Unitization and temporality in associative memory: Evidence from modulation of context effects

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ABSTRACT

It has been proposed that the formation of episodic associations between stimuli may involve different processes when memoranda are from the same or different perceptual domains, and when stimuli are experienced concurrently or sequentially. Such differences are postulated to determine the degree of unitization of memoranda, and are asserted to influence whether such associations are later retrieved via familiarity or recollection. In two experiments utilizing the context effects (CEs) paradigm, we examined effects on associative memory observed when unitization of memoranda is not readily achieved, due to domain differences between stimuli or to asynchronous presentation. In both cases, the standard associative-binding CE of better recognition of probes under contextual reinstatement (i.e., higher hit rates for pairs of repeated probes vs. re-paired probes) was only found when participants explicitly recognized the context stimuli. These results contrast with earlier findings that for concurrent encoding of same-domain stimuli, CEs are obtained even in the absence of explicit memory for contexts. The contrast supports the assertion that in the absence of unitization associative memory is dependent on recollection, while unitized associations may be supported by familiarity strength.

Introduction

Inherent in our most basic ideas about memory is its ability to represent not only discrete stimuli, but also the spatio-temporal relationships between them – i.e., episodic associations. Although episodic associations have been the topic of much research, numerous significant questions about this aspect of memory remain open. Two of the many extant questions are whether common cognitive processes and neural structures are responsible for the encoding, storage, and retrieval of all forms of episodic associations, and whether the same episodic associative process binds stimuli across separation in space and separation in time. In the current study, we attempt to address these two questions.

Stimuli perceived simultaneously may be experienced as independent entities or as a gestalt. *Unitization* refers to the perception and encoding of a number of discrete stimuli as a single unit (Graf & Schacter, 1989; LaBerge & Samuels, 1974). A recent taxonomy of episodic association has proposed that associative memory comprises three types of associations, reflecting differing degrees of unitization: intra-item associations, i.e., items that were unitized into one entity (e.g., two interactively encoded objects); within-domain associations, formed between similar kinds of items that are not remembered as one entity (e.g., two unrelated words); and between-domain associations, formed between different kind of items or modalities, such as faces and voices (Mayes, Montaldi, & Migo, 2007). Unitization is postulated to have manifold effects on associative memory. Yonelinas, Kroll, Dobbins, and Soltani (1999) proposed that unitized stimuli may be recognized via processes that rely on familiarity rather than recollection. Following up on that proposal, Bastin, van der Linden, Schnakers, Montaldi, and

Mayes (2010) report that within-domain (face–face) associative recognition was mainly supported by familiarity, while between-domain (face–name) associative recognition required a major contribution of recollection. On the physiological level, event-related potential (ERP) measures of familiarity and recollection dissociate unitized and non-unitized associative representations for faces (Jäger, Mecklinger, & Kipp, 2006) and words (Bader, Mecklinger, Hoppstädter, & Meyer, 2010; Rhodes & Donaldson, 2007, 2008; Wiegand, Bader, & Mecklinger, 2010). In regard to neuroanatomy, Haskins, Yonelinas, Quamme, and Ranganath (2008) and Staresina and Davachi (2008), Staresina and Davachi (2010) have proposed that unitization enables associative representation formation by perirhinal cortex (PRh) independently of hippocampal processes. This notion dovetails with suggestions that have been made regarding PRh-supported "associative familiarity" (Mayes et al., 2007) and reports of the rapid encoding of single and unitized items (Henke, 2010). Furthermore, other studies have shown that unitization and associative strategies modulate aging effects on associative memory (Jäger, Mecklinger, & Kliegel, 2010; Naveh-Benjamin, Brav, & Levy, 2007). These anatomical, physiological, and behavioral findings indicate that distinctions between item and associative memory may be more parametric than binary, depending on the possibility of stimulus unitization.

A related crucial factor in the formation of episodic associations is *temporality*. The differences between associations of concurrently and sequentially experienced stimuli may be seen in forms of learning as simple as eyeblink conditioning, in which the hippocampus is required for trace conditioning in animals and humans (e.g., Cheng, Disterhoft, Power, Ellis, & Desmond, 2008). For declarative memory as well, binding concurrently experienced (*intra-temporal* association) and sequentially experienced (*inter-temporal* association) stimuli may depend on different processes and brain substrates. In studies of associative learning, most commonly stimulus pairs are presented simultaneously (e.g., word pairs – Buchler, Light, & Reder, 2008; Hockley & Consoli, 1999). In neuroimaging research, such as that tracking hippocampal involvement in associative encoding, most often stimuli are temporally concurrent though spatially distinct (e.g., Jackson & Schacter, 2004; Kirwan & Stark, 2004; Staresina & Davachi, 2006, 2008, and many other studies catalogued in Hales and Brewer (2010)). However, other studies have tracked brain activation during successful associative encoding of asynchronously presented stimuli (e.g., Hales & Brewer, 2010; Qin et al., 2007; Staresina & Davachi, 2009). Such studies report activity in bilateral frontal and parietal regions and hippocampi that is specifically predictive of subsequent memory for inter-temporal associative information. It remains to be determined to what degree these latter activation differences reflect fundamentally different cognitive processes for association formation between concurrent stimuli and between sequential stimuli.

Complementing these questions about type-diversity in the formation of episodic associations, there are various methods of assessing the strength of such associations. An important alternative to the more common cued recall and associative recognition tests is provided by measures of memory context effects (CEs). The basic CE is that target information is better retrieved at test in the presence of elements of the encoding context (e.g., Murnane, Phelps, & Malmberg, 1999; Smith & Vela, 2001; Vakil, Raz, & Levy, 2007). Models such as ICE (Item, Context, Ensemble; Murnane et al., 1999) or BIC (Binding of Item and Context; Diana, Yonelinas, & Ranganath, 2007) ground such phenomena in more general models of associative memory. The CE paradigm is reminiscent of source memory paradigms, in which memory for contextual information is directly queried (Johnson, Hashtroudi, & Lindsay, 1993), but has the advantage of assessing the strength of associative binding indirectly, through the impact of associated contextual information on the recognition of a target. This enables the detection of associative strength even in the absence of direct endorsement via cued recall or associative recognition. The robustness of this form of associative assessment has been shown by Cohn and Moscovitch (2007), who label it 'associative reinstatement', and demonstrate its resilience to retrieval manipulations (short response deadline, speeded recognition, and overlapping pairing) that reduced explicit associative recognition (which they call 'associative identification').

In one recent CE study (Levy, Rabinyan, & Vakil, 2008), participants studied pairs of simultaneously presented object pictures, with one object defined as a memory target and the other serving as background context. Later, they performed yes/no recognition judgments on targets and foils in the presence of the same or different background context stimuli. Probability of hits and false alarms was calculated as a function of whether the contextual pair-members were endorsed, i.e., judged as previously seen. Notably, the impact of context reinstatement on recognition persisted even when the associated pair-members of relevant probes were not explicitly recognized. These findings are in line with other studies documenting implicit memory influences on retrieval in Target-Context learning. For example, patients with closed-head injuries presumably involving frontal lobe damage, who exhibit general declarative memory impairments including deficits in direct source recollection, nevertheless benefit from context reinstatement at retrieval (Vakil, Openheim, Falck, Aberbuch, & Groswasser, 1997). Similarly, elderly individuals, whose source memory and other frontal-lobe based functions may be more impaired than their item memory relative to younger adults (e.g., Spencer & Raz, 1995), can nevertheless benefit equally from context reinstatement (Cohn, Emrich, & Moscovitch, 2008; Naveh-Benjamin & Craik, 1995; Vakil, Raz, & Levy, 2010).

The formation of an association leading to CE can also take place when items are processed in temporal proximity (e.g., Malmberg & Annis, 2011; Schwartz, Howard, Jing, & Kahana, 2005). Schwartz et al. (2005) conducted a study aimed at assessing the fit of the Temporal Context Model (TCM), previously successfully applied to recall, to recognition memory (Howard & Kahana, 2002). TCM offers an explanation for the lag-recency effect – the finding that after recalling an item from a given serial position, the item recalled next tends to come from a nearby position