The Effect of Retrieval Interference on Different Types of Implicit Memory

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Abstract

Previous research has shown conflicting findings regarding whether retrieval interference affects implicit memory, with one important factor potentially stemming from differences in the types of implicit memory tests employed. The present study used a study-test paradigm and conducted four experiments to examine the effects of retrieval interference on perceptual identification implicit tests, conceptual identification implicit tests, perceptual production implicit tests, and conceptual production implicit tests, aiming to achieve a more comprehensive understanding of the relationship between retrieval interference and implicit memory. The results demonstrated that: (1) the priming effects in lexical decision tasks (perceptual identification) and semantic categorization tasks (conceptual identification) disappeared under retrieval interference, (2) while significant priming effects were still observed in production lexical decision tasks (perceptual production) and production semantic categorization tasks (conceptual production) under retrieval interference, the magnitude of priming effects also showed significant reduction compared to the no-interference condition. Thus, different types of implicit memory are all affected by retrieval interference, and identification priming is more vulnerable to disruption by retrieval interference than production priming.

Full Text

The Effects of Retrieval Interference on Different Types of Implicit Memory

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Abstract

Previous studies have shown inconsistent findings regarding whether interference during the retrieval stage affects implicit memory, with one important factor potentially stemming from differences in the types of implicit memory tests employed. Using a learning-test paradigm, the present study conducted four experiments to examine the effects of retrieval interference on identification-perceptual implicit tests, identification-conceptual implicit tests, production-perceptual implicit tests, and production-conceptual implicit tests, aiming to achieve a more comprehensive understanding of the relationship between retrieval interference and implicit memory. The results showed that: (1) the priming effects in lexical decision tasks (identification-perceptual) and semantic classification tasks (identification-conceptual) disappeared under retrieval interference, and (2) production lexical decision tasks (production-perceptual) and production semantic classification tasks (production-conceptual) still exhibited significant priming effects under retrieval interference, but the magnitude of priming was also significantly reduced compared to the no-interference condition. These findings indicate that different types of implicit memory are all affected by retrieval interference, with identification priming being more vulnerable to disruption by retrieval interference than production priming.

Keywords: implicit memory; retrieval interference; identification; production; perceptual priming; conceptual priming
Classification Codes: B842.3; G442

1 Introduction

Implicit memory refers to the phenomenon where, on indirect tests that do not require conscious recollection (such as lexical decision or semantic classification tasks), participants exhibit faster reaction times and higher accuracy for previously studied stimuli compared to novel stimuli, typically measured as priming effects. For nearly three decades, the notion that "unconscious implicit memory involves automatic processing" has dominated the memory field, as priming effects on indirect tests are generally unaffected by "attentional interference" during encoding. Researchers have frequently employed dual-task paradigms, requiring participants to perform an irrelevant distraction task while memorizing study materials, followed by implicit (indirect) or explicit (direct) memory tests. Results consistently show that interference during encoding significantly impairs explicit memory performance (e.g., recall and recognition) but does not diminish priming effects on implicit memory tests (Dew & Cabeza, 2011; Lozito & Mulligan, 2010; Spataro, Cestari, & Rossi-Arnaud, 2011), demonstrating that priming effects are "resistant to interference" from encoding demands.

Encoding represents the initial processing of information that creates memory traces, while retrieval involves the activation of these encoded engrams. However, retrieval is not necessarily a simple replication of encoding (Spaniol et al., 2009). Consequently, whether the "interference resistance" observed for encoding extends to retrieval interference requires further investigation. Meng and Guo (2007, 2009) were among the first to systematically examine the relationship between retrieval interference and implicit memory. Using a learning-test paradigm, participants studied word lists before completing implicit memory tests, while simultaneously performing a target "cross" counting task (the interference task) during either the learning or test phase. The results revealed that although encoding interference did not affect priming in lexical decision tasks, no priming effect was observed under retrieval interference. ERP data further supported these findings, showing that encoding interference did not impact the parieto-occipital N400 old/new effect (an electrophysiological correlate of implicit memory; Lucas, Taylor, Henson, & Paller, 2012), whereas this effect was absent under retrieval interference. These results suggest that while priming effects may be resistant to encoding interference, they are vulnerable to retrieval interference.

However, this finding contradicts traditional perspectives and conflicts with other studies reporting that retrieval interference does not affect implicit memory (Clarke & Butler, 2008; Lozito & Mulligan, 2010; Prull, Lawless, Marshall & Sherman, 2016; Sbicigo, Janczura, & Salles, 2017). For instance, Clarke and Butler (2008) used word stem completion as an implicit memory test, requiring participants to simultaneously perform a syllable monitoring interference task during testing, and found no effect of retrieval interference on priming. Similarly, Lozito and Mulligan (2010) employed a comparable paradigm and observed no retrieval interference effects on priming in perceptual identification, word stem completion, or category exemplar generation tasks. Given these discrepancies in experimental designs, Meng and colleagues further manipulated variables that might account for the divergent results, such as presenting interference and memory stimuli in different modalities (similar to Clarke et al. and Lozito et al.; Meng & Yu, 2012) and changing from delayed-response interference (which consumes more attentional resources) to immediate-response interference (as used by Clarke et al., 2008 and Lozito et al., 2010). Nevertheless, retrieval interference effects on priming persisted. Moreover, these effects were observed regardless of whether interference and memory stimuli were presented simultaneously or sequentially (Lin, Meng, & Lin, 2017). These findings indicate that implicit memory—at least priming in lexical decision tasks—does not exhibit "interference resistance" to retrieval demands.

Although Meng and colleagues' follow-up studies consistently demonstrated retrieval interference effects on implicit memory despite controlling for methodological variations, their research exclusively employed lexical decision tasks, which differ from the implicit tests used in other studies. Implicit memory can be categorized based on test characteristics (Gabrieli et al., 1999; Spataro et al., 2017). First, according to task format, priming can be divided into identification and production forms. Identification tests require participants to identify or judge attributes of presented stimuli, with only one correct response possible. In contrast, production tests provide only target cues that may activate multiple solutions, requiring participants to select and generate one answer. Second, based on the cognitive processes involved, priming can be classified as perceptual or conceptual. Perceptual priming relies primarily on analyzing surface or perceptual features of stimuli, reflecting facilitated perceptual processing, whereas conceptual priming depends on analyzing stimulus meaning, reflecting facilitated conceptual processing. Research has shown that different types of priming rely on distinct neural systems (Leynes, Bruett, Krizan, & Velosa, 2017; Marques, Spataro, Cestari, Sciarretta, & Rossi-Arnaud, 2016). Importantly, encoding interference produces dissociable effects on different types of indirect tests: it affects priming in production tests but not identification tests (LaVoie & Faulkner, 2008), and reduces conceptual priming but not perceptual priming (Mulligan & Lozito, 2006; Newell, Cavenett, & Andrews, 2008). This raises the question: Does retrieval interference similarly affect implicit memory differently depending on test type?

Specifically, the lexical decision task used in Meng and colleagues' experiments is an identification test that is influenced by perceptual similarity between study and test phases (Prull et al., 2016), thus primarily measuring perceptual priming. In contrast, other studies have employed perceptual identification, word stem completion, and category exemplar generation tasks. Word stem completion and category exemplar generation are production tests. Although perceptual identification is considered an identification test, its extremely brief stimulus presentation may lead participants to perceive only partial information, which could activate multiple solutions, leading many researchers to view it as having production test characteristics (Spataro et al., 2017). This raises the question: Is the retrieval interference effect on implicit memory limited to identification-perceptual tests like lexical decision?

To more comprehensively understand the relationship between retrieval interference and implicit memory, the present study built upon Meng and Guo (2007, 2009) by employing different types of implicit memory tests to examine whether retrieval interference effects vary by test type. Given that the two classification dimensions of implicit memory tests intersect (Gabrieli et al., 1999; Prull & Spataro, 2017), four types of indirect tests can be identified: identification-perceptual, identification-conceptual, production-perceptual, and production-conceptual. Therefore, this study conducted four experiments, each implementing one of these four test types, to systematically investigate the effects of retrieval interference on implicit memory.

Experiment 1: Identification-Perceptual Test

2.1 Research Purpose

As noted, lexical decision tasks are influenced by perceptual similarity between study and test phases (Prull et al., 2016) and represent the prototypical identification-perceptual implicit test. Therefore, Experiment 1 employed a lexical decision task to further verify the effect of retrieval interference on identification-perceptual priming. Similar to previous research (Lin et al., 2017), Experiment 1 manipulated encoding depth, as implicit memory tests are generally considered less susceptible to encoding level effects, and including this manipulation provides additional evidence for test validity (Alipour, Aerab-Sheybani, & Akhondy, 2012). Unlike Lin et al. (2017), however, Experiment 1 used structural consistency judgment as the shallow encoding task, requiring perceptual processing of orthographic or word form features, which serves as a more effective perceptual processing manipulation (Wang, Wang, Qin, & Zhang, 2018).

2.2 Method

Participants Thirty-two university students (11 male) voluntarily participated, with a mean age of 24.41 ± 1.25 years. All were right-handed, had normal or corrected-to-normal vision, were physically and mentally healthy, and had no prior experience with similar experiments. Participants received compensation upon completion. Four participants detected the relationship between study and test phases and adopted conscious retrieval strategies (Prull et al., 2016); their data were excluded, leaving 28 valid participants.

Based on the effect size (f = 0.45) for the main effect of the interference variable from Meng and Guo (2007), a priori power analysis using G*Power with power set at 95% and alpha at 0.05 indicated a required sample size of 10 participants (Anderson, Kelley, & Maxwell, 2017). Thus, Experiment 1 had sufficient statistical power. The same criterion was applied to determine sample sizes for the subsequent three experiments.

Materials **Memory materials:** Two hundred forty low-frequency two-character Chinese words were selected from the *Modern Chinese Frequency Dictionary* (1986 edition), with frequencies ranging from 2.3 to 12.2 per million (M = 3.654 per million). All words were emotionally neutral. The words were randomly divided into eight groups (30 words per group). Within each group, half were structurally consistent (e.g., both characters had the same structure) and half were inconsistent. There were no significant differences across groups in stroke count or word frequency [$F(7, 232) = 0.81$, $p = 0.58$; $F(7, 232) = 0.63$, $p = 0.73$]. Four groups were used for the no-interference condition and four for the retrieval-interference condition. Within each condition, two groups were presented during encoding (one for perceptual processing, one for conceptual processing), and the remaining two groups served as new words during the test phase (for perceptual and conceptual encoding conditions). Additionally, 60 pseudowords were created by randomly combining the constituent characters of the low-frequency words, ensuring no phonological or semantic overlap, and divided into two groups for the test phase in each experimental condition. Two filler words were added at the beginning and end of each encoding phase and were not included in the analysis.

Interference materials: Integers from 1 to 8.

Procedure The experiment was programmed using Presentation 0.71 software. All stimuli were presented at the center of the computer screen, with participants seated 80 cm away. Participants completed individual testing sessions in a soundproof laboratory. After practice trials ensuring familiarization, participants proceeded to the formal experiment, which consisted of no-interference and retrieval-interference conditions separated by a 5-minute break, with condition order counterbalanced across participants.

The no-interference condition comprised five phases: (1) **Encoding phase:** Participants performed perceptual or conceptual processing on randomly presented two-character words. Perceptual processing required structural consistency judgments (press F for consistent, J for inconsistent), while conceptual processing required subjective pleasantness judgments (press F for pleasant, J for unpleasant). Each processing condition included 30 words, presented for 500 ms each with an interstimulus interval (ISI) of 1600 ± 200 ms. Processing conditions were counterbalanced across participants. (2) **Distractor task:** A three-digit number was presented centrally, and participants performed backward subtraction by 7 for 1 minute, verbally reporting the final answer. (3) **Standalone interference task:** Fifteen integers (1–8) were randomly presented centrally, and participants made odd/even judgments (press J for odd, L for even). Each number was presented for 800 ms with an ISI of 1400–1800 ms. (4) **Test phase:** Sixty old words (30 from each encoding depth) were mixed with 60 new words and 30 pseudowords and presented randomly. Participants performed a lexical decision task, judging whether each stimulus was a real word (press S) or pseudoword (press F) (see Figure 1 [Figure 1: see original paper]A). Each word was presented for 800 ms with an ISI of 1600 ± 200 ms. (5) **Standalone interference task:** Identical to phase 3.

The retrieval-interference condition differed only in phase 4. During the test phase, numbers and two-character words were presented simultaneously (2 cm apart) at the center of the screen (see Figure 1B). Participants used their left hand to press S/F for the lexical decision task and their right hand to press J/L for the odd/even judgment on numbers. Participants were instructed that both tasks were equally important and should respond as quickly and accurately as possible to both stimuli. All two-character words (in bold) and interference numbers (in Times New Roman) were presented in white 60-point font on a black background.

After the experiment, participants completed an awareness questionnaire (Prull et al., 2016) to exclude those who adopted conscious retrieval strategies, ensuring the relative purity and validity of the implicit test.

2.3 Results

Descriptive statistics for all measures in the lexical decision task are presented in Table 1 .

First, one-way repeated-measures ANOVAs on word type (perceptual-encoding old vs. conceptual-encoding old vs. new) were conducted on reaction times and arcsine-transformed accuracy scores (ACs) in the no-interference condition to confirm the presence of priming effects. Because average accuracy rates on the implicit tests were high (>0.7), arcsine square-root transformations were applied to non-normal accuracy data (ACs = DEGREES(ASIN(SQRT(AC)))) to ensure more stable ANOVA results (Winer, Brown, & Michels, 1971). Priming magnitude was calculated as the mean difference between old and new words in reaction time/ACs. The same procedure was used in Experiments 2–4.

For reaction times, the main effect of word type was significant [$F(2, 54) = 20.43$, $p < 0.001$, $p^2 = 0.43$], with both types of old words responded to significantly faster than new words ($ps < 0.001$), but no significant difference between the two old-word types ($p = 0.99$). For ACs, the main effect of word type was also significant [$F(2, 54) = 28.64$, $p < 0.001$, $p^2 = 0.52$], with both old-word types showing significantly higher ACs than new words ($ps < 0.001$) and no difference between old-word types ($p = 0.99$). Thus, significant priming effects were observed in both reaction times and ACs, with no processing-level differences.

The same analyses were conducted for the interference condition. Results showed no significant main effect of word type for reaction times [$F(2, 54) = 0.96$, $p = 0.34$] or ACs [$F(2, 54) = 1.13$, $p = 0.33$]. Therefore, no significant priming effects were found in the lexical decision task under retrieval interference.

Experiment 1 demonstrated that priming effects in lexical decision tasks disappeared under retrieval interference, replicating previous findings (Meng & Guo, 2007, 2009; Meng & Yu, 2012; Lin et al., 2017). As lexical decision tasks require rapid, non-generative responses and represent a prototypical identification implicit memory test, these results confirm that retrieval interference disrupts identification-perceptual priming.

Experiment 2: Identification-Conceptual Test

3.1 Research Purpose

Although previous research suggests retrieval interference does not impair conceptual implicit memory, the conceptual tests used were primarily production-based category exemplar generation tasks (Clarke & Butler, 2008; Prull et al., 2016). Would similar retrieval interference effects occur for identification-conceptual tests like semantic classification? Experiment 2 addressed this question using a semantic classification task. This task requires participants to classify two-character words as biological or non-biological, sharing the same response format as lexical decision tasks (identification) and has been widely used to assess conceptual priming (Spataro, Mulligan, & Rossi-Arnaud, 2013), enabling direct comparison of retrieval interference effects on perceptual versus conceptual priming.

3.2 Method

Participants Thirty university students (10 male) participated voluntarily (Mage = 24.35 ± 1.06 years). All met the same criteria as Experiment 1. Four participants who detected the study-test relationship and adopted conscious retrieval strategies were excluded, leaving 26 valid participants.

Materials **Memory materials:** One hundred eighty low-frequency two-character words from the same source as Experiment 1 were randomly divided into six groups (30 words per group). There were no significant differences across groups in stroke count or word frequency [$F(5, 174) = 1.50$, $p = 0.19$; $F(5, 174) = 1.97$, $p = 0.09$]. Half of the words in each group were animate and half inanimate. Words were randomly assigned to two experimental conditions: no-interference and retrieval-interference (three groups per condition). Within each condition, two groups were used for encoding (perceptual or conceptual processing) and one group served as new words during the test phase, mixed randomly with old words. Two filler words were added at the beginning and end of each encoding phase.

Interference materials: Identical to Experiment 1.

Procedure The procedure was identical to Experiment 1 except for the implicit memory test in phase 4. During the test phase, 60 old words (30 from each encoding depth) were mixed with 30 new words and presented randomly. Participants performed a semantic classification task, judging whether each word was animate (press S) or inanimate (press F). In the retrieval-interference condition, two-character words and interference numbers were presented simultaneously, requiring dual-task performance (see Figure 2 [Figure 2: see original paper]). Condition order was counterbalanced across participants.

3.3 Results

Descriptive statistics for the semantic classification task are presented in Table 2 and Table 3 .

First, one-way repeated-measures ANOVAs on word type were conducted for reaction times and ACs in the no-interference condition. For reaction times, the main effect of word type was significant [$F(2, 50) = 15.72$, $p < 0.001$, $p^2 = 0.39$], with both old-word types responded to significantly faster than new words ($p1 = 0.003$; $p2 < 0.001$), but no difference between old-word types ($p = 0.10$). For ACs, the main effect was significant [$F(2, 50) = 4.89$, $p = 0.011$, $p^2 = 0.16$], with perceptual-encoding old words showing significantly higher ACs than new words ($p = 0.002$), but no significant differences between conceptual-encoding old words and other conditions ($p = 0.52$), or between old-word types ($p = 0.44$). Thus, significant priming was observed in reaction times for both encoding conditions, but in ACs only for perceptual-encoding old words.

Second, identical analyses were conducted for the interference condition. For reaction times, the main effect of word type was significant [$F(2, 50) = 5.04$, $p = 0.01$, $p^2 = 0.17$], but both old-word types showed significantly *slower* responses than new words ($p1 = 0.033$; $p2 = 0.031$), demonstrating a negative priming effect. No difference existed between old-word types ($p = 0.99$). For ACs, the main effect was not significant [$F(2, 50) = 0.79$, $p = 0.46$]. Therefore, no significant priming effects were found in the semantic classification task under retrieval interference.

Experiment 2 demonstrated that retrieval interference significantly affected priming in semantic classification tasks, manifesting as negative priming. Thus, unlike previous findings using category exemplar generation tasks (Clarke & Butler, 2008; Prull et al., 2016), identification-conceptual priming is vulnerable to retrieval interference.

Experiment 3: Production-Perceptual Test

4.1 Research Purpose

Production-perceptual implicit tests have typically used word stem completion tasks (Clarke & Butler, 2008; Lozito & Mulligan, 2010), which rely on analyzing incomplete or ambiguous perceptual features from word stems to select the first word that comes to mind. However, a limitation of this task is that different stems may activate varying numbers of solutions, and the number of possible solutions correlates positively with attentional demands (Marques et al., 2016). This response competition may confound the source of observed differences. To avoid response competition while maintaining comparability with Experiment 1' s lexical decision task, Experiment 3 combined features of word stem completion and lexical decision to create a production lexical decision task. This task presented the first character of a two-character word as a stem, followed simultaneously by two characters that could combine with the stem to form either a real word or a pseudoword. Participants judged which character formed a real word with the stem. Priming would be evidenced by faster and more accurate judgments for studied versus unstudied words. The task required lexical decisions while maintaining the generative nature of stem completion, but the constrained response options eliminated response competition. Thus, it differed from lexical decision primarily in the identification versus production distinction.

4.2 Method

Participants Thirty university students (11 male) participated voluntarily (Mage = 24.11 ± 1.95 years). All met the same criteria as previous experiments. Three participants who detected the study-test relationship and adopted conscious retrieval strategies were excluded, leaving 27 valid participants.

Materials **Memory materials:** Two hundred forty low-frequency two-character Chinese words were selected as in Experiment 1 and randomly divided into eight groups. There were no significant differences across groups in stroke count, word frequency, first-character stroke count, or first-character frequency [$F(7, 232) = 1.90$, $p = 0.08$; $F(7, 232) = 1.79$, $p = 0.10$; $F(7, 232) = 1.73$, $p = 0.11$; $F(7, 232) = 1.78$, $p = 0.10$]. Half were assigned to the no-interference condition and half to the retrieval-interference condition. Within each condition, two groups were used for encoding (one for perceptual, one for conceptual processing) and two groups served as new words during testing. Two hundred forty pseudowords were created using the same method as Experiment 1, ensuring they shared the same first character as the real words to serve as alternative options during the production lexical decision task.

Procedure The procedure was identical to Experiment 1 except for the test phase. Experiment 3 used a production lexical decision task where a word stem was presented simultaneously with two options in parentheses. One option formed a real word with the stem. Participants judged whether the left or right option formed a real word (press S for left, F for right), with correct options appearing equally often on each side. Among correct options, half were old words from encoding (30 per depth) and half were 60 new words. In the retrieval-interference condition, participants performed the lexical judgment while simultaneously making odd/even judgments on numbers (see Figure 3 [Figure 3: see original paper]). Condition order was counterbalanced across participants.

4.3 Results

Descriptive statistics for the production lexical decision task are presented in Table 4 .

First, one-way repeated-measures ANOVAs on word type were conducted for reaction times and ACs in the no-interference condition. For reaction times, the main effect was significant [$F(2, 52) = 54.62$, $p < 0.001$, $p^2 = 0.68$], with both old-word types responded to significantly faster than new words ($ps < 0.001$), but no difference between old-word types ($p = 0.92$). For ACs, the main effect was significant [$F(2, 52) = 20.95$, $p < 0.001$, $p^2 = 0.45$], with both old-word types showing significantly higher ACs than new words ($ps < 0.001$) and no difference between old-word types ($p = 0.99$). Thus, significant priming effects were observed in both measures, with no processing-level differences.

Second, identical analyses were conducted for the interference condition. For reaction times, the main effect was significant [$F(2, 52) = 4.65$, $p = 0.014$, $p^2 = 0.15$], with both old-word types responded to significantly faster than new words ($p1 = 0.006$, $p2 = 0.036$), but no difference between old-word types ($p = 0.99$). For ACs, the main effect was significant [$F(2, 52) = 8.92$, $p < 0.001$, $p^2 = 0.26$], with both old-word types showing significantly higher ACs than new words ($p1 = 0.018$, $p2 < 0.001$) and no difference between old-word types ($p = 0.54$). Thus, significant priming effects persisted under retrieval interference, without processing-level differences.

Because priming was observed in both interference conditions, we conducted 2 (interference: present vs. absent) × 2 (processing level) repeated-measures ANOVAs on priming magnitude (reaction time difference and ACs difference) to determine whether interference affected priming. For reaction times, only the main effect of interference was significant [$F(1, 26) = 25.11$, $p < 0.001$, $p^2 = 0.49$], with greater priming in the no-interference condition (M = 47.74, 95% CI = 26.03-69.45) than in the interference condition (M = 102.26, 95% CI = 78.57-125.95). Neither the processing-level main effect [$F(1, 26) = 0.001$, $p = 0.99$] nor the interaction [$F(1, 26) = 0.59$, $p = 0.45$] was significant. For ACs, the main effect of interference approached significance [$F(1, 26) = 3.19$, $p = 0.086$, $p^2 = 0.11$], with priming magnitude tending to be larger in the no-interference condition (M = 8.75, 95% CI = 6.55-10.96) than in the interference condition (M = 5.83, 95% CI = 3.37-8.29). Neither the processing-level main effect nor the interaction was significant [$F(1, 26) = 1.39$, $p = 0.25$; $F(1, 26) = 0.81$, $p = 0.38$]. Thus, priming magnitude was significantly reduced under retrieval interference compared to the no-interference condition.

Experiment 3 revealed that significant priming effects persisted in the production lexical decision task under retrieval interference. However, direct comparison of priming magnitude across conditions showed that the priming effect was reduced under interference, indicating that retrieval interference still impacted production-perceptual implicit memory, albeit to a lesser degree.

Experiment 4: Production-Conceptual Test

5.1 Research Purpose

Category exemplar generation is a commonly used production-conceptual priming test (Lozito & Mulligan, 2010; Prull et al., 2016). This task presents category cues and requires participants to generate multiple exemplars, responding with the first one that comes to mind. However, it typically uses verbal or paper-and-pencil formats, resulting in longer response times that prevent direct comparison with the previous experiments. Additionally, as noted, the multiple solutions activated by production cues create response competition that may confound results. Drawing from Experiment 3' s approach and to enable comparison with Experiment 2' s semantic classification task, we developed a production semantic classification task combining category exemplar generation and semantic classification. This task presents a category cue simultaneously with two options, one of which belongs to the indicated category. Participants judge which option belongs to the category. Priming is evidenced by faster and more accurate judgments for studied versus unstudied category words. The task requires categorical judgments similar to semantic classification while maintaining the generative nature of category exemplar production. Thus, like Experiment 2, it assesses implicit conceptual processing, but differs primarily in the identification versus production distinction, allowing examination of whether retrieval interference affects production-conceptual implicit memory.

5.2 Method

Participants Thirty university students (11 male) participated voluntarily (Mage = 24.96 ± 1.14 years). All met the same criteria as previous experiments. Five participants who detected the study-test relationship and adopted conscious retrieval strategies were excluded, leaving 25 valid participants.

Materials Memory materials: Four hundred eighty low-frequency two-character words were selected. Two hundred forty words were drawn from eight target categories (e.g., weapons, buildings, balls, paintings, occupations, clothing, animals, flowers) with 30 words per category. These were randomly mixed and divided into eight groups with no significant differences in stroke count or word frequency [$F(7, 232) = 0.59$, $p = 0.77$; $F(7, 232) = 1.33$, $p = 0.24$], then randomly assigned to no-interference and retrieval-interference conditions. The remaining 240 words were drawn from eight additional categories (e.g., plants, scenery, fruits, daily necessities, food, jewelry, shoes, cities) and used only during the test phase to create incongruent category pairs (e.g., fruit: turtle, strawberry).

Procedure The procedure was identical to Experiment 2 except for the test phase. Experiment 4 used a production semantic classification task where a category cue and two options were presented simultaneously. One option belonged to the category and appeared equally often on the left or right. Participants selected the category member (press S for left, F for right). Among correct options, half were old words from encoding (60 total, 30 per depth) and half were 60 new category words not presented during encoding, each paired with a non-category word. All stimuli were presented randomly. In the retrieval-interference condition, category-word pairs and interference numbers were presented simultaneously, requiring dual-task performance (see Figure 4 [Figure 4: see original paper]). Condition order was counterbalanced across participants.

5.3 Results

Descriptive statistics for the production semantic classification task are presented in Table 4 .

First, one-way repeated-measures ANOVAs on word type were conducted for reaction times and ACs in the no-interference condition. For reaction times, the main effect was significant [$F(2, 48) = 24.15$, $p < 0.001$, $p^2 = 0.50$], with both old-word types responded to significantly faster than new words ($ps < 0.001$) and no difference between old-word types ($p = 0.42$). For ACs, the main effect was significant [$F(2, 48) = 40.16$, $p < 0.001$, $p^2 = 0.63$], with both old-word types showing significantly higher ACs than new words ($ps < 0.001$) and no difference between old-word types ($p = 0.45$). Thus, significant priming effects were observed in both measures, with no processing-level differences.

Second, identical analyses were conducted for the interference condition. For reaction times, the main effect was significant [$F(2, 48) = 7.34$, $p = 0.002$, $p^2 = 0.24$], with both old-word types responded to significantly faster than new words ($p1 = 0.007$; $p2 < 0.001$) and no difference between old-word types ($p = 0.99$). For ACs, the main effect was significant [$F(2, 48) = 9.23$, $p < 0.001$, $p^2 = 0.28$], with both old-word types showing significantly higher ACs than new words ($p1 < 0.001$; $p2 = 0.004$) and no difference between old-word types ($p = 0.99$). Thus, significant priming effects persisted under retrieval interference, without processing-level differences.

As in Experiment 3, we conducted 2 (interference) × 2 (processing level) repeated-measures ANOVAs on priming magnitude. For reaction times, no significant effects were found: interference [$F(1, 24) = 0.20$, $p = 0.66$], processing level [$F(1, 24) = 1.52$, $p = 0.23$], or interaction [$F(1, 24) = 0.02$, $p = 0.96$]. For ACs, the main effect of interference was significant [$F(1, 24) = 5.65$, $p = 0.02$, $p^2 = 0.19$], with greater priming in the no-interference condition ($M = 9.83$, 95% CI = 8.00-11.67) than in the interference condition ($M = 6.78$, 95% CI = 4.33-9.21). No significant interaction was found [$F(1, 24) = 1.10$, $p = 0.31$; $F(1, 24) = 0.37$, $p = 0.55$]. Thus, priming magnitude in ACs was significantly reduced under retrieval interference compared to the no-interference condition.

Experiment 4 revealed that significant priming effects persisted in the production semantic classification task under retrieval interference. However, further comparison of priming magnitude showed that although reaction time priming did not differ significantly between conditions, AC priming was significantly reduced under interference. Thus, retrieval interference also affected production-conceptual implicit memory, though the impact was smaller than that observed in Experiment 2' s identification semantic classification task.

6 General Discussion

The present study systematically investigated whether retrieval interference affects implicit memory by crossing two classic classification dimensions (identification/production and perceptual/conceptual) to create four types of implicit memory tests, using a dual-task paradigm during the test phase. The results showed that for identification tests—both perceptual (Experiment 1' s lexical decision task) and conceptual (Experiment 2' s semantic classification task)—priming effects were eliminated under retrieval interference, with negative priming even observed in the conceptual test. In contrast, for production tests—both perceptual (Experiment 3' s production lexical decision task) and conceptual (Experiment 4' s production semantic classification task)—significant priming effects persisted under retrieval interference, though their magnitude was reduced compared to no-interference conditions. These findings indicate that retrieval interference affects priming across all types of implicit memory tests, but the impact differs by test type, with identification priming being more vulnerable to disruption than production priming.

The traditional view that "unconscious implicit memory involves automatic processing" derives primarily from findings that implicit memory is unaffected by encoding interference (Dew & Cabeza, 2011; Spataro et al., 2011). However, retrieval involves activating encoded memory traces and is not merely a replication of encoding (Spaniol et al., 2009). Therefore, whether implicit memory also shows "interference resistance" to retrieval demands requires further investigation. As noted in the introduction, previous research has yielded inconsistent conclusions, possibly due to differences in the implicit memory tests employed. Studies finding retrieval interference effects used lexical decision tasks (identification-perceptual tests), while studies finding no effects primarily used production tests (e.g., word stem completion, category exemplar generation). The present study found retrieval interference effects across all four test types, suggesting the phenomenon is general rather than limited to identification-perceptual tests. This challenges classical automation theory, which posits that automatic processes are purely unconscious, independent of limited attentional resources, and immune to interference (Moors & De Houwer, 2006; Kiefer, 2012; Kiefer & Martens, 2010). Our results imply that implicit memory retrieval is not fully automatic but is modulated by attentional resources.

This conclusion is supported by other research showing that top-down cognitive control mechanisms—including attentional resources, stimulus expectancy, and task goals—modulate masked semantic priming, demonstrating attentional sensitivity in unconscious information processing (Martens & Kiefer, 2009; Kiefer & Martens, 2010; Adams & Kiefer, 2012). Recent studies modifying Meng and Guo' s (2007, 2009) simultaneous dual-task procedure to sequential presentation found that priming was affected regardless of whether interference preceded or followed memory items (Lin et al., 2017). Critically, when the interval between interference and memory items was extended or some interference trials required NO-GO responses (reducing attentional competition), retrieval interference effects were substantially reduced or eliminated (Lin, Meng, & Lin, in press). This suggests that implicit memory retrieval is not entirely independent of secondary tasks but is regulated by attentional resources allocated to those tasks, producing retrieval interference effects.

Why, then, have some studies failed to find retrieval interference effects (e.g., Clarke & Butler, 2008; Lozito & Mulligan, 2010; Prull et al., 2016)? Our results may explain these discrepancies. As noted, studies finding no effects primarily used production tests (word stem completion, category exemplar generation). We also found that retrieval interference did not eliminate priming in production tests (Experiments 3 and 4), which might suggest that retrieval interference does not affect implicit memory. However, our more sensitive analyses revealed that priming magnitude was significantly reduced under interference in both production tests. This may be attributable to differences between our production tasks and traditional ones.

Traditional production tests typically present cues for relatively long durations (2.5–5 s), which may allow contamination by explicit memory components (Sheldon & Moscovitch, 2010; Miyoshi & Ashida, 2014). Such contamination could produce different results. For example, Prull et al. (2016) found no retrieval interference effect in category exemplar generation when analyzing all participants, but after excluding those who reported awareness of the study-test relationship and used conscious retrieval strategies, retrieval interference significantly reduced priming. To avoid these issues and enhance comparability with identification tests, Experiment 3 combined word stem completion with lexical decision to create a production lexical decision task. This task requires lexical judgments while maintaining the generative nature of stem completion, but constrained options eliminate response competition. The primary difference from lexical decision lies in the identification/production distinction. Similarly, Experiment 4 combined category exemplar generation with semantic classification to create a production semantic classification task that shares judgment requirements with semantic classification while maintaining generative processing. Research suggests that lexical decision tasks, requiring rapid non-generative responses, minimize the likelihood of explicit retrieval strategies, as such strategies would not facilitate fast word/nonword decisions even if participants recognize many studied words (Newell et al., 2008; Spataro et al., 2017). Our four experiments used consistent response formats that should similarly minimize explicit retrieval contamination, allowing more effective detection of retrieval interference effects on priming.

Although retrieval interference affected all four tests, performance under interference differed substantially. Experiments 1 and 2 used identification tasks, where priming was completely eliminated under interference. Experiments 3 and 4 used production tasks, where priming was reduced but still significant. Thus, while retrieval interference broadly affects implicit memory, its impact varies by test type, being more pronounced for identification than production tests.

Research indicates that dual-task execution activates prefrontal cortex, and even simple or automatic tasks require activation of specialized cortical regions associated with dual-task coordination (D' Esposito et al., 1995; Just, Keller, & Cynkar, 2008). Dual-task and single-task conditions differ in activation levels of frontal regions; enhanced activation in single-task regions during dual-task performance can provide additional resources, facilitating task coordination, reducing conflict, and thereby decreasing interference (Just et al., 2008; Tan et al., 2013; Tombu et al., 2011). Studies comparing patients with frontal brain damage to healthy controls show greater prefrontal activation in the patient group during dual-task performance, suggesting that additional prefrontal recruitment facilitates successful dual-task operation (Rasmussen et al., 2008). We propose that compared to identification tasks (which show posterior cortical hemodynamic decreases), production implicit tests typically require prefrontal involvement (Gabrieli et al., 1999; Geraci, 2006). Simultaneously performing a relatively simple interference task (odd/even judgment) during these production tests may produce enhanced prefrontal activation that reduces interference-related disruption. Consequently, production priming was not completely abolished under retrieval interference, unlike identification priming.

In summary, different types of implicit memory are all vulnerable to retrieval interference, indicating that implicit memory retrieval is not fully automatic but is modulated by attentional resources. However, this modulation varies by test type, with retrieval interference affecting identification tests more strongly than production tests.

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Note: Figure translations are in progress. See original paper for figures.