Effects of Inter-associate Connectivity on the Persistence of False Recall

Winston D. Goh (psygohw@nus.edu.sg)
Bee Hong Khoo (seventh@singnet.com.sg)
Department of Psychology, National University of Singapore
11 Law Link, Singapore 117570, Singapore

Abstract

False recall of critical non-presented words in lists of associated words was examined with immediate testing and after a one-week delay. The word lists were manipulated such that the density of the inter-associate connectivity – the number pre-existing connections between the associates of the critical non-presented target – was either high or low. When recall occurred immediately after the study phase, high connectivity lists facilitated veridical recall compared to low connectivity lists, but connectivity had no effect on false recall. When recall was delayed for a week, low connectivity lists induced more false recall than high connectivity lists, but connectivity had no effect on veridical recall. The overall pattern of results is broadly consistent with the predictions of the Processing Implicit and Explicit Representations model of associative memory and not with the predictions of Fuzzy Trace Theory.

Keywords: False recall; connectivity effects; retention interval; associative memory; long-term memory.

Introduction

More than a decade ago, Roediger and McDermott (1995) adapted Deese's (1959) original list learning procedure and introduced what is now known as the Deese-Roediger-McDermott (DRM) paradigm for producing false memory in the laboratory. In this paradigm, participants are presented a study list of words (e.g. *bed*, *rest*, *awake*, *tired*, *dream*) which are the strongest associates of a critical target (e.g. *sleep*) that was not presented. The extent of false memory is indexed by the probability of remembering the critical non-presented target in a subsequent free recall or recognition test.

Research on false memory using this paradigm or variants of it has been extensive. However, only a handful of studies have explicitly examined the persistence of false memory over time (e.g. McDermott, 1996; Thapar & McDermott, 2001; Toglia, Neuschatz, & Goodwin, 1999). The common finding among these studies is that false memory tends to persist over time, although the specific trends differ. McDermott (1996) reported that false recall exceeded veridical recall after a two-day retention interval. Toglia *et al*. (1999) reported that the level of false memory was not affected by retention intervals that varied between 0, 1, and 3 weeks, athough veridical recall declined over time. Thapar and McDermott (2001) reported that both veridical and false memory declined over retention intervals of 0, 2, and 7 days, but the rate of decline for veridical memory was more pronounced than that of false memory. Across these studies, veridical memory declined over time, as expected. Despite the inconsistent trends for false memory rates, taken together, the general pattern of results strongly suggests that the false memory effect using the DRM lists is robust and persistent over time.

One theoretical account that has been used to explain the persistence of false memory is Fuzzy Trace Theory (Reyna & Brainerd, 1995; Brainerd & Reyna, 2002). In this theory, two types of independent memory representations are extracted in parallel – verbatim and gist traces. Verbatim traces are representations of the surface features of an experienced word and the concurrent contextual cues. Gist traces include overall patterns of the experience during list presentation, including meaning, relations, and patterns that are retrieved during the encoding of the words. When DRM lists are presented, an item-specific verbatim trace is created for each word. At the same time, the overall theme of each list is extracted and contributes to the gist traces. Memory for a word is dependent on both verbatim and gist traces. However, when one of the other trace is stronger, retrieval can be predominantly based on the stronger trace. Veridical memory is based on both types of representations, but false memory of critical non-presented targets can only arise from the gist traces since there is no verbatim trace. Gist and verbatim traces are assumed to have different rates of forgetting, with gist traces being more stable while verbatim traces fade more quickly. The loss of verbatim traces over time leads to the decline of veridical memory. As false memory of critical targets is dependent on the more stable gist traces, false memory is predicted to persist.

An alternative account of false memory has been suggested that is based primarily on the idea of activations among associative networks, but which also relies on having two types of memory representations. The Processing Implicit and Explicit Representation (PIER 2) model of associative memory (Nelson, McKinney, Gee, & Janczura, 1998; Nelson, Schreiber, & McEvoy, 1992) assumes that the encoding of a word generates two independent memory representations – explicit and implicit representations. An explicit representation contains contextual information of the presentation of the word and its relation to other presented items, and arises through conscious processing. An implicit representation is created when the word's lexical representation and its network of inter-related associates in long-term working memory are automatically and unconsciously activated. The spreading activation metaphor is used to describe the encoding of words by the implicit processing component. The sum activation of the encoded word depends on the number and strength of pre-existing connections between the word and its associates, as well as the density of the connections between associates, or inter-associate connectivity. In the DRM paradigm, presentation of associates of a critical non-presented target will activate each associate's implicit representation and some of these implicit representations will include the critical target. Hence, the non-presented target is repeatedly activated and becomes more accessible and susceptible to being falsely remembered.

McEvoy, Nelson, and Komatsu (1999) demonstrated a novel prediction of false memory arising from the assumptions of PIER 2. Greater activation converging on a word leads to greater accessibility of the word. A recalled word can also act as a retrieval cue for further recall, i.e., words that are recalled first will prompt recall of more associated words. Therefore, high connectivity lists in the DRM procedure facilitated veridical recall of presented words because a recalled word can potentially cue many other presented associates and these have higher activation levels compared to words from low connectivity lists. Counter-intuitively, the effect was the opposite for false recall. Although critical non-presented targets from high connectivity lists gained higher activation from densely connected associates, false recall of the critical targets was shown to decrease with increased inter-associate connections. This is because the non-presented targets are less likely to be cued by already recalled words as the range of alternative associates available for cueing is greater. In other words, critical non-presented targets are less likely to be retrieved due to competition from other presented associates, resulting in lower false recall. Low connectivity lists, on the other hand, produced less veridical but more false recall because a recalled word is sparsely connected to other associates and therefore have potentially fewer associates to cue, which in turn increased the chances of falsely recalling a critical non-presented target.

One problem for associative accounts is the persistence of false memory across time. Implicit activation has been commonly assumed to be short-lived and decays over time (e.g. Collins & Loftus, 1975; Anderson, 1983; Hutchison & Balota, 2005). In McEvoy *et al*. (1999), the memory tests were conducted immediately after list presentation. One of the goals of the present study is to determine if the effects of inter-associate connectivity will persist across time. It is possible that connectivity effects may persist within the PIER 2 framework. The model assumes that target activation is reinstated when cues are presented. A critical non-presented target can therefore be reactivated during free recall by recalled items that are associates of the target. False recall is thus possible, through reactivation at test even after the original activation of the critical target by the DRM lists have decayed. This idea is similar to the associative activation during retrieval hypothesis proposed by Hutchison and Balota (2005), who adapted Anderson's (1983) argument that associates of recalled items may overlap sufficiently with associates of the critical target to induce a sense of familiarity through which the target is misattributed as a list item. The critical target need only be activated or perhaps re-activated during test to be falsely remembered. False memory would have persisted due to the reactivation and cueing processes during retrieval.

Fuzzy Trace Theory in a strict sense would not be able to account for connectivity effects because an exact definition of the gist representation and factors affecting gist strength has not been specified (Payne, Elie, Blackwell, & Neuschatz, 1996; Roediger, Watson, McDermott, & Gallo, 2001). Connectivity may not affect the strength of the gist trace since all lists are created the same way, around a central theme, which is extracted during encoding. The theory could assume that densely linked associates would have greater semantic relatedness than sparsely connected associates. One could then argue that the overall meaning of the list would be stronger and easier to detect for high connectivity than low connectivity lists. However, this conceptualization would predict that high connectivity would result in higher false recall because the theory predicts that false memory correlates positively with gist strength. Since gist traces are relatively stable across time, this effect of connectivity should also be evident at a longer retention interval.

The fuzzy trace framework would therefore predict an outcome for false recall that is opposite to that predicted by PIER 2. The present study will also allow an investigation of the pattern of connectivity effects across time to see if the results are more consistent with either one of the theoretical accounts. Specifically, Fuzzy Trace Theory would predict that both false and veridical recall would be higher for high connectivity than low connectivity lists, and this pattern would be true across immediate and delayed recall. On the other hand, based on McEvoy *et al*'s (1999) results, PIER 2 would predict that for immediate recall, veridical recall would be higher for high connectivity than low connectivity lists, whereas false recall would be higher for low connectivity than high connectivity lists. This pattern of connectivity effects may or may not persist at delayed recall.

Method

Participants

Ninety-six psychology undergraduates from the National University of Singapore participated for course credit.

Design

A 2 x 2 x 2 mixed design was used, with Connectivity (high, low) and Recall Type (veridical, false) run within-subjects and Retention Interval (immediate, delayed [1-week]) run between-subjects.

Materials

Twenty-four lists, with 12 in each of the high and low connectivity conditions, were constructed. Eighteen were adapted from McEvoy *et al*. (1999) while 6 were selected from the University of South Florida Free Association Norms (Nelson, McEvoy, & Schrieber, 1998). Each list comprised a critical non-presented target and 10 associates. Care was taken to ensure that associates that appeared in more than one list were not selected.

The connectivity level of each list was determined by the mean number of connections per associate of the critical non-presented target (ConnM). High connectivity lists were defined as those with a ConnM value greater than 2.00, while low connectivity lists were defined as those with ConnM value less than 1.00. An independent t-test showed that the average connectivity of the lists in the high condition (M = 3.08, SD = 0.43) was reliable denser than those in the low condition (M = 0.75, SD = 0.10), $t(22) = 18.41, p < .01$.

The lists were also equated on other word properties pertaining to the critical non-presented target and its associates listed in the norms. These include meaning set size (Mss), which refers to the number of associates of the target, the average meaning set size of the target's associates (MssA), the concreteness rating of the target (Conc), the average concreteness rating of the target's associates (ConcA), the frequency of the target (Freq); the resonance or probability that associates produce the target as an associate (ResP), and the backward associative strength (BAS), which refers to the probability that the 10 selected associates produced the critical target as an associate. Additionally, familiarity ratings (FAM) of all critical non-presented targets were obtained from 24 undergraduates who did not take part in the main experiment. They rated each word on a 7-point scale where 1 = do not know the meaning of the word at all, 7 = know the meaning of the word, and points 2-6 represented intermediate levels of familiarity.

Separate independent t-tests for each property revealed non-significant differences between the high and low connectivity lists, all ps > .05. The mean property values are summarized in Table 1.

Table 1: Equated Properties of the Word Lists.

	Connectivity			
	High		Low	
Property	*M*	*SD*	*M*	*SD*
Mss	20.08	4.17	19.50	3.09
MssA	15.08	1.59	15.14	1.44
Conc	3.88	2.55	3.59	2.74
ConcA	4.12	0.57	4.07	1.41
Freq	23.58	26.15	55.50	56.55
ResP	0.30	0.17	0.32	0.19
BAS	0.55	0.68	0.80	1.58
FAM	6.86	0.18	6.93	0.09

Procedure

Participants were tested in small groups in a computer laboratory. Half were randomly assigned to the immediate recall condition while the other half were assigned to the delayed recall condition.

During the study phase, words were presented one at a time in uppercase letters centered on a computer monitor at a rate of one word per second. Each list was preceded by a "READY" prompt followed by a fixation cross and ended with a row of hexes to indicate the end of the list. Within each list, words were presented from the strongest associate to the weakest, following the procedure of Roediger and McDermott (1995). The order of presentation of the 24 study lists was randomized for each participant.

To ensure that participants paid attention to the monitor display during the 240-word presentation, a secondary task was interspersed within the presentation of each list. An arrow (either ← or →) sometimes appeared on screen after a word was removed from the display. At this point, participants were to respond as quickly as possible by pressing the corresponding arrow key on the keyboard. In each list, there were three such arrows. Response latency for this secondary task was recorded in order to subsequently screen out participants who may not have been paying attention to the monitor.

After all 24 lists have been presented in the study phase, participants in the immediate recall condition proceeded to the recall phase immediately, while the participants in the delayed recall condition returned a week later for the recall phase. During the recall phase, participants were given 10 minutes to write down as many words as they could remember from the study phase on a recall sheet.

Results

The mean reaction time for the secondary arrow task was 583.72 ms (SD = 727.51) across all participants. The average reaction time of two participants in the delayed recall condition was more than two SDs above this mean, and the subsequent analyses did not include these two participants as their slow response may indicate that they were not paying attention to the monitor display during the study phase.

Table 2 summarizes the average recall rates across the experimental conditions. A three-way mixed design analysis of variance revealed significant main effects of Retention Interval, $F(1, 92) = 23.13$, $MSe = 0.004$, $p < .001$; Recall Type, $F(1, 92) = 16.80$, $MSe = 0.002$, $p < .001$; and Connectivity, $F(1, 92) = 4.55$, $MSe = 0.002$, $p < .05$. All two-way interactions were also significant, all Fs $(1, 92) > 12$, ps $< .01$. There was also a reliable three-way interaction, $F(1, 92) = 8.08$, $MSe = 0.001$, $p < .01$. The following analyses will focus on the interpretation of the highest order interaction.

Table 2: Recall Rates.

	Retention Interval			
	Immediate		Delayed	
Connectivity	*M*	*SD*	*M*	*SD*
	Veridical Recall			
High	.099	.061	.021	.022
Low	.047	.032	.016	.015
	False Recall			
High	.026	.049	.016	.038
Low	.031	.068	.033	.048

The source of the three-way interaction was the differential nature of the significant Recall Type x Connectivity simple interactions at each Retention Interval level [for immediate recall, $F(1, 47) = 32.13$, $MSe = 0.001$, $p < .001$; for delayed recall, $F(1, 45) = 7.32$, $MSe = 0.001$, $p < .05$], as shown in Figures 1 and 2.

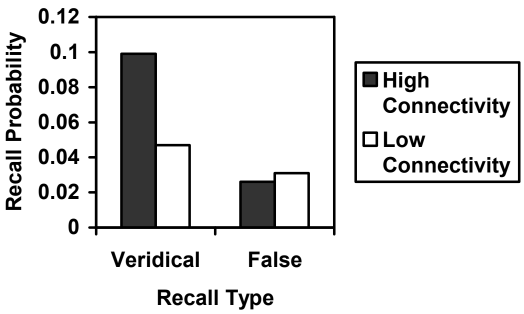

Figure 1. High connectivity facilitates veridical recall in the immediate recall condition.

In the immediate recall condition, simple effects analyses showed that high connectivity lists facilitated veridical recall compared to low connectivity lists, $F(1, 47) = 44.39$, $MSe = 0.00$, $p < .001$; whereas the effect of connectivity was not reliable for false recall, $F < 1$.

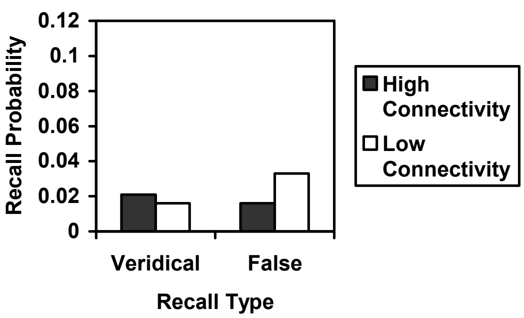

Figure 2. Low connectivity facilitates false recall in the delayed recall condition.

In the delayed recall condition, simple effects analyses showed an opposite pattern of results. The effect of connectivity was not reliable for veridical recall, $F(1, 45) = 2.18$, $MSe = 0.00$, *ns*; whereas low connectivity lists facilitated false recall compared to high connectivity lists, $F(1, 45) = 4.12$, $MSe = 0.00$, $p < .05$.

Discussion

Does the effect of inter-associate connectivity on false recall persist over time? Is the pattern of connectivity effects consistent with the predictions of Fuzzy Trace Theory or PIER 2? These were the questions the present study set out to investigate.

In the immediate recall condition, the pattern of results partially replicates the findings of McEvoy *et al*. (1999). High connectivity DRM lists facilitated recall of presented words compared to low connectivity lists. However, we did not replicate the previous results where low connectivity lists induced more false recall than high connectivity lists. Although the trend was in the correct direction, the difference was not statistically reliable.

The facilitation of false recall by low connectivity lists emerged only when the recall phase was performed a week after the study phase, whereas connectivity effects for veridical recall was not evident. The present results seem to indicate that connectivity effects may dissipate over time for veridical recall but become more prominent for false recall.

The general pattern of connectivity effects for false recall is more consistent with the predictions of PIER 2 than Fuzzy Trace Theory. In the latter, the prediction was that high connectivity lists would produce more false recall as a result of increasing the strength of gist traces. There was no evidence of this in immediate testing and the effect was the opposite at delayed testing. The increase in false recall rates with low connectivity lists is consistent with PIER 2's claim that false memory is mediated by reactivation of the implicit traces at encoding and subsequent cueing of associates, including the critical non-presented target. When there are fewer associates to be cued in the low connectivity lists, the chances of retrieving the critical non-presented target are higher.

PIER 2 also predicts that connectivity effects should be evident for veridical recall. High connectivity lists should facilitate recall for associated words because multiple activation and cueing from denser connections should result in greater activation strengths for their implicit representations. This was clearly the case in immediate recall, but not in delayed recall. If activation strength decreases over time, then the diminishing effects of connectivity for veridical recall after a week is not unexpected. However, why does diminished activation still result in reliable connectivity effects for false recall?

We offer the following plausible explanation, although it remains speculative and will require further research. Recall that PIER 2 proposes that encoding a word results in an explicit as well as an implicit representation. Both types of representations can affect veridical recall. Explicit representations are made by conscious encoding processes and should not be affected by the pre-existing connections to other words in long-term memory, which constitute the implicit representation of the word. During immediate recall, when the activation levels of the implicit representations are high, connectivity effects arising from the implicit representations should be evident. However, when activation levels have diminished in delayed recall, more emphasis may have been placed on a search for explicit representations for veridical recall. Since conscious, explicit encoding processes during the study phase should not be affected by the underlying connectivity, the probability of recovering words from high or low connectivity lists should be the same. Decreased activation and increased reliance on explicit search may explain the lack of connectivity effects for delayed veridical recall. On the other hand, since critical non-presented targets would not have an explicit representation, the *only* way to retrieve them would be via the underlying associative connections, which may be reactivated upon retrieving other associated words. Hence, the effects of connectivity would be more evident for delayed false recall.

We should point out a number of limitations of the present study. The recall rates are low compared to the previously cited studies on false recall, which can be as high as 50% depending on the condition. One possible reason for this is that the number of words used in our study is relatively large and the presentation rate of one second per word is also relatively fast compared to previous studies, which ranged from two to four seconds per word. The use of a secondary task during the study phase could also have inadvertently led to lower levels of encoding.

In summary, the main goal of the present study was to determine if connectivity effects on false recall persisted across time. Connectivity effects were evident for veridical recall at immediate testing, but emerged for false recall only at delayed testing. The overall pattern of results is broadly consistent with the predictions of the PIER 2 model of associative memory and not with the predictions of Fuzzy Trace Theory.

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