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Semantic-to-autobiographical memory priming causes involuntary autobiographical memory production: The effects of single and multiple prime presentations

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Abstract
A number of studies (Mace et al., *Memory & Cognition, 47,* 299–312, 2019; Mace & Unlu, *Memory & Cognition*, *48*, 931–941, 2020) have demonstrated that the activation of semantic memories leads to the activation of autobiographical memories on an involuntary memory task (the vigilance task; Schlagman & Kvavilashvili, *Memory & Cognition, 36*, 920–932, 2008), suggesting that this form of priming (semantic-to-autobiographical) plays a role in the production of involuntary autobiographical memories in everyday life. In the current study, we investigated the effects of prime repetition on involuntary memory production in the vigilance task. Primed participants were either treated to one priming session, where they judged the familiarity of words (e.g., *parade*), or three priming sessions, where they also judged the familiarity of words as well as decided whether sentences containing the words made sense (e.g., the *parade* dragged on for hours), and if their corresponding images were sensible (e.g., an image of a parade). The results showed that primed participants produced more involuntary memories with primed content on the vigilance task than control participants, and three-session primed participants produced more memories than one-session primed participants. Similar to other areas where prime repetition has been investigated (e.g., implicit memory, semantic priming), the results show that prime repetition enhances semantic-to-autobiographical memory priming. The results also further support the idea that semantic-to-autobiographical memory priming may play a significant role in the production of involuntary memories in everyday life, as concept repetition is a likely part of everyday experience. These implications, as well as others, are discussed.

Keywords Semantic-to-autobiographical priming · Involuntary memory priming · Prime repetition · Involuntary autobiographical memory · Autobiographical memory

Throughout the course of a day, one processes massive amounts of information from many different sources (e.g., reading a newspaper or a book, watching television, engaging in conversation). Conway has argued that such routine, general information processing continuously activates memories in the autobiographical memory system, which, while remaining in the background for the most part, occasionally become conscious when they link up with goals of the self (e.g., Conway, 2001, 2005). Mace and colleagues have further argued that this source of priming (deemed semantic-to-autobiographical memory priming) may be a significant source of everyday involuntary memory production, as well as in some instances of voluntary memory production (e.g., Mace, 2010; Mace et al., 2019; Mace & Unlu, 2020; see reviews on involuntary memory in Berntsen, 2009; Mace, 2007). Thus, according to this view, repeated activation (or priming) of memories in the autobiographical memory system increases the likelihood that they will surface as involuntary memories when one has contact with cues that index the primed memories in some way.

To illustrate the simplest form of this process, imagine that one processes the concept *dog* (e.g., reads about, sees one in a movie or in a television commercial). This processing event will activate a pool of related autobiographical memories, consisting of both general autobiographical

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memories (e.g., I had a dog when I was little; my sister has dogs; experientially based images of dogs, e.g., my dog), as well as specific autobiographical memories (i.e., episodic memories, e.g., taking my dog for a walk; playing with my sisters dogs). Given that such autobiographical knowledge is likely to remain activated for a significant period of time (days to perhaps weeks, e.g., Mace, 2005; Mace & Hidalgo, 2022; Mace & Petersen, 2020), such activations have the potential of entering consciousness as involuntary memories when cues cause further activation in the system. For example, if one hears a dog bark or sees someone walking or playing with a dog, these cues could induce the spontaneous retrieval of any of the associated autobiographical memories (e.g., I had a dog when I was little; playing with my sister's dogs).

Evidence for semantic-to-autobiographical memory activations dates back a couple of decades (Conway, 1990), but more recent works have focused on how such activations may influence involuntary and voluntary autobiographical memory production (Mace & Hidalgo, 2022; Mace et al., 2019; Mace & Unlu, 2020). In the first study of this recent series, participants in Mace et al. (2019) rated words for the familiarity of their meanings (e.g., *music*, *summer*, *quip*) and then recalled autobiographical memories in response to unrelated word cues (e.g., *flower*). The results showed that primed participants produced significantly more autobiographical memories involving the content of primes (e.g., a memory about music) than unprimed participants, suggesting that prior semantic access had primed related autobiographical memories, thereby causing their subsequent voluntary production on the memory task.[1] Similar priming was also observed on a measure of involuntary memory in that report. In Experiment 2, participants also rated words for the familiarity of their meanings, and the effects of priming on involuntary memory production were subsequently assessed with the vigilance task (e.g., Schlagman & Kvavilashvili, 2008). The vigilance task elicits involuntary memories by presenting participants with slides containing horizontal or vertical lines with embedded verbal cues (e.g., *relaxing on the beach*), in which, in addition to performing a menial perceptual task (i.e., to monitor and indicate when the slides contain vertical lines), they are to report the occurrence of spontaneous memories and thoughts (see examples in Barzykowski & Niedzwienska, 2018; Schlagman & Kvavilashvili, 2008; Vannucci et al., 2015). The results of this experiment also showed that participants who had received the prior semantic priming task were more likely than controls to report involuntary autobiographical memories with content that overlapped with primes, supporting the idea that generic priming of this sort can influence everyday involuntary memory production.

In the second study in this series, Mace and Unlu (2020) followed up on the involuntary memory findings by expanding the type of priming stimuli. In that report, they presented participants with sentence primes (decide if sentences make sense, Experiment 1), picture primes (decide if pictures have sensible meanings, Experiment 2), or word primes (decide if words have sensible meanings, Experiments 1–2, similar to Mace et al., 2019). As in Mace et al. (2019), the word priming tasks led to significant priming on the vigilance task relative to controls, and additionally, the results also showed that both sentences and pictures had primed involuntary memory production on the vigilance task. Mace and Unlu (2020) argued that the results further supported the notion that generic priming is involved in the production of involuntary memories in everyday life by showing that multiple stimuli are involved, consistent with Conway's (2005) general claim.

One remarkable aspect of Mace et al. (2019) and Mace and Unlu (2020) is the observation that semantic-to-autobiographical memory priming may help explain why we experience involuntary memories. That is, while other factors (e.g., cue characteristics, e.g., Berntsen et al., 2013) and priming processes (i.e., reminiscence priming, e.g., Barzykowski & Niedzwienska, 2018; Mace, 2005; preoccupations and current concerns priming, e.g., Ball, 2015; Johannessen & Berntsen, 2010; Mace, 2005) may be at work in the production of involuntary memories in everyday life, we believe that semantic-to-autobiographical memory priming is likely to have the largest and most invariable influence, as such processes are continuous, rather than variable, as in the case of reminiscence priming (e.g., Barzykowski & Niedzwienska, 2018; Mace, 2005), for instance. The magnitude of this influence might increase with increasing encounters with the same or conceptually similar stimuli. For example, if one is exposed to the concept *dog* repeatedly, each priming encounter may enhance the probability that a personal memory involving dogs may be experienced spontaneously. It seems likely that common concepts would be experienced repeatedly in everyday life in a variety of different contexts (e.g., while reading, in conversation, watching television, and so forth).

In the current study, we were interested in learning whether repeated encounters with conceptual primes increases the likelihood that they will be experienced as involuntary autobiographical memories. While there have been no other studies examining the effects of repetition on priming in autobiographical memory, there have been numerous studies on the effects of stimulus repetition on explicit memory performance (e.g., dating back to Ebbinghaus, 1885/1964), as well as its effects on priming in semantic and implicit memory. In the explicit memory literature,

[1] We discuss priming and voluntary memory production further in the General Discussion.

there is a plethora of studies showing that stimulus repetition enhances performance on recall and recognition memory tasks (e.g., see Baddeley, 1997, for reviews). In the implicit memory literature, the findings are mixed, with many studies showing null effects (e.g., Greene, 1990; Roediger & Challis, 1992), but also many others showing positive effects (e.g., Challis & Sidhu, 1993; Chen & Squire, 1990; Graf & Mandler, 1984; see reviews in Roediger & McDermott, 1993). For example, Chen and Squire (1990) found that four stimulus repetitions produced stronger priming on a word-stem completed than a single presentation, but Parkin et al. (1990) did not on a similar perceptual priming task (word fragment completion). The results of stimulus repetition in semantic priming have been more consistent, with studies typically showing positive effects (see McNamara, 2005). For example, Forbach et al. (1974) found that two stimulus presentations produced more priming than one on a lexical decision task (see further examples of positive findings in McNamara, 2005).

Among the theories used to explain repetition effects, activation accounts (e.g., Anderson & Bower, 1973) have a long history, dating back to the 19th century (e.g., Ebbinghaus, 1885/1964; Ward, 1893). Activation accounts have also been used to explain priming and other memory phenomena, including how stimulus repetition may enhance priming effects (e.g., Anderson, 1983; Anderson et al., 1998; Bower, 1996; Graf & Mandler, 1984; McClelland, 1996; Rogers & McClelland, 2008). Accordingly, based on these accounts, and the empirical literature, we propose that as one processes concepts repeatedly (e.g., reads about a *dog*, listens to a story about one, sees one, hears one bark), that the likelihood that one will have a spontaneous autobiographical memory involving these concepts increases.

To test this hypothesis, we used the vigilance task to assess the effects of semantic-to-autobiographical priming on involuntary memory production (Experiments 1a and 1b). In addition to a baseline control group, we exposed one priming group to a single priming session (a word familiarly task, Mace et al., 2019; Mace & Unlu, 2020), while another priming group was exposed to three separate priming sessions (Experiments 1a and 1b). The priming sessions in this group utilized word, sentence, and picture primes (Mace & Unlu, 2020), respectively, each spaced a few minutes apart from one another. The sentences contained the words from the word-familiarity task (e.g., *lake*, the *lake* is big), whereas the pictures were the corresponding images for the words (e.g., image of a lake). We selected different stimuli (i.e., words, sentences, and pictures) for the priming tasks in the three-session priming group for two reasons. One, to reduce potential semantic satiation (or attenuation) effects that might have occurred if we had presented the same stimuli repeatedly (see Kuhl & Anderson, 2011). Semantic satiation, or stimulus attenuation, has been classically offered as a reason for why some repetition paradigms have been shown to be inferior to others (e.g., massed versus spaced repetition, e.g., Bekerian & Baddeley, 1980; Cuddy & Jacoby, 1982; Hintzman, 1976). Two, most importantly, we reasoned that this approach corresponded better with everyday experience, as it seems that concepts are more likely to be experienced in different contexts rather than in the exact same form. It is also important to note that in Mace and Unlu (2020), word, sentence, and picture primes produced equivalent priming effects and each had similar effects on total memory production. Thus, we reasoned that potential enhancements in the three-session priming group relative to the one-session group, should be a function of multiple concept presentations, and not the different stimuli representing them.

Theoretically, our motivations for this study were of a functional nature. As noted above, we have argued that generic priming may help to explain the experience of involuntary memories in everyday life. Showing that such priming can be influenced by prime frequency may help to further establish some boundaries for its role in everyday memory production. For example, if three priming sessions produce more memory production than one priming session, then one may infer that involuntary memory production following single encounters with primes in everyday life is a low-probability event compared with multiple encounters. Thus, in one scenario (e.g., after a single prime) involuntary memory production might be very unlikely, while in another (e.g., after 10 prime encounters) it may be a near certainty. We further discuss this line of reasoning in the General Discussion.

Experiment 1a

Experiment 1a examined the effects of semantic-to-autobiographical priming following single and multiple priming sessions (as described above and below). In addition, we pioneered a greatly shortened version of the vigilance task that contained just 54 stimuli. We created this shortened version of the task in part because we had concerns about potentially greater fatigue in the multiple priming session group, should they be exposed to the typical length of the vigilance task (typically containing approximately 500 stimuli), and we also wanted to show that shorter versions of the task could be used as design variations (e.g., see other design variations in Mazzoni, 2019; Vannucci et al., 2015).

Method

Participants

The participants were 99 undergraduate students from Eastern Illinois University, who participated in exchange for

course credit. Fifty-nine of the participants were females, and 40 were males, with an age range of 18 to 46 years (M = 19.39 years). Participants were randomly assigned to the groups, with equal numbers (33) serving in each group, and similar gender and age compositions.

Design

The experiment contained three independent groups (one-session priming, three-session priming, and control). The one-session group was treated to a single word priming task (word familiarity; Mace, et al., 2019; Mace & Unlu, 2020), as well as the vigilance task. The three-session group was treated to three separate priming tasks (blocked treatments of word familiarity, sentence-meaning sense, and picture-meaning sense, Mace & Unlu, 2020), as well as the vigilance task. The control group was treated to a "sham" filler task in place of the priming session (deciding if letter strings were in alphabetical order), as well as the vigilance task.

Materials

The stimuli used for the word-familiarity task consisted of 64 relatively high (e.g., *music*) and low frequency (e.g., *quip*) words, as well as a few nonwords (see Appendix Table 3), printed and presented in booklet form. The high frequency words (54) had frequency counts in the *Corpus of Contemporary American English* ranging from 4,905 to 526,938 (M = 94,936), while the low-frequency words (7) had a range of 140 to 2952 (M = 909). As in Mace et al. (2019) and Mace and Unlu (2020), we were not interested in manipulating word frequency, nor did we expect semantic-to-autobiographical priming to occur with low-frequency words. The low-frequency words were used merely to legitimize the cover story. Thus, in total there were 54 high-frequency words which were deemed as the target primes. The stimuli used for the sentence meaning task were constructed from the 64 stimuli used in the word priming task list (also printed and presented in booklet form; see Appendix Table 4). Stimuli for the picture-meaning task consisted of 64 color images. The images were either photographs (53), an icon (1), or abstract images (10, i.e., various abstract forms, e.g., fragments of geometrical forms). The abstract images were used in place of the low frequency words and nonwords (Appendix Table 3), and none had any obvious meaning. Each of the photo images was the photographic representation of the high-frequency concept words (e.g., a photo of a car; see Appendix Table 3 for the list of high-frequency words). Most of these clearly represented the concept (e.g., *car*, *mountain*, *beach*), some may have been interpreted in more than one way (e.g., the picture for *home* could also be interpreted as house; for *city* as buildings), while a few were more suggestive of the concept (i.e., *friends*, *summer*, and *internet*, where, *friends* was represented by a group of young people appearing to have fun, *summer* by an image suggestive of summer, *internet* by the Microsoft Explorer icon), and could also be interpreted in more than one way. The images were public domain images extracted from Google Images. They were placed individually in Microsoft PowerPoint slides, all of the same approximate size (roughly 3.5 in. × 6.0 in.), and each in a plain, white background slide. Appearing in the top-left-hand corner of each slide was the slide number, beginning with number 1 and ending with 64. The filler task consisted of 64 nonword, letter strings (e.g., EFG). The strings ranged from 3 to 5 letters, with one-half arranged in alphabetical order (e.g., EFG), one-half not (e.g., BCDZ).

The stimuli for the vigilance task consisted of 54 slides containing either horizontal or vertical lines, each with a unique word phrase (e.g., *growing a garden*) embedded in the center of the slide. Forty-seven of the slides contained horizontal lines, while seven contained vertical lines. All 54 of the slides contained content that directly overlapped with the target primes (50, e.g., *growing a garden, visiting the zoo*, for the primes *garden* and *zoo*), or were related (4, *warm weather, petting a dog*, for the primes *summer* and *pet*; see Appendix Table 5 for the complete list). In our previous studies (e.g., Mace et al., 2019) we used embedded phrases that overlapped with primes, were associated with primes, or were unrelated to primes. All were shown to elicit primed memories, but overlapping and associated phrase cues are more powerful elicitors of primed memories. Thus, we selected overlapping and related cues to maximize the priming effect.

Procedure

All participants in the experiment were tested individually. Participants in the priming groups (one session and three) were first engaged in a priming task (or tasks), and then the vigilance task. Participants in the control group were engaged in the letter-string task, followed by the vigilance task. Each task was presented to participants as a separate study. In the one-session priming group, participants received the word-familiarity task in the priming phase. They were told the study concerned word definitions, and they were instructed to consider the definitional meanings of words, and then rate them using a 0–5 scale, where 0 indicated word definitions were *unknown*, 1 indicated word definitions were *very unfamiliar*, and 5 indicated *high familiarity* with word meanings, indicating their ratings in the booklet next to the words. In the three-session priming group, participants received the word-familiarity task (as above), the sentence-sense task, and the picture sense task in the priming phase. In the sentence-sense task, participants were told that they were being involved

in a study on sentence meanings. They were instructed to read the sentences printed in the booklet and decide if they had a sensible meaning, answering "yes" or "no" by circling one of the two responses printed next to each of the sentences. In the picture sense task, participants were told that they were being involved in a study on image meanings. They were instructed to view each image and decide if they had a sensible meaning, answering "yes" or "no" by circling one of the two responses printed on an answer sheet that was numbered 1–64 with the words "yes" and "no" printed in each numbered space. The pictures were presented on a computer screen via Microsoft PowerPoint. The order of the three tasks was randomized across participants, the items in each task were arranged differently, and there was a 2-minute break separating the tasks. In the control group's filler phase, participants were told the study concerned alphabetical order recognition. They were instructed to view the letter strings printed in the booklet, and decide if they were in alphabetical order, answering "yes" or "no" by circling one of the two responses printed next to each letter string. Each group worked through the priming or filler stimuli at their own pace. In the vigilance task, all participants were told that they were being involved in a study on concentration. They were told they would see slides with either horizontal or vertical lines, and they were to say "yes" out loud whenever the slides contained vertical lines. They were further told that the slides would also contain phrases, but they were to ignore them. To ensure their understanding of the instructions, they then received four practice slides. Three of the practice slides had horizontal lines, one had vertical lines, and none of the phrases used in these slides were related to the primes. Once it was clear that they understood, they were further instructed that it was possible that they may experience task-unrelated spontaneous thoughts or memories (the concept of involuntary memories was explained to them), and if they experienced one or the other, they were to click the mouse and record them in a booklet that contained sheets of lined paper. Once this aspect was understood, the task commenced. On trials where participants clicked the mouse, an instruction screen would pop up, reminding them to record their thoughts or memories in the booklet, and clicking the mouse again when finished to return to the vigilance program. The slides were presented randomly for 1.5 seconds on a computer screen via the SuperLab (Version 4.5) software. Following the vigilance task, all participants were asked to read through their booklet, marking entries as either spontaneous thoughts or memories. They were further instructed on the differences between general (i.e., more abstract autobiographical memories, such as "I went to London in 2005") and specific autobiographical memories (i.e., episodic memories, such as remembering "having a flat tire while driving across the Tower Bridge"), and they were asked to mark their memories as general or specific. Following this session, participants were debriefed, where they had an opportunity to express their thoughts about the study both before and after the research hypothesis was revealed to them.

Table 1 Number of spontaneous thoughts and autobiographical memories (both specific and general) produced on the vigilance task for the control, one-session priming, and three-session priming groups in Experiment 1a

Group	Spontaneous thoughts	Spontaneous memories
Control		
M	0.57	2.49
SD	0.77	1.81
One-session priming		
M	0.50	4.30
SD	0.73	2.44
Three-session priming		
M	0.61	6.64
SD	0.86	3.72

Categorization method

The content of the autobiographical memories for both the control and priming groups was read by two independent judges. The judges read the memories to confirm that they were about the content indicated in the cues (e.g., for the cue *growing a garden*, the memory might be *I remember working in my garden when . . .*). Such memories were deemed primed, and memories that did not coincide with cue content were deemed unprimed unless they were found to overlap with other primes (e.g., *vacation*) from the priming list. Any disagreements between the judges were settled through discussion, and there was perfect agreement between the judges ($K = 1.0$).

Results and discussion

Table 1 shows the results of the experiment. As can be seen in the table, the priming and control groups do not appear to differ on number of spontaneous thoughts produced on the vigilance task, $F(2, 96) = 0.16$, $MSE = 0.44$, $p = .85$, $\eta_p^2 = .003$, but they do appear to differ on the number of spontaneous memories. To assess the differences in total memory production, we submitted the memory data in Table 1 to a one-way independent-samples analysis of variance (ANOVA). The results of the ANOVA were significant, $F(2, 96) = 18.62$, $MSE = 7.68$, $p < .001$, $\eta_p^2 = .28$, and we followed up on this

finding with Fischer's least significant difference (LSD) statistic to assess differences among the groups. The results of this analysis (LSD = 1.36) showed that both priming groups had differed from the control group in total memory production, while the three-session priming group showed more memory production than the one-session priming group ($ps < .05$). A further examination of the memories produced in the three groups showed that all contained primed content (in the two priming groups), while nearly all (96%) contained primed content in the control group.

In addition to these analyses, we also examined specific/general autobiographical memory generation rates in the three groups, as well as the distribution of vigilance task cues in the entire data set. The specific memory generation rates were 67%, control group; 69%, three-session priming group; and 67%, three-session priming group, with the remaining balance of memories produced in all groups being general autobiographical memories. Not surprisingly, a chi-squared test found no differences among the specific memory generation rates, $\chi^2(2) = 0.16$, $p = .92$, V = .019, thus indicating that the production of specific and general autobiographical memories was balanced across the groups.[2] An analysis of the distribution of vigilance task cues in the data showed that all 54 cues were involved in memory production, thus showing that the results were not driven by a small set of cues. Finally, at debriefing, none of the participants indicated that they had knowledge of the hypothesis, had made connections between the priming tasks and the vigilance task, or used intentional recall on the vigilance task.

In sum, this experiment showed that semantic-to-autobiographical memory priming increases with increasing encounters with primes. Additionally, the results were obtained with a novel, shortened version of the vigilance task. Nevertheless, this version of the task could be perceived negatively if one worries that its reduced length may have adversely affected the results (e.g., in some way suppressed involuntary memory production because of its shortened length). We address this potential concern with a further design modification in Experiment 1b.

[2] We routinely examine this variable in studies involving the vigilance task and other autobiographical memory measures (e.g., Mace et al., 2019). We discuss its relation to semantic-to-autobiographical priming and other issues in the General Discussion.

Experiment 1b

The goal of Experiment 1b was to replicate the results of Experiment 1a with a modified version of the vigilance task used in that experiment. Thus, Experiment 1b utilized the same priming and control groups as in Experiment 1a, but with a design modification that followed features used in Vannucci et al. (2015) and Mazzoni (2019), respectively. This involved the use of 200 slides (Mazzoni, 2019), where only some (54) contained target phrases, while the rest of the slides contained horizontal or vertical lines without embedded phrases (e.g., Vannucci et al., 2015).

Method

Participants

The participants were 105 undergraduate students from Eastern Illinois University, who participated in exchange for course credit. Sixty-four of the participants were females, and 41 were males, with an age range of 18 to 22 years ($M = 18.98$ years). Participants were randomly assigned to the groups, with equal numbers (35) serving in each group, and similar gender and age compositions. Sample sizes were estimated by Experiment 1a, which achieved significance with slightly smaller numbers.

Design and materials

The designs for the one-session and three-session priming groups were identical to Experiment 1a, whereas the control group design was also identical to Experiment 1a. All of the stimuli for the priming tasks (one-session and three-session groups) and the filler task (control group) were also identical to Experiment 1a.

The stimuli for the vigilance task consisted of 200 slides containing either horizontal or vertical lines. Of the 200 slides (after Mazzoni, 2019), 54 contained a unique word phrase (e.g., *growing a garden*) embedded in the center of the slide. As in Experiment 1a, all 54 of the slides containing phrases were related to the target primes (e.g., *growing a garden*, *visiting the zoo*; Appendix Table 5). Forty-seven of these slides contained horizontal lines, whereas seven contained vertical lines. Of the remaining 146 slides, none contained words or word phrases (after Mazzoni, 2019; Vannucci et al., 2015). One-hundred and thirty-four of these slides contained horizontal lines, whereas 12 contained vertical lines.

Table 2 Number of spontaneous thoughts and autobiographical memories (both specific and general) produced on the vigilance task for the control, one-session priming, and three-session priming groups in Experiment 1b

Group	Spontaneous thoughts	Spontaneous memories
Control		
M	0.66	2.43
SD	0.83	1.96
One-session priming		
M	0.63	4.09
SD	1.56	2.48
Three-session priming		
M	0.71	6.14
SD	0.83	4.43

Thus, the design of the target slides (slides containing phrases related to primes) was the same as in Experiment 1a, but with an additional 146 slides without embedded phrases. Using slides with and without text is consistent with a design approach successfully used in Vannucci et al. (2015), but the version of vigilance task used here still had fewer total slides than in Vannucci et al. (2015), who used 450. The 200 slides used here was consistent with another design innovation, used in Mazzoni (2019), who also successfully produced credible results with many fewer slides than the typical vigilance task (e.g., 500 or more, e.g., Mace & Unlu, 2020; Schlagman & Kvavilashvili, 2008), including slides without embedded phrases (100 in Mazzoni, 2019).

Procedure

All participants in the experiment were tested individually. The procedures for the one-session priming task, the three-session priming tasks, and the letter-string task were identical to Experiment 1a. As in Experiment 1a, when these tasks were completed, participants were then engaged in the vigilance task. The procedure for the vigilance task was also identical to Experiment 1a with two minor exceptions. One, participants were told that some of the slides would contain phrases (rather than all, as in Experiment 1a). Two, instead of four practice slides, they received eight practice slides, four with phrases and four without, with each set of four containing one slide with vertical lines (none of the phrases were related to the primes). Otherwise, all other instructions for the vigilance task were identical to Experiment 1a, including the instruction to report all spontaneous memories and thoughts. Post vigilance task activities (i.e., participants' identifications of memories and thoughts, and debriefing) were all identical to those in Experiment 1a.

Categorization method

This experiment also utilized two independent judges, and the categorization method was identical to that in Experiment 1a. Agreement between the judges was perfect (K = 1.0), as in Experiment 1a.

Results and discussion

Table 2 shows the results of the experiment. As can be seen in the table, the priming and control groups do not appear to differ on number of spontaneous thoughts produced on the vigilance task, $F(2, 102) = 0.05$, $MSE = 1.29$, $p = .95$, $\eta_p^2 = .001$, but they do appear to differ on the number of spontaneous memories. To assess the differences in total memory production, we submitted the memory data in Table 2 to a one-way independent-samples ANOVA. The results of the ANOVA were significant, $F(2, 102) = 12.27$, $MSE = 9.88$, $p < .001$, $\eta_p^2 = .19$, and we followed up on this finding with Fischer's least significant difference (LSD) statistic to assess differences among the groups. The results of this analysis (LSD = 1.50) showed that both priming groups had differed from the control group in total memory production, while the three-session priming group showed more memory production than the one-session priming group ($ps < .05$). A further examination of the memories produced in the three groups showed that all contained primed content (in the two priming groups, as well as the control group).

In addition to these analyses, we also examined specific/general autobiographical memory generation rates in the three groups, as well as the distribution of vigilance task cues in the entire data set. The specific memory generation rates were 67%, control group; 69%, three-session priming group; and 71%, three-session priming group, with the remaining balance of memories produced in all groups being general autobiographical memories. A chi-squared test found no differences among the specific/general memory generation rates, $\chi^2(2) = 0.23$, $p = .89$, $V = .009$, thus indicating that the production of specific and general autobiographical memories was balanced across the groups. An analysis of the distribution of vigilance task cues in the data showed that 51 of the 54 cues were involved in memory production, thus showing that the results were not driven by a small set of cues. Finally, at debriefing, none of the participants indicated that they had knowledge of the hypothesis, had made connections between the priming tasks and the vigilance

task, or used intentional recall on the vigilance task, as in Experiment 1a.

In sum, Experiment 1b replicated the results of Experiment 1a with a modified version of the vigilance task, one which used design features from Mazzoni (2019) and Vannucci et al. (2015). We discuss all of the results more fully below.

General discussion

Mace et al. (2019) and Mace and Unlu (2020) demonstrated that the activation of semantic memories leads to the activation of involuntary autobiographical memories on the vigilance task. They argued that such effects suggest that semantic-to-autobiographical priming might be responsible for much everyday involuntary memory production. In the current study, we replicated those priming effects across two groups, with the added dimension that prime repetition enhanced the magnitude of the effect. In Experiments 1a and 1b, we presented participants in the one-session priming group with word primes (e.g., *bowling*), while participants in the three-session priming group received these same primes, but also received them in picture (e.g., image of someone *bowling*) and sentence form (e.g., *she went bowling*) in two additional priming sessions. These groups showed more memories on the vigilance task associated with the primes than the control groups, and importantly, the three-session priming groups showed more priming than the one-session groups. These findings further show the power of semantic-to-autobiographical priming to influence involuntary memory production by showing that such memory elicitation increases as encounters with primes increases. We discuss the implications of these findings, as well as others, in the remainder of this paper.

Theoretical implications of semantic-to-autobiographical priming for involuntary memory production

The findings of the three-session priming groups are in line with findings reported in the implicit memory and semantic priming literature, where multiple prime presentations were shown to produce greater priming than single prime presentations (e.g., Chen & Squire, 1990; Grant & Logan, 1993; Salasoo et al., 1985). However, the theoretical implications for the findings discussed in that literature are different from the implications that we are proposing here (for examples of the discussions in implicit memory and semantic priming, see McNamara, 2005; Roediger & McDermott, 1993). As stated at the outset, our interest in this variable is to help explain everyday involuntary memory production. The data presented here expand the potential of generic priming to explain this form of memory production, as they suggest that the more we encounter primes in everyday experience, the greater the likelihood that one may experience involuntary memories related to those primes. From this observation, one can build a simple model which states that at one end of a repetition continuum (e.g., after a single prime encounter), involuntary memory production has a fairly low probability, but at the other end of that continuum (e.g., after 10 or more prime encounters), it may be a near certainty or a very high probability. Similar observations have been made in classic studies of repetition, where, for example, free recall following a single presentation may have produced very low performance but comparatively quite high performance after many repetitions, sometimes reaching 100% performance levels (see reviews in Baddeley, 1997; and Greene, 1992). While it is not known how frequently one experiences the same concepts in everyday life, the model itself should be amenable to future testing in the laboratory.

Thus, we believe that the prime frequency effects found in this study bolsters claims made elsewhere (e.g., Mace et al., 2019; Mace & Unlu, 2020) that semantic-to-autobiographical priming has a significant role in everyday involuntary memory production. We should note that in asserting this position that we are not claiming that semantic-to-autobiographical priming is a sole factor in such memory production, as other factors are likely to be at work (e.g., other forms of priming Ball, 2015; Barzykowski & Niedzwienska, 2018; Johannessen & Berntsen, 2010; Mace, 2005), and other factors may frequently combine with semantic-to-autobiographical priming (e.g., various cuing phenomena, e.g., Berntsen et al., 2013). What we are saying, however, is that the data make a strong case for generic priming's role in everyday involuntary memory production. In other words, we believe that involuntary memory production may often be a direct consequence of semantic-to-autobiographical activations, and it is for this reason, and perhaps no others, that we sometimes experience these memories. This may at times include other factors, as they may often have a mitigating role in involuntary memory production (e.g., in the case of cue characteristics, making production more or less likely, e.g., Berntsen et al., 2013). Such a conclusion may suggest on the one hand that involuntary memories are cognitive failures (e.g., see discussions in Mace et al., 2019; Mace & Unlu, 2020), or on the other that they are functional to cognition because their activations in cognitive processing might suggest that they have an independent role there (e.g., color or somehow add to the understanding of concepts, see discussion in Mace et al., 2019).

We have used activation accounts (e.g., Anderson, 1983; Graf & Mandler, 1984) as a working theory to explain semantic-to-autobiographical activations and memory production in this context (e.g., Mace et al., 2019). According to this model, priming raises the activation level of autobiographical memories, making their conscious production more likely than memories with lower levels of activation. It is relatively straightforward to explain the present findings with this approach, as the theory predicts that each encounter with a prime raises the activation level of memories, making memory production progressively more likely (e.g., Bower, 1996). Barzykowski and colleagues have a similar activation view, which they have used to explain involuntary memory production more broadly (e.g., Barzykowski & Mazzoni, 2022; Barzykowski et al., 2019; Barzykowski & Staugaard, 2016). In their approach, involuntary memories occur because they have activation levels high enough to pass an awareness threshold, where they enter one's stream of conscious content. One can also apply their theory here, noting that priming generally reduces the awareness thresholds, while repeated priming reduces them even further still, making conscious memory production that much more likely.

Finally, to conclude this section, concerning specific and general autobiographical memory production in this study, both types of memories were observed in the groups, though the priming groups tended to show more specific memory production relative to control, while not approaching significance. The predictions regarding specific and general memory production differ somewhat with respect to the working theoretical model of semantic-to-autobiographical activations, and its practical implications on the production side. With respect to the activation model, we believe that most semantic-to-autobiographical activations involve access down to the specific memory level (e.g., Conway & Pleydell-Pearce, 2000). Nevertheless, it is certainly possible that the strength of an association and the strength of an activation may also play a role, making general memory production more likely in some cases because activation did not reach the specific level (see Sheldon et al., 2020). With respect to memory production, our hypothesis does not distinguish between specific and general production as we expect both types of memories on the production side, partly because retrieval factors may frequently influence what type of memory (general or specific) is produced. This is consistent with observations of this variable in laboratory tasks, and naturally occurring involuntary memories, where both types of memories are typically produced (e.g., Barzykowski & Niedzwienska, 2018; Berntsen, 1998; Kvavilashvili & Schlagman, 2011; Laughland & Kvavilashvili, 2018; Mace, 2006; Mace et al., 2019).

Implications for other areas

The implications of the prime frequency findings should also extend to other forms of autobiographical memory priming. That is, unless there is something unique about this finding with respect to semantic-to-autobiographical priming, reminiscence and preoccupation priming (e.g., Ball, 2015; Johannessen & Berntsen, 2010; Mace, 2005) should also vary according to prime frequency. Among these forms of priming, multiple encounters with the same or similar primes might be very common in some circumstances (e.g., in reminiscence when it is a persistent behavioral pattern; e.g., Fitzgerald, 1996, and in preoccupations, such as persistent thoughts of dieting, e.g., Ball, 2015). Future studies may wish to investigate the frequency factor within these paradigms, perhaps comparing the effects among different priming types, including semantic-to-autobiographical priming.

As noted in the Introduction, generic priming has also been shown to affect voluntary memory production. In the first study to examine this priming variable, Conway (1990) reported shortened retrieval times in the voluntary recall of autobiographical memories following generic priming. Also as noted, Mace et al. (2019) showed that the content of voluntary memories following priming was more likely to involve the content of prior semantic primes than in unprimed conditions. While it seems more likely that involuntary memory production would be affected by priming more than voluntary memory production, as the latter is typically goal oriented, Mace et al. (2019) argued that there may be a few circumstances where voluntary remembering may be influenced by priming. For example, reminiscing about the past may not always be goal oriented, except to recall memories from a particular time period, and it may be in these circumstances where priming may have an impact (e.g., see Mace & Clevinger, 2013; Mace & Petersen, 2020, as well as further discussion in Mace et al., 2019). With respect to the present results, one would expect that priming's effect in reminiscence recall should be further enhanced by prime repetition, as shown here, and by this variable's long history in explicit memory enhancement.

Potential limitations

There are two potential limitations with the current study. Regarding the first, in the three-session priming groups, instead of exact stimulus repetition (e.g., repeating the same words), we used concept repetition (i.e., words, sentences, and pictures representing the same concepts)

in the three-session priming group. As noted earlier, the findings reported in Mace and Unlu (2020) revealed no differences among these stimuli with respect to priming or total memory production, and we also reasoned that variable stimuli were more consistent with everyday experience, where one is likely to experience primes in multiple different forms. We should add that theoretically, we believe that regardless of the stimulus form (e.g., a word or its corresponding image) that the same set of autobiographical memories are activated in the priming process, so long as there is concept apprehension. Nevertheless, it is still possible that the results from the three-session priming groups were in part enhanced a bit more by one of the stimulus sets (e.g., greater saliency in the picture stimuli), or alternatively, reduced because one stimulus set reduced conceptual processing (i.e., either sentence or pictures). Also, our results do not allow one to compare exact stimulus repetition with concept repetition, and therefore, future studies may wish to take up this variable.

Regarding the second potential limitation, we used a small number of cues in the vigilance task relative to other studies (54 vs 500 or more, e.g., Mace et al., 2019; Schlagman & Kvavilashvili, 2008), and the task only contained a total of 54 (Experiment 1a) or 200 slides (Experiment 1b), where others typically used 500 or more (e.g., Schlagman & Kvavilashvili, 2008). To our knowledge, the total used in Experiment 1a is the shortest duration for the vigilance task in all published studies involving this task, and the 54 slides with embedded phrases (Experiments 1a and 1b) is the smallest number of slides with verbal cues. This could be perceived negatively, if these versions of the task are seen as somehow changing the nature or number of memories elicited, or positively, if they are seen as successful iterations of a shortened vigilance task. We argue for the latter of these options and believe there are a number of positive indicators consistent with this idea. Concerning the nature of the memories elicited, we note that the rates of general and specific memories observed here are consistent with our other studies where the task was much longer (e.g., Mace et al., 2019). Also, at debriefing, participants did not make any connection between the priming phase and the vigilance task, express knowledge of the hypothesis, or indicate that they used intentional retrieval. If there was a change in the type of involuntary autobiographical memories produced, or if participants had used intentional retrieval to produce them, particularly in the priming groups, then one might expect changes in the rates of general and specific memories relative to other studies, or greater general memory production in the priming groups relative to controls, as intentional recall tends to favor this pattern (e.g., Berntsen, 1998; Mace, 2006; Schlagman & Kvavilashvili, 2008). None of these trends were seen in the data (see also Barzykowski et al., 2021, for a discussion of involuntary versus voluntary memory responding in the vigilance task). Concerning the number of memories produced, the memory production in our control groups was consistent with memory production in a similar group used in Vannucci et al. (2015). They used approximately twice the number of slides (450 vs. 200) and nearly two times the number of slides with phrases (90 vs. 54) and reported a little more than two times the number of memories (6.04, their study, vs. 2.49 and 2.43, our study, Experiments 1a and 1b). We believe these similarities show that our version of the task achieved the same effect, and therefore did not significantly alter involuntary memory production in any way, as one should have seen proportionally very different rates of memory production if the task designs had negatively impacted the results.

Thus, we believe that the tasks performed as other longer and modified versions (e.g., Vannucci et al., 2015) of the vigilance task, and may prove useful in future studies where there may be a need to have a shorter task. There are a number of involuntary memory studies which have successfully used abbreviated methods to collect data. For example, in a diary study on everyday involuntary memories, Ball and Little (2006) collected a single involuntary memory from each of their participants and reported results consistent with longer diary studies (1 to 2 weeks, or longer, e.g., Berntsen, 1996; Mace, 2005; Schlagman et al., 2006, see also Mace & Atkinson, 2009). Laughland and Kvavilashvili (2018) found better involuntary memory recording performance in a 1-day recording condition compared with a 1-week condition (see their study for further details). Shorter versions of the vigilance task may not be superior to longer versions, but there may be circumstances where they may be the better option, as they may help mitigate potential problems, such as memory suppression effects (i.e., failure to report experienced memories due to fatigue or frustration).

Finally with respect to the design implications, we only used phrase cues in the vigilance task that directly overlapped with or were related to the primes, but mostly the former type. As noted, in our other studies (e.g., Mace et al., 2019) we used overlapping and related cues, as well as unrelated cues. Given that we essentially used overlapping cue type here, we were unable to report on the effects of overlapping, related, and unrelated cue types. It would be interesting to see their individual effects, and most importantly, for the subject of this report, how they may have interacted with the prime frequency variable. Future studies should direct their attention towards these variables.

Conclusions

The repetition variable has a long history in the study of memory, showing that repetition enhances declarative memory performance, as well as priming in multiple priming paradigms, including implicit memory. In this study, we have shown that prime repetition also plays a role in a newer priming paradigm, semantic-to-autobiographical memory priming. Our interest in this variable was functional—namely, how such generic priming may be involved in the production of involuntary memories. Conway (2005) has argued that generic cues constantly activate memories in the autobiographical memory system, and that such activations occasionally result in involuntary autobiographical memories. This study and others (Mace et al., 2019; Mace & Unlu, 2020) have lent support to this idea, however the current study has gone one step further in showing that involuntary memory production becomes more likely with increasing encounters with generic primes. This finding supports claims made elsewhere (Mace et al., 2019; Mace & Unlu, 2020), that semantic-to-autobiographical priming plays a significant role in the production of involuntary memories in everyday life, one, because generic information processing is a constant process, and now, when it is a repetitive process. Future studies may wish to pursue this line of research to further explore its parameters, including determining how large of a role this form of priming may play in everyday involuntary memory production.

Appendix 1

Table 3 Words used in the word-familiarity task

Music*	Lilt**	Lake*
Friends*	Internet*	Zoo*
School*	Cat*	Moving*
Quip**	Betlel**	Train*
Concert*	Cartoons*	Bowling*
Parade*	Reading*	Storm*
Art*	Proclivity**	Hotel*
Pensive**	Hiking*	Singing*
Doctor*	Movie*	Winter*
Vacation*	Sports*	Instrument*
Home*	Ruyel**	Flowers*
Ostentatious**	Car*	Woods*
Pet*	Exercise*	Cooking*
Summer*	Garden*	Party*
Blatant**	Mountain*	Writing*
Lotely**	Window*	Sledding*
Scruple**	Beach*	Barbeque*
Clothing*	Airplane*	Games*
Books*	Bike*	Boat*
Garrulous**	Swimming*	Shopping*
Cell phone*	Running*	Concert*
City*	Laughing*	

*Denotes a high-frequency word.

**Denotes a low-frequency word or nonword.

Appendix 2

Table 4 Sentences in the sentence-sense task

People enjoy listening to music.	She never had a pet growing up, but she wants one now.	Mary finds cartoons to be a great way to unwind after a long day.	People are laughing.	I like shopping.	He likes cooking.
Joe's shows great proclivity.	Joe's summer ended too soon.	He is reading in bed.	The lake is big.	He cleaned the windows.	Jill likes writing.
Mary colored the wall in a blatant grey.	Yesterday he rolled through a ruyel.	The deviled eggs tasted very pensive.	People go to the zoo.	They stayed in a hotel.	They went sledding.
Her friends go paintballing each weekend.	The list was organized in a lotely manner.	Hiking through the woods relaxed her.	Moving is not fun.	Winter is cold.	I like boats.
The school just got repainted with its colors and mascot.	Her clothing got soaked during the rainstorm last night.	The movie had a predictable ending.	I like riding on a train.	She played her instrument.	Games can be fun.
The parade dragged on for hours.	The lightning came down with great betlel.	Joe's car overheated during a road trip.	She went bowling.	The flowers smell fragrant.	She went to a barbeque.
Art is part of John's everyday life.	Their outfits that day were very quip.	She rode her bicycle.	I like singing.	The woods are interesting.	Most people like the beach.
The doctor wrote a prescription.	He threw the rock with such garrulous force.	Jim likes sports.	He got out of the storm.	Most people like a party.	Phil likes concerts.
The students had to scruple to class.	The books on this shelf are dusty.	Mary likes to exercise.			
It rained throughout Mary's entire vacation	The cell phone dropped in the sink.	Jim likes working in his garden.			
He just bought his first home.	The city is loud and congested	She went to the mountain			
The table had a small lilt to the right.	He does most of his research and work on the internet.	People like to go swimming.			
	She is very allergic to his cat.	People fly on airplanes.			
	Joe has always been an ostentatious wall flower.	Phil likes a concert.			
		Michelle goes running a lot.			

Words underlined were primary targets or foils (e.g., *lilt*) used in the word familiarity task

Appendix 3

Table 5 Phrase cues used in the vigilance task

Getting ready.*	Freezing cold air (for winter).	Going sledding.
Crossing the road.*	Being in a parade.	Answering a phone call.
Flying a kite.*	Warm weather (for summer).	Coloring a picture (art).
Drinking from a bottle.*	Searching the internet.	Staying at a hotel.
Getting exercise.	Riding in an airplane.	Going on vacation.
Growing a garden.	Riding a train.	Singing a song.
Hanging your clothes.	Getting a cat.	Being at the beach.
Home sweet home.	Climbing a mountain.	Going to a party.
Laughing a lot.	Riding in a boat.	Looking out the window.
Visiting the zoo.	Going to the lake.	Swimming in a pool.
Planting flowers.	Running in a field.	Playing an instrument.
Playing a game.	Going to the doctor.	Going shopping.
Playing a sport.	Watching a movie.	Going to a concert.
Reading a book.	Petting a dog (for pet).	Being at a friend's house.
Writing a letter.	Reading a magazine.	Taking a hike.
Last day of school.	Watching a storm.	Listening to music.
Riding in a car.	Going bowling.	Being in the woods.
Moving to a new state.	Visiting a new city.	Being at a barbeque.
Purchasing a new bike.		Cooking dinner.
A cartoon character.		

Words underlined were targets used in the priming tasks. *Practice cues

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