Journal of Memory and Language 102 (2018) 28–40

Contents lists available at ScienceDirect

Journal of Memory and Language

journal homepage: www.elsevier.com/locate/jml

Temporal contiguity in incidentally encoded memories☆

M. Karl Healey

Michigan State University, Department of Psychology, 316 Physics Road, East Lansing, MI, United States

ARTICLE INFO

Keywords:
Episodic memory
Free recall
Temporal contiguity

ABSTRACT

Thinking of one event often triggers recall of other events experienced nearby in time. This Temporal Contiguity Effect has been extensively documented in laboratory list learning tasks, but its source is debated. Is it due to task-general automatic processes that operate whenever new memories are formed? Or is it due to task-specific encoding strategies that operate only during deliberate rote learning? I test these theories by presenting over 3500 subjects with a surprise free recall test after various incidental encoding tasks. Experiments 1 and 2 show that temporal contiguity is dramatically reduced under incidental encoding. Experiments 3 and 4 show that although the effect is reduced, it is not eliminated—temporal information is encoded incidentally and is used to guide memory search during both free recall and serial recall. These results demonstrate that contiguity is not an artifact of strategy, but the dramatic reduction of the effect also challenges models that posit a strong link between successful memory encoding and contiguity.

Introduction

Recalling one event tends to trigger recall of other events experienced nearby in time (for a review, see Healey & Kahana, submitted for publication). Although this Temporal Contiguity Effect (TCE) manifests in many memory tasks (Davis, Geller, Rizzuto, & Kahana, 2008; Schwartz, Howard, Jing, & Kahana, 2005), it is most readily observed in free recall where subjects study a list of words presented serially and then try to recall the words. Despite the fact that subjects are free to recall the items in any order, the order of recall tends to recapitulate the order of study (Kahana, 1996; Murdock, 1974; Postman, 1971, 1972).

The TCE can be illustrated by computing the probability of successively recalling items as a function of their distance, or lag, from each other in the study list (Kahana, 1996). For example, if after recalling the word studied in the 5th serial position, your next recall is the word from the 6th serial position, you have made a $lag = +1$ transition. If instead you transitioned from recall of the 5th serial position to the 3rd position, you have made a $lag = -2$ transition. For each value of lag, the conditional-response probability (CRP) is computed by dividing the number of times a transition of that lag was *actually* made by the number of times it *could* have been made (e.g., if you have just recalled the last item in the list, it is not possible to make a $lag = +1$ transition. Transitions to already recalled items are also excluded from the counts as subjects rarely repeat items; Kahana, 1996). The lag-CRP typically is highest for $lag = +1$ and -1 (but with a forward asymmetry) and decreases sharply for larger absolute values of lag. That is, memory search tends to transition between words that were studied nearby in time.

The TCE has shaped theories of the testing effect (Karpicke, Lehman, & Aue, 2014), directed forgetting (Sahakyan, Delaney, Foster, & Abushanab, 2013), retrieval induced forgetting (Kliegl & Bäuml, 2016), childhood development (Jarrold et al., 2015), cognitive aging (Healey & Kahana, 2016; Wahlheim & Huff, 2015), event segmentation (Ezzyat & Davachi, 2014), time estimation (Sahakyan & Smith, 2014), and even perception (Turk-Browne, Simon, & Sederberg, 2012). Moreover, out of several of factors that influence free recall (i.e., primacy, recency, and semantic similarity), the magnitude of the TCE has been found to be the most predictive of overall memory ability and general intellectual ability (Healey, Crutchley, & Kahana, 2014; also see Sederberg, Miller, Howard, & Kahana, 2010; Spillers & Unsworth, 2011).

Yet, we still do not know which cognitive mechanisms generate the TCE (Healey & Kahana, submitted for publication). Here, I will consider two classes of explanation. First, that the TCE arises from task-specific mechanisms that are only engaged when we are deliberately studying a serially presented list. Second, that the TCE arises from task-general mechanisms that the memory system automatically engages whenever new memories are formed.

Task-specific mechanisms

Control processes (Atkinson & Shiffrin, 1968; Lehman & Malmberg, 2013) allow us to strategically process information during memory encoding, maximizing recall (e.g., Delaney & Knowles, 2005; Unsworth, 2016). Some work suggests that the TCE arises from such task-specific strategies, implemented by control processes to handle the idiosyncratic

☆ I thank Mitchell Uitvlugt and Kimberly Fenn for helpful discussions. I am grateful to James S. Nairne and an anonymous reviewer for invaluable comments.
E-mail address: khealey@msu.edu.

https://doi.org/10.1016/j.jml.2018.04.003
Received 15 December 2017; Received in revised form 16 March 2018

demands of laboratory tasks (Hintzman, 2016). In other words, because laboratory tasks require subjects to do something they do not usually do (e.g., learn lists of largely unrelated words), they are forced to devise novel strategies to adapt to the peculiarities of the task. Such task-specific strategies, rather than task-independent memory mechanisms, could account for the contiguity effect.

As an example, the standard free recall task may encourage subjects to adopt the strategy of linking successive list items together to tell a story (Delaney & Knowles, 2005). Another example of a task-specific contiguity-generating mechanism is the method of loci, in which the list items are associated with a pre-memorized sequence of locations. Both of these strategies require subjects to pay attention to the order of presentation and recapitulate it during recall. Thus, both would produce a TCE.

But critically, subjects deploy these contiguity-generating strategies only because they happen to be well-suited to the specifics of the task. If the specifics of the task change, subjects may adopt different strategies, and these new strategies may not generate contiguity. If the strategies are the only mechanism generating contiguity, any change in the specifics of the task that causes subjects to abandon contiguity-generating strategies should eliminate the TCE entirely. The most decisive test of this prediction is to have subjects process a list under incidental encoding conditions, which should prevent adoption of any deliberate encoding strategy, and then complete a surprise free recall test (Hintzman, 2016).

Task-general mechanisms

Subjects obviously adopt task-specific strategies. And these strategies doubtlessly contribute to the TCE. But task-specific strategies may not be the only mechanisms that generate the TCE.[1] Many theories of episodic memory propose *task-general* mechanisms that automatically encode information about the temporal proximity of events when forming episodic memories, even if no specific encoding strategy is adopted. If these models are correct, a residual TCE should remain even after removing any impetus to engage encoding strategies.

As an example, some theories assume that new events form associations to a representation of time (Brown, Neath, & Chater, 2007; Howard, Shankar, Aue, & Criss, 2015). This allows recall of one event to trigger recall of temporally adjacent events via associations to adjacent temporal representations. These theories assume time is directly encoded by the memory system, but this is not the only way the memory system might automatically encode information about presentation order. Other theories assume that events experienced close together in time become associated, not with a temporal representation, but with similar states of a drifting mental context representation (Lohnas, Polyn, & Kahana, 2015; McGeoch, 1932; Polyn, Norman, & Kahana, 2009). This allows recall of one word to trigger recall of a word studied nearby in time via associations to a common state of mental context. Either of these mechanisms would provide the necessary ingredients to produce a TCE during free recall.

But critically, these encoding mechanisms are assumed to support memory in a range of situations and not just during laboratory list learning tasks. If the specifics of the task change, subjects may adopt different strategies, but they must still rely on the fundamental mechanisms of the memory system. Therefore, changes in the specifics of the task might modulate the magnitude of the TCE by changing the contribution of context-generating strategies, but they should not eliminate the TCE entirely. Thus, these theories would predict that a residual TCE should be observed even under incidental encoding.

[1] Indeed, Hintzman (2016) suggests that in addition to engaging deliberate contiguity-generating strategies, subjects might also automatically notice similarities among temporally proximate items and therefore remember them together at recall.

Incidental encoding of temporal order

The task-specific and task-general perspectives make competing predictions about the influence of removing the intention to encode on the size of the TCE. The literature on incidental encoding provides some data relevant to these predictions, but scholars' interpretations of these findings are mixed.

Glenberg and Bradley (1979) tested for incidental encoding of temporal associations by having subjects repeat a pair of words while trying to retain digits for a varying interval. After 81 such trials, subjects were given two surprise memory tests for the words. The first was an item recognition test (i.e., was the probe seen before); the second was either a cued recall test (given one word from a pair, recall the other) or a pair recognition test (discriminate intact from mismatched pairs). Performance was above chance on the item and pair recognition tests but was very low on the cued recall test, suggesting subjects had limited access to information about which words appeared together. A second experiment also found very low cued recall performance but above chance performance on an associative matching test. Bradley and Glenberg (1983) replicated their earlier findings and added many control conditions, including a "sheer contiguity" condition in which the words were not presented simultaneously as in the previous experiments but merely in close temporal proximity (as is the case in free recall). In this condition, performance on the associative recognition task was not above chance. Bradley and Glenberg (1983, p. 665) concluded "that sheer temporal contiguity, that is, adjacency of processing, is not sufficient to produce the associations observed in these experiments."

Data from Nairne (1990, 1991) suggest a different conclusion. In several studies, subjects viewed lists of serially presented words under the guise of a rating task. This incidental encoding task was followed by a surprise order reconstruction task in which subjects were shown the words and had to reconstruct their order. They could do this with considerable accuracy, even when they were shown multiple lists and required to place each word in both its correct list and its correct within-list position (Nairne, 1991). Moreover, even when subjects made a mistake on the reconstruction task, the errors were not random. Instead, order errors following incidental encoding tended to take the form of putting items in positions adjacent to the correct ones, much as they do after explicit encoding (Healy, 1974). This work suggests that subjects have relatively easy access to temporal information (for related examples of access to order information after incidental encoding, see Burns, 1996; Serra & Nairne, 1993).

But other work suggests that this knowledge of order might depend on semantic similarity. Even after explicitly studying a list for a recognition task, subjects preform poorly if they are instead given a surprise spacing judgment task, which requires them to guess the lag that separated pairs of words in the original list, *unless* the words in the pair were semantically related (Hintzman & Block, 1973; Hintzman, Summers, & Block, 1975). These results have been taken as evidence that temporal information is only encoded when subjects notice semantic similarities among items in the list (i.e., study phase retrieval, Hintzman, 2016; Hintzman & Block, 1973; Hintzman et al., 1975).

In all of these studies, the test directly asked subjects to access information about temporal order. But being explicitly aware of the order of a list and being able to report it is not the same thing as allowing temporal information to influence memory search during free recall. It is possible that subjects could have the temporal information needed to complete an ordering task but fail to use that information to guide a free memory search. Or vise versa, subjects could have difficulty explicitly recalling order yet still implicitly access temporal information to guide memory search. Do subjects spontaneously use incidentally encoded temporal information to produce a TCE in free recall?

Among a series of studies on how the generation effect influences memory for order, Burns (1996) reported a condition in which subjects preformed an incidental encoding cover task on a list composed of 32