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Memory as a Hologram: An Analysis of Learning and Recall

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We present a holographic theory of human memory. According to the theory, a subject's vocabulary resides in a dynamic distributed representation—a hologram. Studying or recalling a word alters both the existing representation of that word in the hologram and all words associated with it. Recall is always prompted by a recall cue (either a start instruction or the word just recalled). Order of report is a joint function of the item and associative information residing in the hologram at the time the report is made. We apply the model to archival data involving simple free recall, learning in multitrial free recall, simple serial recall, and learning in multitrial serial recall. The model captures accuracy and order of report in both free and serial recall. It also captures learning and subjective organisation in multitrial free recall. We offer the model as an alternative to the short- and long-term account of memory postulated in the modal model.

Keywords: hologram, memory, learning, recall

If you were asked whether you know the meaning of the word "apple," you are likely to be able to affirm your knowledge in less than a second. Likewise, if you were asked whether you know a fact that you do not know (e.g., Margaret Trudeau's maiden name), you are likely to confirm that you do not know within a comparable time (see Glucksberg & McCloskey, 1981). In both examples, you have to search what you do know. If search involved an item-by-item process, quick confirmation of both what you know and what you do not know is hard to explain—if search were serial, instead of reading the remainder of this sentence, you would still be lost in thought, seeking Margaret Trudeau's maiden name. Given that you are not lost in an exhaustive item-by-item search, you must have used a parallel search, likely with a content-addressing mechanism.

In this article, we present an account of memory as a hologram—a method of data storage that supports a content-addressable search. To present the model, we will focus on learning and ordered recall. How we order recall is a fundamental problem because behaviour is extended in time. Because verbal report is necessarily a serial process, subjects must order their responses, even though multiple potential responses are available in memory.

Analysis of how subjects order behaviour has been a longstanding topic of controversy (e.g., Lashley, 1951). Order of recall must depend on the words stored in memory, on associations among them, and on information about the words and the context in which they were stored. Particularly controversial has been the balance of two contributing sources of information: item-to-item associations and item-to-context associations. The latter refers to information about the words, such as their position in a spatial or temporal stream (e.g., Dennis, 2009).

Ebbinghaus's (1885/1913) account was based on information taken from the list; to order report, it depended on associative links among items, particularly item-to-item links. Young (1962) used a transfer paradigm to argue against the associative-link idea; a rebuttal by Johnson (1975) showed that Young's analysis was fatally flawed. Fifteen years later, Lewandowsky and Murdock (1989) revived interest in the associative-link idea. In their account, memory was a holographic store. At the start of each trial, memory was empty, and as subjects studied a list of words, the hologram stored the studied items and the pairwise associations among adjacent items. During recall, subjects used the associative chain to drive report. Mewhort and Popham (1991) used the same associative-chain ideas to simulate report of tachistoscopically presented letter strings under conditions of masking and letter spacing; that is, they exploited pairwise associations to handle left-to-right scanning (see Mewhort & Campbell, 1981).

In the last two decades, however, a wealth of data has surfaced that challenge the item-to-item chaining mechanism. Instead, current theorists focus on mechanisms based on context, specifically on item-to-context associations. As we will document later, our account does not use context-to-item associations (either temporal or spatial) to account for simple list-learning paradigms, but we acknowledge that subjects use such information in more complex situations. Indeed, one of the desirable characteristics of our holographic model is the ability to combine sources of information, in particular, item-to-item information and item-to-context information.

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