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Positive and negative priming differences between short-term and long-term identity coding of word-specific attentional priorities

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Abstract
Two experiments investigated positive priming and negative priming effects in a lexical decision task. A priming task was used in which participants were required to make a verbal naming response to a prime target word, flanked by a distractor word, followed by a lexical decision response to a probe target word or nonword, flanked by a distractor word. The longevity of both positive and negative priming was explored in short-lag and long-lag conditions in which stimuli were presented once and only once, except in order to fulfill the priming manipulations. The results showed significant immediate positive priming and negative priming effects, but only negative priming was sustained for over 8 minutes with many intervening trials, whereas there was no evidence of positive priming after the same delay. These intriguing results have implications for the nature of inhibitory processing and differing predictions between inhibition-based and episodic retrieval accounts of priming.

Keywords Selective attention · Negative priming · Positive priming · Lag · Retrieval

People are continuously exposed to a large amount of visual sensory information, and thus mechanisms are needed to ensure that overload does not occur. Consequently, psychologists have become interested in how humans apply strategies to distinguish between relevant and irrelevant information (Strayer & Grison, 1999). It has been established that unwanted, covert responses, created automatically by visual processes, can be induced without any conscious plan to do so. In order to control these nonconscious responses, it is imperative that we have the ability to inhibit responses that may not be desirable for the current task (Tipper, 2001).

Negative priming

The negative priming phenomenon has been useful for investigating the mechanisms underpinning visual selective attention and, in particular, the possibility that an active inhibitory mechanism suppresses conflicting, "to-be-ignored" information (e.g., Christie & Klein, 2008; see Frings, Schneider, & Fox, 2015, for a review). A typical negative priming experiment involves using trial couplets containing a prime display followed by a probe display, with each containing a target stimulus that the participant responds to and an irrelevant distractor that is ignored. The ignored repetition (IR) condition involves the distractor in the prime display either matching, or being highly similar to, the target in the probe display. In the control condition, there is no relationship between the four stimuli in a prime–probe couplet. Negative priming effects are evidenced by slower, or more error-prone, responses on IR trials compared with control trials. The observation that an ignored distractor can influence later behavior demonstrates that this distractor must be processed in some way—either consciously or nonconsciously. However, the exact mechanism as to how this occurs is widely debated. There are two main theories of conceptual negative priming—inhibition-based and episodic retrieval (Neill & Valdes, 1992).

Inhibition-based theory

The inhibition-based theory claims that momentarily irrelevant and distracting information is actively inhibited as a function of target selection (e.g., Neumann & DeSchepper, 1991, 1992; Neumann & Levin, 2018). Proponents of this theory contend that the inhibition of distracting information is as equally necessary for selective attention as the activation of

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target information (see also Cerf et al., 2010). A critical feature of the inhibition account of negative priming is that it operates in a "forward" direction, starting at the prime display and continuing to the subsequent probe display. When the prime stimuli are displayed, the ignored object is actively inhibited, and this inhibition carries forward, creating impairment when the ignored item becomes a target on the probe display (e.g., Fox & DeFockert, 1998).

Episodic retrieval theory

The episodic retrieval theory of negative priming was proposed by Neill and Valdes (1992) after a series of experiments in which a decrease in the magnitude of negative priming was found as response-to-stimulus intervals (RSIs) increased. This relationship was demonstrated by an exponential decay function whereby differences in negative priming were harder to detect at long RSIs as opposed to short RSIs. Neill and Valdes (1992) discovered that this decay function of negative priming was similar to characteristic decay functions that have been reported for both sensory memory (Sperling, 1960) and short-term memory (Peterson & Peterson, 1959). Logan's (1988) theory of automatization proposed that behavior, and therefore subsequent performance, can be mediated by the retrieval of prior processing episodes involving the same stimuli. In line with Logan's ideas, the episodic retrieval account of negative priming suggests that task reaction times can vary due to retrieval of certain episodes. These episodes contain both identity information and information pertaining to whether the prime display item was previously a target (respond tag) or a distractor (do-not-respond tag). Hence, when the probe trial is displayed, the memory of the previous prime trial is elicited and interferes with the response in ignored repetition (IR) trial couplets where there are conflicting response tags (i.e., "do not respond," "respond"). It is the extra time required to overcome the conflicting tags in the IR condition, compared with the control condition, that produces negative priming. Unlike the inhibition account, episodic retrieval works in a "backward" direction with the probe trial target acting as a memory retrieval cue.

Temporal discrimination theory

A third account of negative priming phenomena is the temporal discrimination theory (Milliken, Joordens, Merikle, & Seiffer, 1998). This theory postulates that a probe target stimulus is categorized as "old" or "new" at the time of the impending probe response. In an IR trial, the probe target is ambiguous in the sense that it is familiar due to its appearance in the prime, immediately stopping a facilitated "new" response, but not familiar enough to be categorized as "old." It is this momentary ambiguity that ostensibly leads to the slowed responses causing negative priming.

To provide support for their theory, Milliken et al. (1998) conducted experiments where the prime consisted of a single masked prime word, followed by two interleaved words in the probe of which one word was to be named. Importantly, no response was required in the prime. Significant negative priming was nevertheless observed in the "repeated" condition, where the prime word became the probe target. It was suggested that this finding is evidence that selecting against a prime distractor is not necessary for negative priming to occur. However, as Mayr and Buchner (2007) and others (e.g., Noguera, Ortells, Abad, Carmona, & Daza, 2007; Tipper, 2001) have pointed out, it is likely that participants actually selected against the singular prime, as prime responses needed to be withheld from it. This finding can therefore be accounted for by either episodic retrieval, where a "do-not-respond" tag was attached to the entire prime episode, or by an inhibition-based perspective, where the prime episode involved selective inhibitory processing.

Further, evidence against a temporal discrimination account comes from Frings and Wühr (2007), using a distractor repetition manipulation. In a distractor repetition trial, the prime and probe both contain the same distractor stimulus, but different target stimuli. Hence, there is "old" information in the probe display, because the distractor stimulus is the same as the distractor used in the previous prime and "new" information, because the target is different from the one in the prime. The clear prediction from temporal discrimination is that this conflicting "old" and "new" information should lead to ambiguity during the impending probe response, and consequently to a slowed response. Conversely, however, experiments that involve distractor repetition conditions, compared with control conditions, actually produce facilitated responses rather than slowed responses (e.g., Neumann & DeSchepper, 1991; Nett, Bröder, & Frings, 2016; Stadler & Hogan, 1996). This is the opposite of what the temporal discrimination theory predicts. For these reasons, both Frings and Wühr and Mayr and Buchner (2007) conclude that temporal discrimination is not a viable candidate for explaining negative priming effects (see also Li, Neumann, & Chen, 2017).

Attempted reconciliation between episodic retrieval and inhibition-based perspectives

Tipper (2001) attempted to reconcile the opposing views inherent in the episodic retrieval and inhibition-based accounts of negative priming by pointing out that both encoding factors, affecting prime display processing, and memory retrieval factors, affecting probe display processing, are necessary for a more accurate and complete theory of what underlies the negative priming effect. Tipper holds that the inhibition-based account and the episodic retrieval account are not mutually exclusive, but rather should be integrated. More specifically, when a probe target is presented on an IR trial, prior processing episodes associated with that stimulus will be retrieved. These will include both information about the stimulus, and a reinstatement of the internal representations of the distractor. These representations result from selective attention mechanisms acting upon the stimulus when it appeared moments before as a prime distractor. Given that the probe target was inhibited when it appeared as a prime distractor, it follows that the retrieved episode will also include that inhibition. Tipper further argues that traditional accounts of inhibition place too much focus on the encoding process, whilst the episodic retrieval account over emphasizes the retrieval process. Consequently, a complete view of the inhibition-based and memory-based processes involved in negative priming should include accounts of what transpires at both encoding and retrieval.

Positive priming

Positive priming (repetition priming) is a phenomenon whereby presentation of a stimulus facilitates processing on subsequent presentation of the same stimulus. Thus positive priming is evidenced by a faster or less error prone response to stimuli that have previously been presented compared with new stimuli. The positive priming literature indicates that there are two components to positive priming: a short-term component and a long-term component. The short-term component is most evident in the masked form priming paradigm, whereby the prime is displayed very briefly preceded by a mask, and immediately followed by a target probe, making it unable to be identified. This type of positive priming encourages the prime and target to merge into one event and has been shown to disappear if more than a few items intervene between the prime and the target (Forster & Davis, 1984). In contrast, positive priming can be long-lasting when the prime and target are experienced as separate events. For example, it has been found that positive priming in a lexical decision task was evident after a 2-day delay (Scarborough, Cortese, & Scarborough, 1977).

Two major theories have been proposed to account for positive priming using word stimuli. The first is referred to as an abstractionist account, whereby positive priming is said to occur due to an increase in the accessibility of a word's abstract lexical representation. For example, Morton (1969) proposed the logogen model. A logogen is a type of unit that activates during word recognition and includes information about the properties of a word including its definition, sound, and appearance. The logogen model proposes that the presentation of a word lowers the threshold of that word's logogen, thus making it more accessible at second presentation. The second theory is an episodic account and was developed by Logan (1990). This theory posits that facilitation occurs due to retrieval of a recent episode of an encountered stimulus. This facilitation is proposed to occur because memory retrieval acts faster than the processing it would normally take to classify the stimulus. For example, when asked to make a lexical decision, the first presentation requires processing to decide whether or not the item is a word. At the second presentation, it is assumed that memory retrieval of the last presentation is faster than having to complete the processing again (Logan, 1990). This episodic account is very similar to Neill and Valdes's (1992) episodic retrieval theory, but it uses slightly different terminology.

Long-term positive priming

In support of an episodic account of positive priming, Bentin and Moscovitch (1988) conducted a series of experiments that explored the time course of positive priming effects for words and unfamiliar faces at lags of 0, 4, and 15 items between first and second presentations. The first experiment involved a lexical decision task whereby both words and nonwords were assessed for priming effects over the three lags. This experiment also included a task requiring participants to respond as to whether an unfamiliar face or "nonface" was a normal human face. The nonfaces were made by switching the locations of certain features (i.e., eyes, nose, and mouth). All four categories of stimuli produced significant positive priming effects at Lag 0. Conversely, only words produced significant positive priming effects at lags of 4 and 15 intervening stimuli. The authors suggested that although these results are consistent with a logogen model they may also be consistent with a memory perspective, given that the first presentation of an unfamiliar stimulus may have been unable to create a strong enough memory trace to sustain effects at longer lags. They suggested that words are processed more deeply due to their familiarity, especially if lexical decisions are involved, thereby creating stronger memory traces. Given that the face versus nonface task does not require deep processing, participants may have focused only on superficial features leading to the formation of a relatively "weak" memory trace. To test this assumption, the authors conducted a second experiment to establish whether the positive priming effect found for words at long lags can be eliminated if the task constrains the participants to attend to the superficial attributes of the words rather than to deeper internal representations. In this experiment, participants were required to determine whether the first and last letter of each word or nonword was in alphabetical order. This new paradigm demonstrated no evidence of positive priming at lags greater than zero for either words or nonwords. Overall, the authors concluded that items with a preexperimental representation (i.e., real words) are more likely to produce a positive priming effect due to their ability to create a stronger and more accessible trace in memory.

Additional support for an episodic account comes from a study that explored positive word priming in a lexical decision task over lags of 0, 1, 4, or 8 intervening stimuli (Kersteen-Tucker, 1991). Participants were advised that they would see a series of letter strings appearing on the screen and that they needed to respond as to whether the letter string constituted a word or not. It was found that there was significant positive priming at all lags but that the magnitude of the effect at Lag 0 was greater than at all other lags independently. The authors concluded that the long-term positive priming effect was consistent with the idea of participants retrieving a consciously accessible episodic record of the first presentation of the stimulus.

It has been argued that an abstractionist model of positive priming (such as the logogen model discussed earlier) struggles to explain long-term positive priming effects (Tenpenny, 1995). If the lexical unit of a word could remain more accessible for a long period of time, the number of these "accessible units" would become extremely large, making this explanation improbable. It has been suggested that the lexicon is ordered by frequency and recency (Taft & Forster, 1976), yet this explanation similarly struggles to explain a long-term effect. Any words intervening between the first and second presentation of the target would push the target word ever more backward, making it less likely to produce facilitation. Bowers (2000), however, argues that an abstractionist account of long-term repetition priming is very plausible. He suggests that although we encounter many words in daily life, this may not mean that words in the experimental session are already primed. Kirsner and Speelman (1996) have reported that, with a reading rate of 25,000 words a day, a low-frequency word would be encountered only once every 40 days. It is proposed that this may account for the lack of long-term repetition priming found with high-frequency words, as high-frequency words are more likely to suffer interference effects from lexical competition due of the number of times they are encountered in everyday life (Bowers, 1999, 2000).

There are also arguments as to why an episodic account may have difficulty in explaining long-term positive priming. This is most evident in research that extends priming over a longer time period than has been discussed so far. Wheeldon and Monsell (1992) argue that in the case of word recognition, it seems implausible that participants would have time to retrieve an episodic record, given that in the majority of reaction time experiments unprimed performance is fast and accurate. This is especially true in the case of experiments with long lags between prime and probe displays. These authors designed a series of experiments in order to minimize the chance of an episodic memory being retrieved. They achieved this by creating a design where unprimed performance was efficient and fast, leaving very little time following the prime trial for elaborative encoding. Further, they included many new intervening items between the prime and probe, and gave no explicit encouragement to expect any kind of repetition. The design was such that the stimulus on the prime trial was not repeated on the probe trial. This was achieved by using a picture-naming probe task. In the first experiment, participants were asked to respond by producing a spoken word to the picture probe. They had been primed previously with either a definition prime (a definition appeared on the screen and they responded with the word) or a printed word prime (a singular word was presented on the screen that participants needed to read aloud). This stimulus change, between prime and probe, was employed to decrease the chance that the probe stimulus could elicit an episodic memory of the prime stimulus. There was a short lag condition where prime and probe trials were separated by 2–7 intervening trials, and a long-lag condition where they were separated by 60–120 intervening trials. Significant facilitation was observed at both short and long lags when the same word had previously been produced in response to a definition or reading a printed word. Facilitation was, however, greater at short lags. The authors concluded that the long-lag effect is consistent with a persistent change in the state of the processing pathway. It is unclear how this change occurs, however. It may be that production of a phonological form is facilitated by the prior production of that phonological form. Alternatively, when the participants produced the word at the prime stage, this activated the appropriate meaning and it is the meaning itself that facilitated the response to the probe target picture with the same meaning. It is also possible that facilitation occurs due to a combination of both; that is, the phonological form is more easily retrieved when there has been prior rehearsal of the link between the meaning and phonological form.

Therefore, Wheeldon and Monsell (1992) also investigated whether the production of a phonological word form was facilitated by the prior production of that phonological form in another experiment that compared positive priming and homophone priming. In homophone priming, the word form generated at the prime is in response to a different meaning. Some of the homophone pairs were homographic (e.g., "bat," wherein both meanings have the same spelling) and some pairs were heterographic (e.g., "son"–"sun," wherein both meanings have different spelling). Further, the prime definitions were designed to either induce the same meaning as the pictured item, or the same word form as the pictured item with an unrelated meaning. For example, if the probe was a picture of the sun, the two prime definitions supplied were "It rises in the east and sets in the west" and "Like father like . . . ." If the long-term positive priming effect found in the first experiment was purely due to production of the same phonological form, the homophone priming condition should show significant facilitation. There was no evidence of homophone priming. Interestingly, there was evidence of some facilitation in the homophone condition where the pairs used were homographic (although this did not reach significance). Heterographic pairs also showed no facilitation. These results suggest that prior production of the same phonological word form does not produce facilitation over long lags.

Long-term negative priming

In contrast to long-term positive priming, considerably less research has been undertaken into long-term negative priming. One of the first studies to explore the idea of long-term negative priming was conducted by DeSchepper and Treisman (1996), who used overlapping novel shapes, distinguished by color, in a same–different decision task to establish the existence of long-term negative priming after lags of 1, 10, 100, and even 200 trials. This task involved two overlapping shapes on the left side of the screen (a red and a green shape) and a white shape on the right side of the screen. Participants were instructed to ignore the red shape and respond to whether the green shape was the same or different as the white shape. Similarly, Grison, Tipper, and Hewitt (2005) found long-term negative priming, after an average delay of 3 minutes, using experimentally novel face and object stimuli. These results clearly support DeSchepper and Treisman's (1996) observation of long-term negative priming, but also extend long-term negative priming effects to meaningful stimuli rather than to novel "blob" shapes. Grison et al. (2005) concluded that memory processes were important in long-term negative priming, but considered it improbable that sustained inhibition could be maintained over a delay as long as 3 minutes, while attending to many other intervening stimuli. They also discuss the possibility that long-term negative priming is dependent on the subject being able to retrieve only one prior instance of the ignored distractor. This is consistent with the results of DeSchepper and Treisman (1996), who used novel shapes, making it unlikely that the subject had any previously stored instances of the stimuli. Treisman and DeSchepper (1996), however, reported no significant long-term negative priming with meaningful word stimuli using a same–different matching task with words distinguished by different colors. They concluded that the many previous interfering tokens attached to words in memory reduced the likelihood of long-term negative priming. A similar point was made by Tipper and Milliken (1996), who reported that unpublished studies they conducted consistently failed to show negative priming effects with lags between the prime and probe displays in excess of 7 seconds. These studies used stimuli previously seen by participants, thereby having multiple representations attached to them in memory. They concluded that because of the mixture of "respond" and "do-not-respond" tags attached to distractor items, these multiple representations interfered with retrieval of the appropriate episode.

The current study

The current study aims to further investigate the temporal dimension of both negative and positive priming. As discussed above, both the inhibition-based and episodic retrieval theories make sound arguments for the findings so far, and there is large disagreement between these theories about the mechanisms underlying priming effects, most especially at lags. The two following experiments will explore both negative and positive priming with word stimuli at short and long lags and further discuss how these results relate to both the inhibition-based and episodic retrieval accounts of priming.

Experiment 1

Experiment 1 employed a paradigm previously used by Neumann, McCloskey, and Felio (1999). The task involved naming a prime target followed by a lexical decision (i.e., word or nonword judgement) to the probe target. Recent research suggests that people are able to quickly create arbitrary associations between a stimulus and its response, referred to as a stimulus–response (S–R) binding (Henson, Eckstein, Waszak, Frings, & Horner, 2014). These bindings can occur with respect to both responses to prime targets and to prime distractor stimuli. According to Henson et al. (2014), S–R bindings can cloud the purity of priming effects. To avoid such unwanted artifacts, these authors recommend using a large pool of stimuli, combined with a naming or identification task for the prime stimulus, and a change of task between prime and probe. For example, if the prime involved naming the target stimulus, the probe could involve some sort of classification task, such as lexical decision. They further contend that if these conditions are met, then at the time of the prime display each stimulus will be associated with a distinctive response that is not reiterated at the time of the probe display, and thus cannot moderate the priming effect by S–R binding. Besides the current study, there are only a few studies that have followed these important precautions advocated by Henson and colleagues (i.e., Neumann et al., 1999; Neumann, Nkrumah, & Chen, 2018; Nkrumah & Neumann, 2018).

In prime and probe couplets, lowercase and uppercase items appeared immediately above or below one another. Each prime and probe selection display consisted of an uppercase distractor word and a lowercase target, both printed in black. The uppercase distractor was always a word, but the lowercase probe target was a word in half of the trials, and a pronounceable nonword in the remaining trials. Target and distractor items were placed one above the other with minimal separation, with letter case as the selection cue. The ability to parse displays into target and distractor was further challenged by varying the location on the screen of prime displays (Langley, Overmier, Knopman, & Prod'Homme, 1998). Like Neumann et al. (1999), participants were required to name the lowercase word in prime displays while ignoring a competing uppercase distractor word that appeared at random above or below the target. Similarly, probe targets were displayed in lowercase in the presence of a competing uppercase word, and equally often probe targets formed English words or pronounceable pseudowords and required a lexical decision response. The most critical novel manipulation in the current study involves the temporal dimension; specifically, whether long-term negative priming for words can be obtained. If long-term negative priming exists, there are significant implications, as it would indicate that previously ignored information leaves a trace that can alter behavior over an extended time course (Grison et al., 2005).

Method

Participants Fifty-seven (41 female) participants ages 18–64 years were recruited. Twenty students participated to fulfill credit for an introductory psychology course, while the remaining 37 participants were from the University of Canterbury and the general public. These participants were rewarded with a $10 grocery voucher for their participation.

Stimuli and apparatus Stimulus layout and examples of the IR, control, and nonword trials are presented in Fig. 1. Stimuli were presented on a Philips 19-inch LCD monitor in Arial 20-pt font. The prime stimuli were randomly positioned across trials either on the left, right, or center of the screen such that they appeared one third of the time in each position. Probe displays were always presented in the center of the screen. When the prime was presented on the left, the visual angle of the space between the rightmost edge of the prime and the leftmost edge of the probe was 1.5°. Similarly, when the prime was presented to the right, there was a 1.5° angle between the leftmost edge of the prime and the rightmost edge of the probe. Target and distractor words were presented one above and one below pseudorandomly, such that 50% of the time the target appeared in the upper position. The experiment was generated using E-Prime 2.0. The E-Prime software enabled reduced separation between the target and distractor stimuli, such that their closest edges were always 1 pixel apart. The purpose of this was to increase selection difficulty and consequently the likelihood of obtaining negative priming.

From a pool of 1008 three-letter to eight-letter nouns, verbs, and adjectives, 240 words were randomly assigned as targets, and the remaining 768 words were used as filler words. Nonword stimuli consisted of 144 pronounceable nonwords that were three to seven letters in length. All stimuli were presented once and only once, except in order to fulfill the IR condition. Target words were always presented in lowercase letters, and distractor words in uppercase letters.

Prior to the main trials, all participants completed 24 practice trials. Twelve were nonword trials and 12 were control trials (there were no IR trials during practice). Prime displays were initially presented for 500 ms, reducing to 400 ms and then to 200 ms from the ninth trial onward. There were 288 trials in the experiment proper. Of these, 144 were nonword filler trials and the remaining 144 trials were configured as follows: 48 control trials, 24 long-term ignored repetition (LTIR) trials, 24 short-term ignored repetition (STIR) trials, and 24 word filler trials. To clarify, the LTIR manipulation required 48 "trials" as each of the 24 analyzed trials also had to have a linked trial 144 trials earlier to make the manipulation possible. For example, in the first half of the experiment, a trial had the prime distractor "GRASS," and 144 trials later, the probe target was "grass." This represents an LTIR trial. As such, there were 24 trials in each of the four conditions.

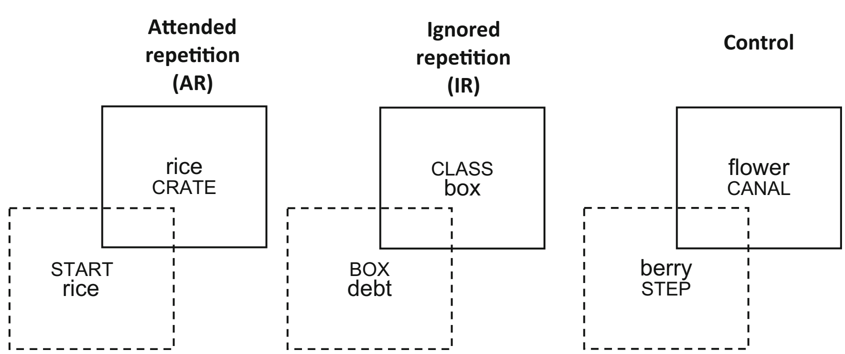

Fig. 1 Sample trial conditions. For prime displays (dashed outline), participants named the lowercase word (target) while ignoring the uppercase word (distractor). Prime displays were visible for 200 ms. The probe display followed 1,000 ms later. For probe displays, participants made a lexical decision to the lowercase string (target). The probe display remained visible until a lexical decision response was registered. On ignored repetition trials, the ignored uppercase prime distractor became the target of a lexical decision on the immediately following probe display (note the repetition of the word *box*); on control trials, there was no relationship between words on prime and probe displays; on nonword trials (half of all trials), the probe target was not an English-language word. Note prime displays appeared in the center of the screen or words were centered on a point 70 pixels to the left or to the right of screen center. Probe displays were always in the center of the screen. On every display, the spatial separation between target and distractor items was determined by the need to avoid overlap of lowercase ascenders and descenders with adjacent uppercase words. All uppercase and lowercase items were separated by the distance necessary to allow one screen pixel between the ends of ascenders or descenders and the top or bottom of the adjacent uppercase word (see the ignored repetition and control prime displays for examples of the need to avoid overlap with lowercase ascenders and descenders, and note the absence of ascenders and descenders in the control probe display in this example). Targets and distractors were displayed in bold 20-point Arial font, all in black on a white background

Half of the trials were "word" trials, and the remaining half were "nonword" trials. Further, by having half of the targets appear as nonwords, the proportion of IR trials was kept low. It has been established that negative priming is more likely to emerge in these conditions (Mayr & Buchner, 2010; Tse, Hutchinson, & Li, 2010) because it reduces the incentive to attend to the prime distractor due to anticipating that it might be the next probe target.

Design A within-subjects design was employed in which the dependent variables were lexical decision times and lexical decision error rates. The independent variables were priming (control vs. IR), and lag (short vs. long). In the STIR condition, prime and probe displays were in the same prime–probe couplet, whereas in the LTIR condition, 144 trials intervened between the prime and the probe displays. Table 1 shows a sample of the LTIR condition.

Three versions of the experiment were created for the purpose of counterbalancing. Participants were assigned at random to one of the three counterbalancing versions. The 144 probe target words were randomly divided into sets A, B, C, D, E, and F of 24 words each. Participants were assigned at random to one of three groups to achieve counterbalancing. The experiment was divided into two halves for counterbalancing, as no comparisons were made between the first and second half of trials. In the first half of the experiment, participants in Group 1 experienced Set A as IR trials and Set B as control trials; Group 2 experienced Set B as IR trials and Set C as control trials; and for Group 3, Set C were IR trials and Set A were control trials. In the second half of the experiment, participants in Group 1 experienced Set D as LTIR trials and Set E as control trials; Group 2 experienced Set E as LTIR trials and Set F as control trials; and for Group 3, Set F were LTIR trials and Set D were control trials. The entire trial set comprising 144 word and 144 nonword trials (common to all groups) was arranged in random order. The same random order was used for all participants, regardless of group. Further details about the current method of counterbalancing, as they apply to both experiments, are given in the Method section of Experiment 2.

The final trial was a catch trial that was included to identify whether participants were able to recall and/or recognize the prime distractor. The prime display was presented in the same way as the previous prime displays. However, instead of a probe display, a blank screen appeared, and the participant was given 5 s in which to name the prime distractor on the previous display. If they were unable to do so, they were asked to select the prime distractor from a display of three uppercase words.

Procedure Participants were tested individually in a quiet, artificially lit room. Following description of their task in the experiment, participants signed an informed consent form. They were then given printed and verbal instructions to name the lowercase word on each prime display and to ignore the uppercase word as best they could and to make a lexical decision to the lowercase item on probe displays as quickly as possible while trying not to make any errors. Participants were informed of naming, lexical decision, and procedural errors during practice trials. No feedback was given during the main trials. Participants were asked to make the lexical decision response on a Mitsumi electronics serial mouse. If the stimulus presented was a "word," participants were asked to press the left button with their index finger, and if the stimulus was a "nonword," they were asked to press the right button with their middle finger. On each trial, participants first saw a small fixation cross in the center of the screen for 500 ms. This was followed after a 200-ms blank screen by the prime display, which was visible for 200 ms. The screen then remained blank for 1,000 ms to allow participants time to name the prime target word aloud before the probe display appeared and was replaced by the fixation cross after registration of the lexical decision response. Appearance of the fixation cross indicated the commencement of the next trial couplet. The short prime display timing was designed specifically to increase attentional demands, which is known to increase the likelihood of a negative priming effect being observed (e.g., Neumann & DeSchepper, 1991; Wyatt & Machado, 2013).

The experiment consisted of 289 trials (including the catch trial) and on average took participants 25 minutes to complete. After the completion of 144 trials, there was a break of approximately 1 minute before the second half of the experiment began. Participants were informed of this and were asked to press the spacebar to begin trials again when prompted by the experimenter. At the commencement of the second half, all participants completed six warm-up trials that were not analyzed. The experimenter recorded the participant's verbal

Table 1 A sample of the long lag IR condition in Experiment 1

Prime display	Probe display				Prime display	Probe display
warrior PRISON	blob CLOUD	➡	144 intervening trials	➡	vacancy INCH	prison GRASS

Note. The prime distractor is the same word as the probe target 144 trials later. The entire trial set was arranged in random order. Hence, the trials preceding the long-lag IR condition were randomized as were the trials preceding the short-lag IR condition. This condition is identical to the short-lag IR condition, except for the additional 144 intervening trials response to the prime target on a response sheet. The criteria for a naming error was lenient, such that for a naming error to be recorded the participant must have either failed to name any word or failed to name a word that began with the same letter or sounded at all like the prime target word.

Results

Trials involving either commission or omission naming errors were treated as failures of selective attention and were thus removed from the RT analyses, as were trials where participants committed a lexical decision error. By definition, investigating mechanisms of selective attention requires participants to selectively process a target stimulus in the midst of nontarget information. In our task, confirmation of successful selection is supplied by a correct prime target word-naming response. This is a minimal mandate required by both the inhibition-based and episodic retrieval theories. If the task instructions were changed to first name the lowercase item, followed immediately by naming the uppercase item in the prime display, for example, it would no longer be considered a selective attention task. Instead, it would be considered a divided attention task, and neither theory would predict a negative priming outcome in such a scenario.

Cutoffs for naming and lexical decision errors were 20%. One participant failed to meet these criteria (for lexical decision errors). A further 10 participants were eliminated from further analysis due to a lexical decision error rate exceeding 20% in at least ONE of the control or IR conditions, although their total lexical decision error rates fell below 20%. These 10 participants did not exceed the overall cutoffs of 20% (naming errors) and 20% (lexical decision errors). Forty-six participants remained.

Analysis As can be seen in Fig. 2, there was a substantial difference in the mean RTs in the short-lag and long-lag conditions. This was expected, because participants tend to be faster overall during the second half of the experiment due to practice effects. More importantly, the IR conditions produced relatively slower responses than did the control conditions for each lag condition (see Fig. 2). These patterns were borne out by the analysis of variance (ANOVA) results and follow-up *t* tests. A 2 (priming: control vs. IR) × 2 (lag: short vs. long) repeated-measures ANOVA confirmed that RT was 70 ms faster in the long-lag conditions compared with the short-lag conditions, $F(1, 45) = 18.59$, $p < .001$, $\eta_p^2 = 0.292$. RT was 70 ms slower in the IR conditions relative to the control conditions, $F(1, 45) = 7.279$, $p = .01$, $\eta_p^2 = 0.139$. The Lag × Priming interaction was nonsignificant, $F(1, 45) = 1.966$, $p = .168$, $\eta_p^2 = 0.042$, indicating that there was no difference in IR impairment between the short-lag and long-lag conditions.

Due to the specificity of the aims of the current experiment, planned comparisons were conducted to determine whether the STIR condition and/or LTIR condition each independently produced negative priming. It was demonstrated that RT in the STIR condition was 86-ms slower than in the short-lag control condition, $t(45) = 4.217$, $p < .001$, 95% CI [45.36, 128.30], $d = 0.622$, indicating a negative priming effect. When comparing the long-lag control condition and the LTIR condition, RT was 54 ms slower in the LTIR condition, $t(45) = 2.759$, $p < .01$, 95% CI [14.59, 93.45], $d = 0.407$, once again demonstrating a negative priming effect. These analyses confirmed that negative priming was present at both short and long lags, independently. Across participants, the lag times between prime distractor and coupled probe target words for the LTIR manipulation ranged between 7.22 and 12.40 minutes ($M = 8.51$ minutes).

Error rates were analyzed in a similar manner and were larger in the long-lag conditions than the short-lag conditions, $F(1, 45)$ 9.520, $p = .003$, $\eta_p^2 = 0.175$ (see Table 2). Hence, although participants were overall faster to respond in the second half of the experiment, this speedup was compromised

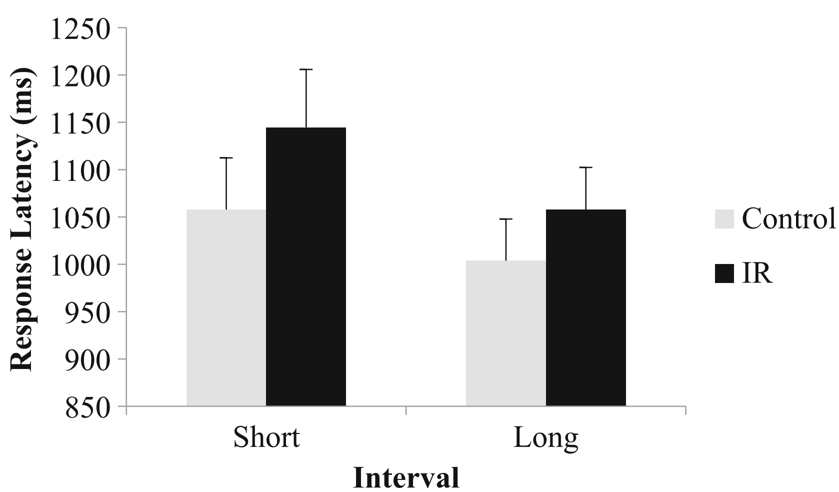

Fig. 2 Mean response latency (in milliseconds) as a function of lag and priming. Error bars indicate standard error of the mean

Table 2 Mean lexical decision error percentage for each condition in Experiment 1

	Control	Ignored Repetition
Short lag	3.79%	4.31%
Long lag	5.97%	6.54%
Total mean response errors	4.92%	

by committing more errors in the second half. The priming main effect for error rates was nonsignificant, $F(1, 45) = 0.982$, $p = .327$, $\eta_p^2 = 0.021$, thus indicating that error rates were not significantly different between the IR and control conditions. The Lag × Priming interaction was also nonsignificant, $F(1, 45) = 0.002$, $p = .964$, $\eta_p^2 < 0.001$. Overall, the error rate analyses indicate that a speed–accuracy trade-off does not compromise the negative priming effects obtained in the response latency data.

Analysis of the catch trial results demonstrated that only one out of 46 participants was able to recall the prime distractor in the catch trial. This was not subjected to further analysis, as clearly there is no evidence of explicit knowledge of the identity of the prime distractor word here. However, on the subsequent recognition portion of the catch trial, 22 out of 45 participants were able to correctly choose the prime distractor among the three options in the catch trial. A binomial test indicated that a higher proportion of participants recognized the prime distractor than would be expected by chance (0.33), ($p < .01$). Due to this, both the RT and error analyses were rerun with "catch recognition" added as a between-groups factor. In the RT analysis, it was found that catch recognition did not significantly interact with either lag or priming. Further, the main effect of catch recognition was not significant, $F(1, 43) = 1.504$, $p = .227$. In the error analysis, catch recognition did not interact with either lag or priming, nor did it produce a main effect, $F(1, 43) = 0.261$, $p = .612$. Collectively, these analyses demonstrate that negative priming across conditions was similar for participants who were able to identify the catch trial and participants who were not.[1]

Discussion

The results show that negative priming persisted over a delay of 144 trials or approximately 8 minutes. To our knowledge, this is the first documented finding of a protracted negative priming effect using common word stimuli. Indeed, other work using words as stimuli suggests that the negative priming effect is quite fleeting (DeSchepper & Treisman, 1996; Neumann et al., 2018). Although Grison et al. (2005) found long-term negative priming when using experimentally novel face and object stimuli, they concluded this was due to memory processes, as it was inconceivable to them that the inhibition of the prime distractor information could have been maintained over the delay. Further, the stimuli used by Grison et al. (2005) were novel, so participants would have had no prior mental representation of these stimuli. Yet, in the current experiment, long-term negative priming was found despite the fact that common word stimuli would carry many preexperiment representations in memory.

Some researchers have claimed that it is unlikely that inhibition lasts through the interference of many intervening trials (Grison et al., 2005; Treisman & DeSchepper, 1996). However, at this stage, the possibility that inhibition is the proximal cause of negative priming cannot be ruled out (Li et al., 2017). For example, the consequences of having suppressed a prime distractor may result in a raised threshold of activation for such distractor representations (Neumann & DeSchepper, 1991). In effect, this could yield negative priming effects that last over the course of minutes and many intervening stimuli. Intriguingly, consistent with the work of Treisman and DeSchepper (see also DeSchepper & Treisman, 1996), what our negative priming results with nonrecycled common words clearly show is that, just like nonrecycled novel shapes, the mechanism that affects a prime distractor can have long-term consequences, despite many intervening stimuli and time lapses on the order of at least minutes.

In terms of the interpretation of long-term negative priming from an episodic retrieval perspective, a possible argument is that when the probe was presented, the most recent memory of that stimulus would be retrieved. Although this appears to be a plausible explanation, Treisman and DeSchepper (1996) claim that the recency effect in retrieval, when words are used, disappears within two trials such that if the presented item was seen more than two trials earlier, it will be just as likely that the retrieval of that item will elicit an "attend" tag as an "ignore" tag. Consistent with this, memory research shows that the recency effect is cancelled out if there are intervening working memory tasks that exceed 15–30 seconds in duration (Bjork & Whitten, 1974). With respect to the current results, it is possible that the relevant context occurred 8 minutes beforehand. Although the task involved a response change between the prime and its coupled probe, as well as a change from uppercase to lowercase letters, it could be argued that other features (e.g., two words always shown on the screen; the same size and color of the fonts; subjects always responding to the lowercase word and ignoring the uppercase word) made the encoding and retrieval contexts similar. This similarity between the prime and probe episodes could have made the

[1] It should be noted that data were subsequently also analyzed without the error rate exclusion constraint set for each condition. This meant that only one participant (rather than 12) was excluded. All trends in the data were the same under these more lenient exclusion conditions and would not have altered the interpretation of the results. More specifically, for both the RT and error-rate analyses, the results were the same regarding all statistically significant effects, as well as all nonsignificant effects, and would not have altered the interpretation of the results.

retrieval of the prime episode, including elicitation of the "do-not-respond" tag attached to the distractor word, accessible and thus plausibly predict long-lag negative priming. Hence, the results from the Experiment 1 could be explained either by an inhibition or by an episodic retrieval account.

Experiment 2

The current experiment aims to pursue these alternative explanations by using a positive priming paradigm that is identical to the paradigm used in the Experiment 1, with the exception that it tests for immediate and lagged attended repetition positive priming effects instead of IR negative priming effects. An attended repetition (AR) trial involved the target word on the prime trial being identical to the target word on the probe trial. In this case, positive priming would be evidenced by faster or less error-prone responses to the AR conditions compared with the control conditions. In the current experiment, the long-term AR (LTAR) manipulation occurred with exactly the same number of intervening trials as in the IR negative priming study. Moreover, all word lists, timing of stimuli, presentation of stimuli, and response requirements were designed to match the previous IR experiment. The only difference in the current experiment was that the word stimuli from the previous IR conditions were altered so that instead of the prime distractor word becoming the probe target, it was the prime target word that became the probe target word in the short-term AR (STAR) and LTAR conditions.

If the long-lag IR negative priming observed in the previous experiment can be explained by an episodic retrieval account, then it would be expected that long-lag AR positive priming should be observed in the current experiment. At the presentation of the probe trial, the prior episode of similar context (the prime trial) should be retrieved with a "respond" tag and thus should lead to facilitation. Indeed, there is actually greater similarity between the prime target and probe target in the current AR experiment, compared with the IR experiment. In the current experiment, the word and font are identical in the AR conditions, whereas in Experiment 1 there was a font change from uppercase to lowercase letters between prime and probe targets in the IR conditions. According to episodic retrieval theory, the similarity between the prime and probe targets in the current experiment should create optimal conditions for producing priming effects due to more similar perceptual overlap between the target prime and target probe words. Under these conditions, in contrast to IR conditions, it should be even more likely that the probe target is able to elicit the prime target along with its congruent "respond" tag and thus produce a positive priming effect. Accordingly, episodic retrieval would predict a greater likelihood of obtaining AR positive priming in Experiment 2, compared with obtaining IR negative priming in Experiment 1.

Method

Participants There were 54 (43 female) participants, ages 17–46 years. Twenty students participated to fulfill credit for an introductory psychology course, while the remaining 34 participants were recruited from the University of Canterbury and the general public. These participants were rewarded with a $10 grocery voucher for their participation.

Stimuli and apparatus All stimuli and apparatus were identical to Experiment 1, with the exception of STIR trials being replaced with STAR trials, and LTIR trials being replaced with LTAR trials. The 144 word trials were configured as follows: 48 control trials, 24 LTAR trials, 24 STAR trials, and 24 word filler trials.

Design A within-subjects design was employed in which the dependent variables were lexical decision times and lexical decision error rates. The independent variables were priming (control vs. AR) and lag (short vs. long). In the STAR condition, prime and probe displays followed immediately, whereas in the LTAR condition, 144 trials intervened between the prime and the probe displays. Table 3 shows a sample of the LTAR condition. The counterbalancing of the experiment was identical to Experiment 1, with AR trials replacing IR trials and LTAR trials replacing LTIR trials. The overall method of counterbalancing was designed to eliminate potential word list artifacts independently for the short-lag conditions and the long-lag conditions in the two experiments. This was done by having all of the probe target words in the short-lag conditions in Experiments 1 and 2 counterbalanced across participants, and all of the probe target words in the long-lag

Table 3 A sample of the long-lag AR condition in Experiment 2

Prime display	Probe display		Prime display	Probe display
prison	blob	144 intervening trials	vacancy	prison
WARRIOR	DOG		INCH	GRASS

Note. The prime target is the same word as the probe target 144 trials later. This condition is identical to the short-lag AR condition except for the additional 144 intervening trials conditions in Experiments 1 and 2 counterbalanced across participants. The aim was to ensure that, across participants, the STAR, STIR, and control conditions were perfectly counterbalanced with one another. This way, the same probe target words (in exactly the same trial serial positions) would be encountered as the target probes in the STAR, STIR, and control condition, respectively. The same logic applied to the LTAR, LTIR, and control conditions.

The catch trial differed from Experiment 1 in that if participants were unable to recall the prime distractor, they were asked to select the prime distractor from a list of five uppercase words that all began and ended with the same letters.

Procedure The procedure did not differ from Experiment 1.

Results

The error cutoff rates were identical to Experiment 1. One participant failed to meet this criteria (for naming errors). A further six participants were eliminated from further analysis due to a lexical decision error rate exceeding 20% in at least one of the control or AR conditions, although their total lexical decision error rates fell below 20%. These six participants did not exceed the overall cutoffs of 20% (naming errors) and 20% (lexical decision errors). Forty-seven participants remained.

Analysis Figure 3 shows the means and standard errors of the four conditions. A 2 (priming: control vs. AR) × 2 (lag: short vs. long) repeated-measures ANOVA confirmed that RT was faster in the AR conditions compared with the control conditions, $F(1, 46) = 36.335$, $p < .001$, $\eta_p^2 = 0.441$. There was no statistically significant difference between RT in the short-lag conditions compared with the long-lag conditions, $F(1, 46) = 1.358$, $p = .250$, $\eta_p^2 = 0.029$. Importantly, the Lag × Priming interaction was significant $F(1, 46) = 27.701$, $p < .001$, $\eta_p^2 = 0.376$, indicating a difference in the magnitude of AR facilitation between the short-lag and long-lag conditions.

Due to the specificity of the aims of the current experiment, planned comparisons were conducted to determine whether the STAR condition and/or LTAR condition each independently produced positive priming. It was demonstrated that RT in the STAR condition was 180 ms faster than in the short-lag control condition, $t(46) = 6.447$, $p < .001$, 95% CI [123.80, 236.22], $d = 0.94$, indicating a positive priming effect. When comparing the long-lag control condition and the LTAR condition, RT was not significantly different, $t(46) = 0.097$, $p = .923$, 95% CI [−33.59, 30.51], $d = 0.01$, demonstrating that at the long lag, there was no evidence of positive priming. Across participants, the lag times between prime distractor and coupled probe target words for the LTAR manipulation ranged from 7.06 to 12.30 minutes (M = 8.46 minutes). This was comparable to the LTIR lag time in Experiment 1 (M = 8.51 minutes).

Error rates (presented in Table 4) were similarly analyzed and were greater in the long-lag conditions than in the short-lag conditions, $F(1, 46) = 23.843$, $p < .001$, $\eta_p^2 = 0.341$. The priming main effect for error rates was also significant, $F(1, 46) = 4.647$, $p = .036$, $\eta_p^2 = 0.092$, indicating that error rates were significantly greater in the control conditions compared with the AR conditions. The Lag × Priming interaction was not statistically significant, $F(1, 46) = 0.051$, $p = .822$, $\eta_p^2 < 0.001$. Due to the significant main effect of priming in the error rates, further analyses were conducted to see if each lag independently produced a positive priming effect in the error rates. When comparing the long-lag control and the LTAR conditions, error rates were not significantly different, $t(46) = 1.389$, $p = .172$. Similarly, there was no significant difference between the error rates for short-lag control and short-lag AR, $t(46) = 1.868$, $p = .07$. Overall, the error rate analyses indicated that a speed–accuracy trade-off does not compromise the priming effects obtained in the response latency data.

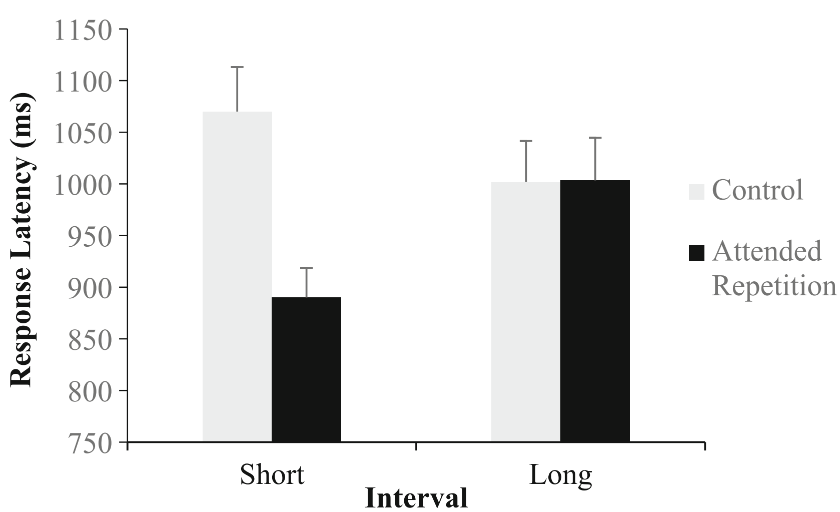

Fig. 3 Mean response latency (in milliseconds) as a function of lag and priming. Error bars indicate standard error of the mean

Table 4 Mean lexical decision error percentage for each condition in Experiment 2

	Control	Attended repetition
Short lag	2.88%	1.65%
Long lag	5.05%	4.03%
Total mean response errors	3.06%	

Analysis of the catch trial results demonstrated that only one out of 47 participants was able to recall the prime distractor in the catch trial. This was not subjected to further analysis, but it clearly indicated that there is little evidence of explicit knowledge of the identity of the prime distractor word. Coincidentally, it was also the case that only one person out of 45 was able to recall the catch trial distractor in the previous IR experiment. On the subsequent recognition portion of the catch trial, 11 out of 46 participants (24%) were able to correctly choose the prime distractor among the five options in the catch trial. A binomial test indicated that the proportion of participants who correctly recognized the prime distractor was no different than what would be expected by chance (20%; $p = .306$).

This forced-choice recognition performance, which is indicative of random chance guessing on the catch trial, is closely in line with other negative priming paradigms that have used a catch trial (e.g., Duscherer & Holender, 2002; Treisman & DeSchepper, 1996). The inability of nearly all of the participants in Experiments 1 and 2 to recall the prime distractor word, combined with the chance recognition performance on the catch trial of Experiment 2, strongly implies that the prime distractor words in both experiments are not explicitly identifiable. Thus any short-term or long-term IR priming effects produced by distractor words are by definition implicit memory effects, whereas any short-term or long-term AR priming effects produced by attended and responded-to words are by definition explicit memory effects.

Discussion The results demonstrate that positive priming occurred in the STAR condition, as evidenced by a decrease in RTs in the AR condition relative to the control condition. This finding is consistent with much previous research suggesting that presentation of a stimulus facilitates subsequent processing of that same stimulus. However, it was demonstrated that this effect failed to persist over the course of several minutes and 144 intervening trials. In combination with the results obtained in Experiment 1, these results have implications for the understanding of mechanisms underlying the temporal dimension of AR positive priming and IR negative priming as detailed below.

General discussion

Temporal dimension of priming

Experiment 1 reported a large negative priming effect that endured over the course of 8 minutes and many intervening trials. The results from Experiment 2, however, showed only a large immediate positive priming effect. Contrary to the results from Experiment 1, this effect was not evident in the 8-minute delay condition. The LTIR effect found in Experiment 1 was, to our knowledge, the first documented finding of long-term negative priming with word stimuli. Treisman and DeSchepper (1996), using lags of 100 and 200 intervening trials, failed to find long-term negative priming with word stimuli selected from a large pool of words, where words were presented only once, except to fulfill the IR manipulation. However, the current experiments differ from that of Treisman and DeSchepper (1996) in that participants are required to name a prime word target and then make a lexical decision to the probe target rather than make a same–different response to both prime and probe targets. Furthermore, the selection cue used was letter case rather than color, as was used in Treisman and DeSchepper (1996). In addition, the change in response requirement from naming in the prime display to a lexical decision in the probe display should increase attentional demands. This is important because it has previously been established that the magnitude of negative priming tends to increase when the attentional demands, due to conflict between target and distractor stimuli, are heightened (e.g., Moore, 1994; Neumann & DeSchepper, 1991; Pritchard & Neumann, 2011; Tipper & Cranston, 1985; Wyatt & Machado, 2013). It is also possible that naming and/or decision lexical tasks would require a deeper level (e.g., conceptual or semantic) of processing of critical stimuli, than making a same–different (more perceptual) judgements in a matching task. Thus, obtaining long lasting NP with words could require a conceptual (semantic) rather than a perceptual level of processing. This could be a critical factor explaining the inconsistences between the results from Experiment 1 and those observed by Treisman and DeSchepper (1996).

Under the current conditions, the word-case selection cue, proximity of the target and distractor in each display, and spatial uncertainty and temporal briefness of the prime display should all contribute to consistent selection difficulty. The aggregate of these efforts to induce a heightened state of attentional selectivity in an experiment-wide manner was designed to produce the circumstances under which a long-term negative priming effect with words should be obtained.

Tipper and Milliken (1996) argued that multiple preexperiment representations of a familiar distractor stimulus would lead to a failure to find long-term negative priming. Yet, in Experiment 1, negative priming was found despite the fact that common word stimuli would carry many preexperiment representations in memory. This finding is somewhat problematic for episodic retrieval proponents. From an episodic retrieval perspective, it could be claimed that the contextual similarities between the prime and probe episodes would be enough for the prime distractor part of the episode (with its "do-not-respond" tag) to be elicited when the probe target episode is presented (e.g., "warrior" preceded by "WARRIOR," respectively, after many intervening attentional displays and minutes). Although the change from naming a prime target to making a lexical decision to a probe target 8 minutes later constitutes a large contextual change, there are also a number of contextual similarities between prime and probe episodes, such as similarity of size and type of font, two words being presented simultaneously, and the subjects' requirement to always respond to the lowercase and ignore the uppercase item). Thus, it could be argued that these contextual similarities were sufficient for episodic retrieval to occur in the LTIR condition of Experiment 1.

Previous research suggests that words are able to produce facilitation at lagged intervals. However, these intervals were much shorter than those used in the current experiments. Among the longest intervals, Kersteen-Tucker (1991) reported significant facilitation at lags as great as eight intervening stimuli. Further, Bentin and Moscovitch (1988) found that words produced significant repetition effects at lags of four and 15 intervening stimuli, and that there was no difference in the magnitude of these effects.

Conversely, in a follow-up experiment, Bentin and Moscovitch (1988) found that this effect was eliminated under conditions where participants directed their attention only to superficial features of the words. They concluded that these conditions led to the creation of a weak memory trace at the prime such that the probe episode was not sufficient to elicit this trace. By contrast, it was proposed that retrieval of the prime episode is the underlying mechanism of facilitation at lagged intervals whenever such facilitation occurs. It could be claimed that in the present Experiment 2, although participants were required to read the target-word aloud, they may not have had adequate time to access a deeper internal representation of the word and thereby create a robust enough memory trace for episodic retrieval to occur 144 trials later. If this reasoning held true, however, it would be improbable that long-term negative priming would be found under the same task conditions. In this regard, it is noteworthy that in Experiment 1 the prime distractor was purposely ignored, and participants should thus be even less likely to access deeper internal representations of this stimulus than one they had spoken aloud in the AR condition.

Wheeldon and Monsell (1992) proposed that facilitation at long intervals is due to a change in the processing pathway rather than to the retrieval of an episodic trace. These authors claim that it is unlikely that there would be time for a prime episode to be retrieved in an experiment such as the current one due to the limited processing time devoted to the prime target. Their experiments are some of the only available that investigate positive priming over intervals, with many intervening trials, more comparable to the present experiment. In their experiments, the prime presented was either a definition or a word prime. After a delay of 60 to 120 intervening trials, a probe appeared in the form of a picture, and participants were required to respond by producing a spoken word. Significant positive priming was found at a long lag when participants were primed with either a definition or a word prime. This result appears to be inconsistent with the results of Experiment 2, where no long-lag positive priming was observed with word primes. However, Wheeldon and Monsell were unsure as to whether it was the production of the phonological word form alone or whether it was the activation of the word's meaning that produced the positive priming effect. They suggested that because their experiment included definitions and pictures, this may have enticed the participants to rehearse the link between the phonological form and the meaning when presented with a word prime. They further commented that their results may have been quite different if the experiment had only included word primes and no definitions or pictures.

Consequently, Wheeldon and Monsell (1992) conducted a follow-up experiment and reported an absence of facilitation when using homophones. They concluded that prior production of the same phonological word form is inadequate in generating a positive priming effect over long intervals. In the present Experiment 2, the prime task involved the participants reading aloud the target word. If production of the phonological word form alone is not enough to produce long-lag priming effects, then it is unsurprising that no long-term positive priming was evident in Experiment 2. However, it would also be expected that there would be no long-term negative priming evident in Experiment 1.

An important feature of the explanation provided by Wheeldon and Monsell (1992) is that priming effects over long lags are mediated by how the initial prime is processed. It was further suggested that the rehearsal of the link between the phonological word form and its appropriate meaning can lead to facilitation. In the present experiments, the initial processing of the prime stimulus used for the long-lag priming conditions is very different between Experiment 1 and Experiment 2. Whilst Experiment 2 requires the participant to read aloud the prime target, making it consciously accessible, Experiment 1 requires the participant to ignore the prime distractor, and it can be assumed that this distractor is not within conscious awareness. These conditions would not encourage rehearsal between the phonological word form and its meaning. Although such rehearsal may explain facilitation effects at long lags, when they are found, it does not explain inhibition effects. It is suggested that the differential processing of the prime stimulus between the AR and IR conditions determines whether these effects will be evident over large delays. It cannot be assumed that the same mechanisms that underlie long-term facilitation also underlie long-term inhibition.

The episodic retrieval perspective has difficulty accommodating the absence of long-term AR facilitation. If long-term IR negative priming results from the retrieval of the prime distractor with a “do-not-respond” tag and its ensuing incompatibility with an upcoming “respond” tag, it would be expected that facilitation should occur in the LTAR condition of Experiment 2, because of the compatibility between the congruent “respond” tags. Clearly, there was no facilitatory LTAR effect, despite observing LTIR impairment in the current study. As specified earlier, Experiment 1 and Experiment 2 were designed almost identically in that all timing and presentation of stimuli, along with the response requirements from the participants, and the number of intervening trials in the delay were identical. Furthermore, the word lists that were used for the LTIR manipulation in Experiment 1 were the same word lists used in the LTAR manipulation in Experiment 2. Therefore, episodic retrieval alone cannot account for why LTIR occurs when LTAR does not occur under identical conditions. In fact, the strictures of the episodic retrieval account would predict that it should have been more likely for LTAR to occur than LTIR in these two experiments. More specifically, since the probe target in the LTAR condition of Experiment 2 is perceptually identical to the prime target presented earlier, it should have created the perfect similarity gradient for episodic retrieval to occur. The probe target in the LTIR condition of Experiment 1, however, although conceptually the same as the prime distractor, differs in that the probe target is presented in lowercase while the prime distractor was presented in uppercase. As such, the elicitation of episodic retrieval in the LTAR condition should be much more likely to occur since the prime and probe targets matched in form as well as meaning, whereas in the LTIR the prime distractor and probe target word matched in meaning, but not in form. The contrary pattern of findings makes it highly questionable whether episodic retrieval is the mechanism responsible for the LTIR effect reported here.

Why, then, is it the case that LTIR can be observed in the absence of LTAR despite using tasks that, under the auspices of episodic retrieval, should be much more likely to produce LTAR than LTIR? From our perspective, a noteworthy difference between the LTIR experiment and the LTAR experiment is how the initial prime word is processed. In the LTIR experiment, the prime distractor word is ignored by the participant and processed implicitly such that there is no conscious awareness of the identity of the prime distractor word. In the LTAR experiment, however, the prime target word is processed explicitly as participants are speaking the prime word aloud and hearing themselves say the word. Based on the contrasting findings, it appears that explicit processing of a prime target word is subject to interference not encountered by the implicit processing of an ignored word. The explicit processing of the prime target makes it highly likely that participants could have noticed that the prime target they read aloud was sometimes immediately presented as the probe target (the STAR condition). It is doubtful, however, that any participant recognized that prime targets sometimes become probe targets 144 trials later (the LTAR condition). If there were any anticipatory biases in the current experiments, then it is plausible that participants could expect that if the prime target word was presented twice, it would be done immediately in the same trial. Accordingly, after making a lexical decision to the probe target in a given trial, any continued activation of the prime target would be considered unnecessary and would likely dissipate, leading to the absence of an LTAR effect. In the LTIR experiment, however, the unconscious processing of the prime distractor word would make it improbable that participants would recognize the relationship between the ignored prime distractor and the probe target, even within the immediate condition.

Catch trial results and implications

The catch trial for Experiment 1 presented only a final prime display, followed immediately by a screen asking participants if they could recall the prime distractor. After 5 seconds, a display of three words of the same length as the prime distractor appeared on the screen, and the participants were instructed to choose which of the three items was previously presented as the prime distractor. Under these conditions, it was found that there was a difference between recollection and recognition memory in the catch trial. While only one participant was able to recall the prime distractor in the catch trial when asked, significantly more than a chance number of participants were able to choose the prime distractor from a list of three words (recognition test).

Typically, in negative priming research, participants are unable to recognize the distractor in catch trials. For example, DeSchepper and Treisman (1996) presented multiple catch trials throughout their experiment that involved four shapes being presented on the screen and requesting participants to choose which one they had seen before. Of these four shapes, one had previously been an ignored distractor whilst the other three were experimentally novel. Thus, participants had a 25% chance of guessing correctly if there was no explicit recognition of the previously ignored shape. It was found that correct recognition of ignored shapes averaged 26%, which was not significantly different from chance. Furthermore, a recent study found that participants demonstrated intertrial priming in the absence of explicit recognition memory for target identification (Jiang, Shupe, Swallow, & Tan, 2016). The explanation for these findings was that the surprise memory test used to assess recognition memory may have disrupted memory for the target item. However, Jiang et al. (2016) also assumed that under some conditions people retain information about visual attributes of stimuli, and this information may be in the form of an implicit memory trace.

Recognition is generally considered a form of explicit memory that requires conscious recollection (Roediger, 1990). This being the case, it is surprising that participants in Experiment 1 were able to recognize the prime distractor if it is accepted that no explicit information about the distractor is stored. If the prime distractor is processed exclusively in the implicit memory system, explicit recognition should not occur. However, a study by Johnston, Hawley, and Elliot (1991) demonstrated that perceptual fluency influenced recognition judgments, but only when there was no explicit memory for the event. Furthermore, they reported that accurate recognition judgments can be obtained even when there is no explicit memory for the item. In Experiment 1, the three word options in the recognition test were all completely different from one another, and each began and ended with different letters. It was therefore assumed that some participants may have recognized some distinguishing tick marks from the letters of the prime distractor that led to above-chance guessing of the correct recognition word.

Accordingly, the catch trial in Experiment 2 was redesigned to test the above assumption. Following a typical prime display, participants were asked if they could recall the prime distractor. After a period of 5 seconds, five items were presented on the screen. All were equal in length to the prime distractor. In addition, they all began and ended with the same letters as the prime distractor. For example, if the prime distractor was "GUIDE," then the five options presented were GLARE, GAUGE, GRATE, GUIDE, and GRIPE. Under these new conditions, it was found that participants were now unable to recognize the prime distractor. This supports the assumption that participants in Experiment 1 were simply recognizing at least a subset of perceptual features of the prime distractor to enable above-chance guessing rather than recognizing the prime distractor word itself and having an explicit memory of the prime distractor word. In order for catch trials to accurately gauge the identification of prime distractor words, future negative priming experiments that involve words as stimuli should follow the present Experiment 2 protocols.

Conclusion

Using a large pool of nonrecycled words, the current experiments found evidence of short-term and long-term negative priming and short-term positive priming, but no long-term positive priming. The lack of positive priming at long lags is consistent with previous research suggesting that the activation of a word's meaning is necessary to produce a durable, ongoing facilitation effect. The present experiments were specifically designed to investigate whether long lag attended repetition positive priming would occur under identical conditions to long lag ignored repetition negative priming. The results demonstrate that long-term positive priming is unlikely to be observed under identical circumstances in which long-term negative priming is clearly observed. Long-term negative priming appears to be a more ubiquitous phenomenon than previously thought.

Taken together, this work provides important new findings that help to understand differences in the durability of priming effects between ignored implicit memories and attended explicit memories. Interference from subsequent explicit information was shown to have a larger impact on the durability of explicit memories, whereas subconscious implicit memory appears to be less burdened by interference from further implicit or explicit memories. Attended repetition and ignored repetition manipulations show different capacities for generating long-term priming effects as revealed by observing different thresholds for quick accessibility upon the reappearance of their respective probe target words. These results contribute to a better understanding of the mechanisms underlying selective attention and question the main tenets of an episodic retrieval perspective of priming.

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