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Mechanisms supporting superior source memory for familiar items: A multi-voxel pattern analysis study

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ABSTRACT

Recent cognitive research has revealed better source memory performance for familiar relative to novel stimuli. Here we consider two possible explanations for this finding. The source memory advantage for familiar stimuli could arise because stimulus novelty induces attention to stimulus features at the expense of contextual processing, resulting in diminished overall levels of contextual processing at study for novel (vs. familiar) stimuli. Another possibility is that stimulus information retrieved from long-term memory (LTM) provides scaffolding that facilitates the formation of item-context associations. If contextual features are indeed more effectively bound to familiar (vs. novel) items, the relationship between contextual processing at study and subsequent source memory should be stronger for familiar items. We tested these possibilities by applying multi-voxel pattern analysis (MVPA) to a recently collected functional magnetic resonance imaging (fMRI) dataset, with the goal of measuring contextual processing at study and relating it to subsequent source memory performance. Participants were scanned with fMRI while viewing novel proverbs, repeated proverbs (previously novel proverbs that were shown in a pre-study phase), and previously known proverbs in the context of one of two experimental tasks. After scanning was complete, we evaluated participants' source memory for the task associated with each proverb. Drawing upon fMRI data from the study phase, we trained a classifier to detect on-task processing (i.e., how strongly was the correct task set activated). On-task processing was greater for previously known than novel proverbs and similar for repeated and novel proverbs. However, both within and across participants, the relationship between on-task processing and subsequent source memory was stronger for repeated than novel proverbs and similar for previously known and novel proverbs. Finally, focusing on the repeated condition, we found that higher levels of hippocampal activity during the pre-study phase, which we used as an index of episodic encoding, led to a stronger relationship between on-task processing at study and subsequent memory. Together, these findings suggest different mechanisms may be primarily responsible for superior source memory for repeated and previously known stimuli. Specifically, they suggest that prior stimulus knowledge enhances memory by boosting the overall level of contextual processing, whereas stimulus repetition enhances the probability that contextual features will be successfully bound to item features. Several possible theoretical explanations for this pattern are discussed.

1. Introduction

Studies revealing recognition memory advantages for novel stimuli over repeated stimuli (i.e., stimuli that were presented in an earlier, "pre-study" phase of the experiment; see, e.g., Tulving & Kroll, 1995) have been influential in cognitive neuroscience, inspiring several theories about neural mechanisms that could induce superior encoding of novel information (e.g., Lisman & Grace, 2005; Tulving, Markowitsch, Craik, Habib, & Houle, 1996). Recent cognitive data, however, indicate that prior observations of superior memory for novel over repeated stimuli occurred because of factors relating to retrieval, rather than encoding: specifically, these data indicate that classic findings of worse memory for repeated items arise from source confusion (mistaking stimuli learned elsewhere for stimuli from the study phase) rather than poor learning of study phase details per se (Poppenk, Köhler, & Moscovitch, 2010a). The question of how novelty affects encoding of study-phase details can be more directly addressed using source memory tests that probe memory for unique contextual details from the study phase (e.g., the encoding task that was performed on the item at study). By focusing the test on details that pertain only to the study phase (as opposed to other

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events involving the queried item), the potential for source confusion at retrieval is greatly reduced, making it possible to examine – in a relatively unconfounded fashion – effects of novelty versus familiarity on encoding. Numerous studies using this kind of source memory test have found better source memory for repeated vs. novel proverbs, scenes, faces and words (Lee, Jung, & Yi, 2012; Poppenk et al., 2010a; Poppenk, McIntosh, Craik, & Moscovitch, 2010b; but see Kim, Yi, Raye, & Johnson, 2012). Furthermore, Poppenk et al. (2010a) found a similar source memory bonus when proverbs known to participants from prior life experience were compared to novel items. These findings call for identification of a mechanism that can explain this source memory bonus for familiar (i.e., repeated or previously known) stimuli.

Here, we consider two (non-exclusive) families of explanations for the familiarity bonus that has been observed in these studies, and then we evaluate these explanations using multivariate pattern analysis applied to an fMRI dataset from Poppenk and Moscovitch (2011). Intuitively, there are two prerequisites that must be met at encoding in order to support good source memory: first, participants must process the relevant contextual (source) features. Second, to retrieve contextual features at test, these contextual features must be successfully bound to the representation of the item. As discussed below, stimulus familiarity can affect both of these steps (initial processing of contextual features, and successful binding of these features to the item representation).

One possible explanation for the familiarity bonus is that stimulus novelty at encoding diverts attentional resources towards processing of the (novel) stimulus and away from processing of contextual details (e.g., encoding task or spatial position), resulting in diminished overall levels of contextual processing at study for novel (vs. familiar) stimuli. This idea encompasses a family of mechanisms that we will describe collectively as the *attention* account. The key shared feature of all of these mechanisms is the prediction that less processing of contextual features should occur for novel vs. familiar stimuli. Attentional diversion could have a negative impact on source memory in a number of ways: divided attention at encoding is known to have negative effects on memory (Craik, Govoni, Naveh-Benjamin, & Anderson, 1996; especially associative memory, Castel & Craik, 2003) and explicitly directing attention towards item features during memory encoding reduces subsequent source memory (Dulas, 2011). Such effects are consistent with the encoding specificity principle (Tulving & Thomson, 1973), which posits that the type of information processing that takes place at encoding will determine the type of information available in memory at test. Along these lines, it has been proposed that the hippocampus captures only the contents of consciously apprehended information in forming episodic memories (i.e., a form of memory that incorporates vivid reinstatement of the contextual details of an event; Moscovitch, 2008). Accordingly, to the extent that attention is diverted away from contextual information and towards item information, contextual details should be lost. There is at least some evidence in the literature suggesting that stimulus-focused processing may be greater for novel stimuli: for example, Diana and Reder (2006) found worse recognition of pictures with low-frequency words superimposed on them than of pictures with high-frequency words superimposed on them, which they argued reflected greater distraction by the (relatively novel) low-frequency words, arising from greater processing requirements of those words. Consistent with this idea, they found in other experiments that recognition of low-frequency words suffered more from divided attention than did recognition of high-frequency words.

Another possible explanation of the familiarity bonus for source memory is that retrieved information from long-term memory (LTM) *facilitates binding of item and contextual information* by providing a scaffold onto which new memories can "stick". This idea encompasses a family of mechanisms that we will refer to collectively as the *scaffolding* account. The key shared feature of all of these candidate mechanisms is that relevant prior experience leads to enhanced binding of item and context features. For example, one variant of the scaffolding hypothesis posits that associations that underlie stimulus representations in LTM permit familiar stimuli to be represented as a single "chunk" of information (Gobet et al., 2001), whereas novel materials must be represented as the combination of their features. To the extent that there are limits on the number of chunks that can be held in consciousness (Miller, 1956), the availability of more complex chunks for familiar items makes it possible to simultaneously represent a greater number of stimulus features for familiar vs. novel items. Putting these points together, if learning of item-context associations is focused on the contents of consciousness (Moscovitch, 2008), and participants can consciously represent more details of events involving familiar items (because of chunking), this implies that a richer web of item-context associations will be formed for familiar than novel items, leading to better source memory for familiar items at test (see Section 4 for other, related views). A closely related idea is that prior knowledge relating to an item promotes deeper, more elaborative processing of that item at study (Craik & Lockhart, 1972). These elaborations can then be linked to contextual features, leading (again) to a richer web of item-context associations than would otherwise be present.[1]

Crucially, the two families of explanations (attention and scaffolding) make different kinds of predictions. The key prediction of the attention hypothesis relates to the *overall amount* of contextual processing that is triggered by familiar vs. novel items: according to the attention hypothesis, there will be more contextual processing associated with familiar than novel items, since attention is directed towards stimulus processing to a greater extent for novel than familiar items. The scaffolding hypothesis, by contrast, does not make any special predictions about relative amounts of contextual processing that are triggered by familiar vs. novel items. Rather, the key prediction of the scaffolding hypothesis concerns the *relationship* between contextual processing at study and subsequent source memory. As noted above, processing of contextual features is not sufficient to yield good source memory; these features also need to be bound to the item representation. If – because of scaffolding – item-context binding is especially effective for familiar items, this implies that any factor that increases contextual processing will lead to a concomitant increase in source memory for these items. Conversely, if item-context binding is relatively *ineffective* for novel items, then it is possible that some factor might boost contextual processing but (because of poor binding) this increase might not lead to better source memory. Putting these points together: if the scaffolding hypothesis is true (such that retrieved LTM knowledge for familiar items facilitates binding), we would

[1] In addition to increasing the number of encoded features, elaboration can also increase the *distinctiveness* of memory traces, which (in turn) will promote good source memory by reducing interference between stored memory traces. The Poppenk and Moscovitch (2011) dataset that we re-analyze in this paper used highly distinctive proverb stimuli; in this situation, we would expect the level of between-trace interference to be relatively low for novel proverbs, and it seems unlikely that familiarization would lead to a substantial reduction in the (already low) level of interference. However, in situations where stimuli are less distinctive – and, consequently, between-trace interference is more of a concern – this mechanism (i.e., prior exposure leading to increased distinctiveness and reduced interference) may have a strong effect on source memory performance.