). Each block contained one artist repeat, one story repeat, and four fillers. Across the experiment, the story and artist of fillers were each presented exactly once while repeat stories and artists were each seen twice (albeit in different illustrations). One-third of the blocks were assigned to be "catch" blocks, which had additional repeats at the end of the block in order to reduce predictability and encourage maintenance of the cued attentional state throughout the block. These additional repeats were not considered further.

Illustrations in the recognition memory test consisted of fillers and repeats from the encoding task (old), as well as lures matched in story or artist to old illustrations. The first-presented illustration in each repeat pair as well as two fillers per encoding block were designated "critical illustrations." Each critical illustration had two lures that depicted the same story (story lures) and two lures created by the same artist (artist lures) presented at retrieval (Figure 1B), allowing us to examine the impact of artist and story attention on false alarms to perceptually or semantically similar images—that is, the tendency to erroneously endorse lures as old.

Lures were validated in a separate experiment with a different group of participants (N=44). We compared false alarms to lures with those to completely new illustrations that depicted novel stories and artists, reasoning that lures should elicit higher memory error rates if they are perceived as being especially similar to the studied illustrations. Participants made more old responses to lures vs. unrelated new images (paired t-test: $t(43)=6.03$, $p<0.0001$), suggesting their behavior was influenced by the greater overall similarity of lures to studied images.

Incidental encoding task Participants performed a modified 1-back task in which they made a keypress response when they detected an illustration that was the same as the immediately preceding image in either story or artist (Figure 1A). Importantly, the assignment of blocks to attention condition was counterbalanced across participants, allowing
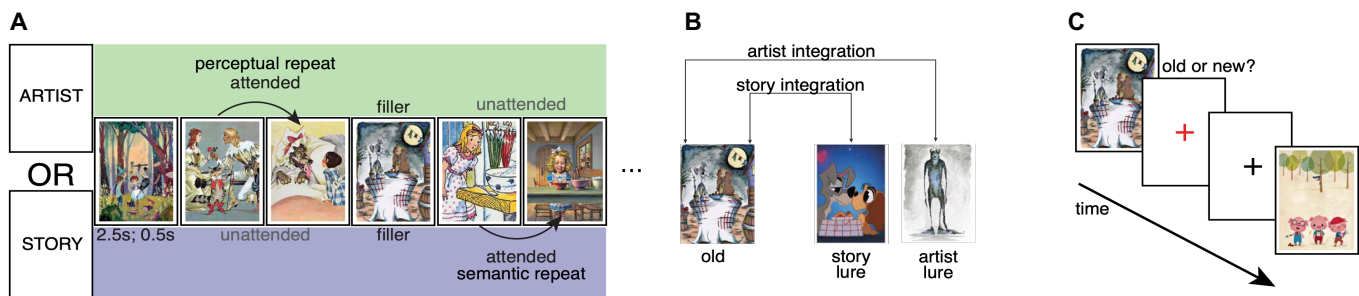
Figure 1: (A) *Beginning portion of encoding block (6/8 illustrations shown).* A given block was assigned to either the artist (green) or story (purple) attention across participants. Story repeats consisted of two illustrations that shared semantic features (i.e., depicted the same story), while artist repeats were two illustrations that shared perceptual features (i.e., were created by the same artist). The remaining illustrations depicted unique stories and artist styles. Arrows denote repeats on the cued dimension, to which the participants should have made a response. (B) *Example story and artist lures presented in the recognition memory test.* Story lures depict the same story but are created by different artists; conversely, artist lures are created by the same artist but depict different stories. Note that while only two lures are depicted here, each critical image had a total of four lures (two artist, two story) in the real experiment. (C) *Old/new recognition memory test.* Participants responded old or new to each illustration presented during the recognition memory test.

us to isolate the effects of attention on subsequent memory.

At the beginning of each illustration block, a cue screen appeared (2000ms with a 500ms interstimulus interval [ISI]) indicating which task should be performed for the upcoming block of images. Illustrations were presented consecutively for 2500ms with a 500ms ISI. Participants were asked to respond to repeats on the cued dimension using keypress "2" and non-repeats with keypress "1". There were nine illustration blocks in each attention condition, with a given block appearing in artist and story attention conditions an equal number of times across participants. Attention blocks were intermixed with baseline blocks (same trial timing and duration) in which participants indicated with a button press in which of three boxes a dot appeared. We included baseline blocks purely to allow participants opportunities to rest during the task and do not consider them further.

Old/new recognition memory test Immediately after incidental encoding, participants performed a surprise old/new recognition memory test for the studied illustrations. Old and lure illustrations (intermixed) were presented one at a time for 500ms followed by a 1000ms response window (red fixation) and 500ms ISI (Figure 1C). Participants made a keypress response during the illustration or response window indicating whether the picture was old or new.

Results

Encoding Performance
Participants were able to detect cued repeats at encoding We first asked whether participants responded correctly to repeats along the cued dimension at encoding. Indeed, a 2x2 repeated-measures ANOVA indicated that the proportion of repeat responses participants made was significantly influenced by the interaction of attention condition (story/artist) and repeat type (story/artist; $F(1, 43)=258.18$,

$p<0.0001$, $\eta=0.66$). Follow-up pairwise tests revealed that as expected, participants made repeat responses more often for story (mean=82%) than artist (44%) repeats during story attention blocks (paired t-test $t(43)=9.67$, $p<0.0001$; discrimination of cued vs. uncued repeats, d' [Banks, 1970] d' mean=1.02; t-test vs. 0; $t(43)=8.57$, $p<0.0001$), and more for artist (79%) than story (21%) during artist attention ($t(43)=16.29$, $p<0.0001$; discrimination of cued vs. uncued repeats, d' mean=1.58; t-test vs. 0; $t(43)=13.92$, $p<0.0001$). This pattern of repeat responses suggests participants were able to follow task instructions and selectively attend to the cued dimension at encoding.

A direct comparison of artist and story tasks revealed better performance for the artist task in both discrimination of cued vs. uncued repeats (paired t-test, $t(43)=3.97$, $p<0.001$) and a trend in response time (paired t-test for correct repeat responses, $t(43)=1.92$, $p=0.06$; faster for artist than story). Therefore, despite participants' likely greater familiarity with the story dimension, the artist task was easier.

Recognition Memory Test Performance
Participants remembered studied illustrations We first examined whether participants could discriminate studied illustrations from all lures. Our logic was that participants should recognize more actually old than actually new (lure) images if they remembered the studied illustrations; and this should occur irrespective of our attention manipulation. Old/new memory test performance was reliably above chance, such that participants were able to discriminate between studied illustrations (hits) and highly similar lures (false alarms to all new images, irrespective of lure dimension; d' mean=1.25; t-test vs. 0; $t(43)=14.44$, $p<0.0001$). To determine whether both artist and story lures were distinguished from studied illustrations, we also compared the proportion of old responses across studied illustrations, artist lures, and story lures. There was a

significant main effect of illustration type (repeated-measures ANOVA; $F_{(2,86)}=212.63$, $p<0.0001$, $\eta=0.69$) driven by reliable differences in the proportion of old responses for old illustrations as compared with both types of lures (old=58%, artist lure=15%, story lure=18%; old vs. story lures: $t_{(43)}=14.60$, $p<0.0001$; old vs. artist lures: $t_{(43)}=14.88$, $p<0.0001$), replicating the results in d' (i.e., discrimination). In addition, participants made more old responses to story than artist lures ($t_{(43)}=3.59$ $p<0.001$), suggesting more difficulty in correctly rejecting lures depicting a studied story than a studied artist overall.

We next separately considered memory for the repeats and fillers. Our reasons for this were twofold: First, as repeats (but not fillers) were task-relevant in that—if the repeat was on the cued dimension—they required a keypress response, we anticipated that memory might be generally better for these images. Second, because repeats by definition provide not one but *two* examples of a specific story or artist, we might expect this additional memory to create more competition (i.e., memory interference) along the repeated dimension. We first consider memory for repeats before turning to fillers.

Memory for repeats *Task-relevance enhanced memory in story but not artist attention.* To investigate the impact of cued attentional state on memory for repeats, we examined the proportion of old responses (i.e., hits) to artist and story repeats encoded in both artist and story attention blocks. A 2x2 repeated-measures ANOVA showed an interaction of attention (story/artist) and repeat type (story/artist) on memory ($F_{(1,43)}=12.21$, $p<0.001$, $\eta=0.04$; Figure 2). Follow-up comparisons showed that participants had better memory (i.e., a higher hit rate) for story repeats encoded in the story than artist attention conditions (paired t-test: $t_{(43)}=5.15$, $p<0.0001$), while memory for artist repeats did not differ as a function of attention at encoding ($t_{(43)}=0.33$, $p=0.74$). In other words, being explicitly instructed to attend to story boosted memory when story information was repeated. However, the same benefit did not apply to artist attention: Participants were no more (or less) likely to make a correct response for artist repeats when they were explicitly cued to attend to artist information.

More memory errors along repeated dimension. We then asked whether memory errors for repeats—that is, false alarms to lures related to repeats—also varied as a function of attentional state. We reasoned that viewing repeated information during the incidental encoding task might serve as a source of memory interference, elevating participants' false alarm rates. Importantly, we would expect such an effect only along the repeated dimension. For example, having seen two illustrations depicting *Goldilocks and the Three Bears* might make you more likely to falsely endorse a new image of the same story as being one that you had seen at encoding. However, since the artist information was not repeated, you should be no more likely to false alarm to new pictures drawn by the same artist. Such a finding would further validate our stimulus structure. That is, it would indicate both that (1) our

intended repeats were indeed perceived as repeated stories or artists by participants, and (2) our lures for those repeats were sufficiently similar to result in elevated false alarms when there is repetition at encoding.
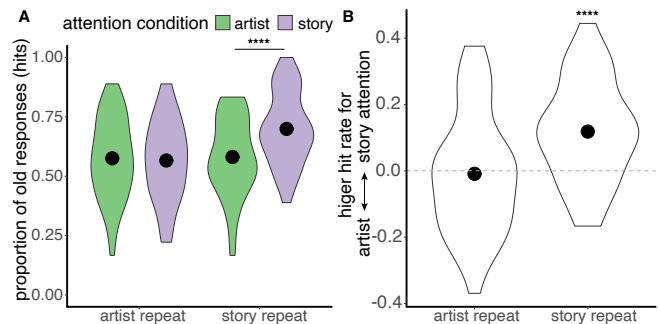

Figure 2: *Memory (hit rate) for repeats.* (A) Proportion of old responses to artist repeats (left pair of violins) and story repeats (right pair of violins) as a function of attentional state at encoding (violin colour). In this and all subsequent figures, large black dots represent the mean. (B) Story-artist attention difference scores showing within-participant effect for artist repeats (left) and story repeats (right). ****$p<0.0001$

False alarms were not significantly related to attentional state (repeated-measures ANOVA main effect of attention; $F_{(1,43)}=2.23$, $p=0.14$); for this reason, the following results are collapsed across attentional state. We found that across both repeat types, participants made more false alarms along the dimension that was repeated compared with not repeated at encoding (2x2 repeated-measures ANOVA interaction of repeat type (story/artist) and lure dimension (story/artist); $F_{(1,43)}=17.05$, $p<0.0001$; $\eta=0.018$; Figure 3). There were higher false alarms to artist vs. story lures for artist repeats (paired t-test: $t_{(43)}=3.05$, $p=0.003$), and to story vs. artist lures for story repeats ($t_{(43)}=3.06$, $p=0.003$). Unlike hits to studied repeats, false alarms to repeat-related lures were not modulated by attention; instead, they were tied to the dimension repeated at encoding.

Within each dimension (i.e., for artist and story lures separately), it was also the case that repetition elevated false alarms (artist vs. story repeat paired t-test, artist lures: $t_{(43)}=4.03$, $p<0.001$; story lures: $t_{(43)}=2.00$, $p=0.048$). Note that this means interestingly, despite our participants not having any prior knowledge of the specific artists used in our task, repeating artist information *did* elevate false alarm rate. Together, these results demonstrate that repetition in the input leads to an increase in false alarms for information that is similar along that dimension, irrespective of attentional state.

Memory for fillers *Better memory for fillers encoded during story versus artist attentional state.* We next turned to fillers, which serve as our cleanest measure of the impact of attention on memory: These images were not task-relevant but were still encoded during the cued attention state, such that the only difference that could contribute to our key comparisons was the attentional state. We leveraged these images to investigate how the attentional state maintained throughout
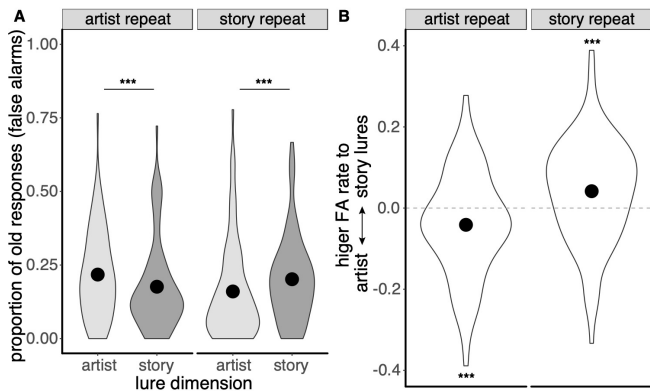
Figure 3: *Repeat-related false memories.* (A) Proportion of false alarms to artist (light grey) vs. story (dark grey) lures for artist repeats (left) and story repeats (right). Because there was no effect of attentional state, data are collapsed across artist and story attention. False alarm rates were higher along the repeated (outer violins) as compared with the non-repeated (inner violins) dimension. (B) Story-artist lure FA difference scores for artist (left) and story (right) repeats. ***p<0.001

the block influences *all* memories formed during that period.

We first assessed the proportion of hits to fillers encoded during each attention condition. Story attention supported higher recognition memory for fillers in comparison to artist attention (paired t-test; t(43)=4.94, p<0.0001; Figure 4), consistent with previous demonstrating the memory benefits of attending to meaning (Bransford & Johnson, 1972; Craik & Tulving, 1975; Lockhart, 2002).
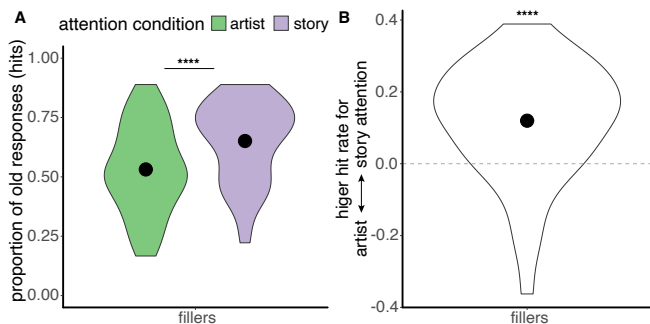

Figure 4: *Memory (hit rate) for fillers.* (A) Proportion of old responses to fillers. Participants had a significantly higher hit rate for fillers studied under the story than artist attention condition. (B) Story-artist attention difference scores for fillers. ****p<0.0001

Memory errors related to fillers were not modulated by attention. We previously discussed false alarms to lures for repeats. Next, we examined false alarms to lures associated with fillers to ask whether attention impacted the integration of these new memories into prior knowledge. Our hypothesis was that attention to story would support integration of new memories into existing story knowledge. Such a phenomenon would result in an elevated tendency to false alarm to illustrations depicting the same story as a studied image from

the story versus artist attentional state. To foreshadow the results, what we found was contrary to our expectations.

We found a significant interaction of attention at encoding (artist/story attention) and lure type (related along artist/story dimension; 2x2 repeated-measures ANOVA: interaction F(1,43)=5.58, p=0.023, η=0.006; Figure 5). The nature of the interaction was such that participants made more false alarms to story than artist lures (repeated-measures ANOVA main effect of lure type: F(1,43)=28.21, p<0.0001, η=0.027), and this difference was larger for memories encoded in the story (paired t-test; t(43)=5.10, p<0.0001) than artist (t(43)=2.18, p=0.035) attentional state. However, the tendency to false alarm to story lures did *not* differ according to whether the related image was encoded in an artist or story attentional state (paired t-test; t(43)=1.61, p=0.115), suggesting that explicitly directing participants' attention to story information did not reliably increase the level of integration into prior story knowledge. In contrast, there was a trend toward higher false alarms to artist lures in the artist vs. story attention condition (t(43)=1.85, p=0.071). Therefore, while story lure false alarm rates were high, this was true irrespective of attention—consistent with integration of story features being high in general.
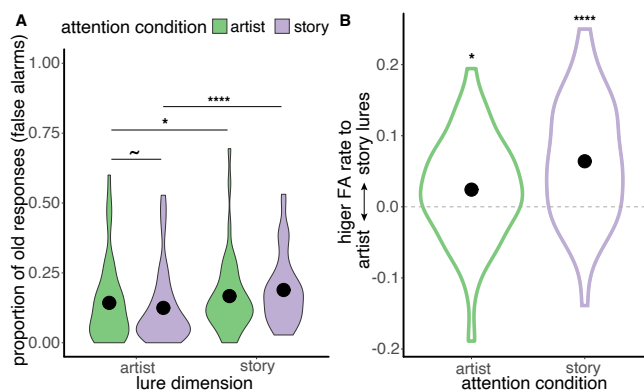

Figure 5: *Filler-related false memories.* (A) Proportion of false alarms to artist lures (left) and story lures (right). (B) Story-artist lure FA difference scores for artist attention (left, green outline) and story attention (right, purple outline). ~p<0.1, *p<0.05, ****p<0.0001

Greater familiarity with story versus artist attentional state does not appear to impact memory Attention to semantic information, in addition to being more related to prior knowledge, may also be a more automatic or familiar form of attention. In contrast, perceptual attention may be slower and more effortful to engage (i.e., require learning during task) and maintain. Although behavioural performance in the encoding task suggests artist attention was easier than story attention (see Encoding Performance), it is possible that initially, the influence of artist attention on behaviour may have been overwhelmed by the automatic nature of semantic attention. If this were the case, one might expect the difference between artist and story attention to be greatest for images encoded later in the task. To assess this possibility, we performed the same analysis of filler-related

memory errors—which showed no reliable difference overall between attentional states (Figure 5A)—again, but this time restricting to only fillers encoded during the last third of the task. Even when restricting to those later-encoded fillers, there was no significant effect of attention overall or in either story or artist lures separately (repeated-measures ANOVA main effects of attention, all $F_{(1,43)}<0.82$, all $p> 0.36967$), suggesting that attention did not modulate false alarms to story lures even after participants had gained some experience with the perceptual attention task.

Discussion

We manipulated participants' attention to either semantic or perceptual features during an incidental encoding task, and then assessed the integration of those subsequent memories along semantic and perceptual dimensions. Semantic attention benefited memory for repeated (story repeats) and independent (filler) stories. However, in contrast to our predictions, explicitly directing attention towards semantic information did *not* increase the likelihood of integration as measured in false alarms to similar lures. While integration was overall more common along the semantic than perceptual dimension, this effect was not modulated by attention.

Semantic versus perceptual attention was associated with superior recognition memory for both fillers and story repeats. This is consistent with prior work demonstrating a memory benefit for information encoded with deeper levels of processing (i.e., greater semantic conceptualization) that may link new information with prior knowledge (Bransford & Johnson, 1972; Craik & Tulving, 1975; Lockhart, 2002). However, the present findings extend this prior work to show that this semantic encoding benefit exists even when both tasks require complex consideration of multiple features. An alternative interpretation of our finding stems from transfer appropriate processing (Lockhart, 2002; Morris, Bransford, & Franks, 1977; Mulligan & Picklesimer, 2012). Namely, it may be the case that semantic attention at encoding better matches the attentional state participants naturally engage at test; in other words, attending to story content might better mimic the default state engaged during an (uncued) memory test. Because we did not manipulate attention at retrieval, we cannot assess this possibility directly in the current data; however, it is an interesting question for future work.

Contrary to our predictions, semantic and perceptual attention did not differentially promote integration along the semantic dimension. In particular, there was no difference in the tendency to false alarm to semantically similar experiences as a function of attentional state. This finding suggests explicit attention towards semantic features is not necessary for the integration of new information into prior related semantic knowledge. Furthermore, even after gaining task familiarity with the opposite dimension (i.e., perceptual attention), there continued to be no influence of attentional state on integration in prior knowledge. One possible explanation for this finding is that semantic integration may serve as the default encoding state that cannot be suppressed by attention to other features (i.e., perceptual features).

Although prior work motivated by the fuzzy trace theory of memory suggests that there is a downside of reliance on semantic information for memory behaviours (Brainerd & Reyna, 1990), we found evidence of only *benefits* conferred by attending to semantic features during encoding. In contrast, attention did not impact the tendency to form semantic "gist" memories of the experience. Put another way, semantic attention differently impacted recognition and false alarms to similar experiences—specifically by increasing hits to studied illustrations but not false alarms to semantically similar ones. The finding that gist extraction is robust to changes in attentional state is consistent with the idea that people extract and store such information automatically and rapidly during encoding (Ahmad, Moscovitch, & Hockley, 2017; Brainerd & Reyna, 1990; Reyna et al., 2002; Webb, Turney, & Dennis, 2016). This may suggest that multiple independent representations can be formed from the same experience, such that a semantic representation and visual representation of the studied illustrations could support different patterns of hit rate and memory errors. This idea is consistent with prior work that suggests independent verbal and visual codes are formed from the same experience, with semantic representations akin to verbal codes (Bahrick & Bahrick, 1971; Bahrick & Boucher, 1968; Nieznański & Obidziński, 2019). Our findings may extend this idea to suggest that attention away from semantic features (i.e., perceptual attention) surprisingly does not inhibit the encoding of both semantic and perceptual codes of an experience.

Interestingly, there were elevated false alarms to story versus artist lures for both fillers and story repeats. While the repetition of story information can increase false alarms to new illustrations that also share the same story, stories presented just once (i.e., as fillers) should have been less prone to semantically related false alarms. One possible explanation for this pattern is that encoding unique stories supports the reactivation of related story experiences, thus yielding memory effects similar to actually viewing two similar illustrations. Semantic information may have promoted the reactivation of related semantic knowledge regardless of the attentional state at encoding. These findings suggest the nature of semantic information may allow for reactivation of related knowledge, irrespective of whether attention is directed to features that may cue that reactivation.

Summary

Semantic attention benefitted memory by increasing recognition of studied illustrations, but it interestingly did not come at the cost of elevated false alarms to similar experiences. Attention to the features related to prior knowledge aided recognition memory but did not increase the integration of new information into existing knowledge. This may suggest that even when attending to semantic features, multiple representations of the same experience are formed and support different memory behaviours.

Acknowledgments

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