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Parallel interactive retrieval of item and associative information from event memory ☆

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ABSTRACT

Memory contains information about individual events (items) and combinations of events (associations). Despite the fundamental importance of this distinction, it remains unclear exactly how these two kinds of information are stored and whether different processes are used to retrieve them. We use both model-independent qualitative properties of response dynamics and quantitative modeling of individuals to address these issues. Item and associative information are not independent and they are retrieved concurrently via interacting processes. During retrieval, matching item and associative information mutually facilitate one another to yield an amplified holistic signal. Modeling of individuals suggests that this kind of facilitation between item and associative retrieval is a ubiquitous feature of human memory.

1. Introduction

Memory contains information about both single events—"items"—and combinations of events—"associations" (Anderson & Bower, 1973; Murdock, 1974). Being able to store and retrieve both of these kinds of information underlies the ability to discover meaningful temporal and spatial structure in the environment (e.g., causal regularities, correlations, and event schemata; Zacks & Tversky, 2001) and dissociations between item and associative memory are important for a variety of neurological diagnoses, including memory deficits with age (Naveh-Benjamin, 2000). Despite the fundamental nature of this distinction, it remains unclear exactly how item and associative information are stored and what processes are used to retrieve them.

Many dual-process theories (Jacoby, 1991; Yonelinas, 1997) posit that item information is retrieved primarily via a "familiarity" process while associative information can only be retrieved using an independent "recollection" process. That these processes retrieve different kinds of information implies that item and associative information are stored separately and may be represented in qualitatively different forms accessible only to particular processes. However, arguments in favor of this view have relied on measures of recognition accuracy that are not diagnostic of the types of processes involved (Dunn, 2004, 2008; Pratte & Rouder, 2012; Wixted, 2007) and that are only reliable under the strong assumption of item and associative independence (Curran & Hintzman, 1995; Hillstrom & Logan, 1997; Ratcliff, Van Zandt, & McKoon, 1995). In contrast, item and associative memory are often correlated: Item recognition is affected by the presence of an intact association, even when it is irrelevant to the task (Clark & Shiffrin, 1987; Tulving & Thompson, 1973) and while participants are able to sep-

☆ All data, experiment code, stimuli, and model code are freely available for download from the Open Science Framework at https://osf.io/uhejm/.

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arately assess memory for items and associations, they are influenced by the strength of *both* items and associations when doing so (Aue, Criss, & Novak, 2017; Buchler, Light, & Reder, 2008). While these results still allow the possibility that item and associative retrieval rely on separate processes, they imply that such processes are not mutually exclusive, with item and associative information being represented in the same memory store (Gillund & Shiffrin, 1984).

Where there are differences between item and associative retrieval, they are most clearly found in retrieval dynamics: People can discriminate between studied and unstudied items faster than they can distinguish learned from unlearned pair associations (Gronlund & Ratcliff, 1989; Nobel & Shiffrin, 2001; Rotello & Heit, 2000). While this delay has been attributed to an independent "recall-to-reject" process for associative retrieval (Rotello & Heit, 2000), this account predicts that partial cues will aid associative recognition (i.e., using a singly presented word to retrieve its studied associate), but in fact they do not (Gronlund & Ratcliff, 1989). Paradoxically, these results are more consistent with a *strong* interaction between item and associative retrieval in which item information serves to "gate" associative retrieval by providing a baseline or context against which later associative information is judged (Cox & Shiffrin, in press; Criss & Shiffrin, 2005; Hockley, 1991). A gating mechanism also explains why focusing on items impairs associative memory, but focusing on associations has no negative impact on item memory (Hockley & Cristi, 1996a) and why associative interference occurs only among pairs comprised of the same types of items (Aue, Criss, & Fischetti, 2012; Criss & Shiffrin, 2004). Once again, these interactions imply not just that item and associative information are stored in the same memory structure, but that the processes used to retrieve them are not independent.

While there appear to be differences in the dynamics with which item and associative information are retrieved, and while it appears these two kinds of information are related in some sense, it remains unclear what the nature of these dynamic differences and relationships are. They may result from two independent retrieval processes operating on correlated memory structures, from interactions during retrieval itself, from some combination of these, or some even more exotic form of interaction. A set of experimental and analytical tools known as Systems Factorial Technology (SFT; Townsend & Nozawa, 1995) is designed to address exactly these questions. Applying these tools to the study of long-term memory has, however, proven difficult due to various technical limitations. In this study, we overcome these limitations. Based on converging evidence from qualitative properties of retrieval dynamics as measured by SFT and from quantitative modeling of individual participants, we show that item and associative information are retrieved concurrently and that they are not independent, nor are independent processes used to retrieve them. After describing our experimental methods, we explain how we applied SFT analyses and individual modeling to derive these conclusions. Finally, we discuss how our results place strong constraints on future theory development and have important implications for understanding how event memory is related to long-term learning.

2. Methods

We measured the dynamics of item and associative retrieval in a recognition paradigm that requires retrieval of both kinds of information. After studying a list of pairs, e.g., AB, CD, EF, etc., participants must later discriminate between intact studied pairs and three kinds of foil pairs. We denote intact studied pairs, like AB, I^+A^+ pairs since both the items in the pair (I) and the association between the items (A) match what was studied ($^+$). I^+A^- pairs, often called "rearranged" pairs, are formed by exchanging items between two studied pairs, e.g., CF or ED; in this case, the items match the study situation, but the association does not. I^-A^+ pairs are formed by replacing the items in an intact pair with similar unstudied items (e.g., A′B′); while the items may not exactly match what was studied, the relational information between them is preserved, leaving the association intact. I^-A^- pairs are formed by performing both of these operations (e.g., C′F′). Thus, neither item nor associative information is sufficient on its own to identify I^+A^+ pairs—*both* item *and* associative information must be retrieved. This can be contrasted with the studies reviewed in the Introduction in which the presence of one or more unstudied items entails that the association is also unstudied.

To be able to apply the tools of SFT, we also separately vary the strength of each kind of information in memory, yielding both high and low associative strength, A_H and A_L, and high and low item strength, I_H, I_L, for all pair types (as shown in Fig. 2). As described below, these strength manipulations allow us to compute one of the critical statistics of SFT which can enable us to determine the nature of the processes by which item and associative information are retrieved and the extent to which they interact (for an overview and tutorial on SFT, see Houpt, Blaha, McIntire, Havig, & Townsend, 2014).

2.1. Participants

135 Syracuse University students took part in this experiment in exchange for course credit after providing informed consent in accord with local Institutional Review Board policy.

2.2. Materials

Stimuli consisted of indoor and outdoor scene images derived from two image sets (Goh et al., 2004; Konkle, Brady, Alvarez, & Oliva, 2010). The images were first screened to remove any legible writing (to preclude this as a strategy to remember particular images) as well as people (since these were particularly salient relative to other scene content). We