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Comparing effects of perceptual and reflective repetition on subjective experience during later recognition memory

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Abstract

Using the Remember/Know procedure, we compared the impact of a reflective repetition by refreshing (i.e., briefly thinking of a just-seen item) and a perceptual repetition (i.e., seeing an item again) on subjective experience during recognition memory. Participants read aloud words as they appeared on a screen. Critical words were presented once (read condition), immediately repeated (repeat condition), or followed by a dot signalling the participants to think of and say the just-previous word (refresh condition). In Experiments 1 and 2, Remember responses benefited from refreshing a word (in comparison with reading it). In Experiment 2, this benefit disappeared when participants had to refresh one of three active items. Perceptual repetition increased Remember responses in Experiment 1, but not in Experiment 2 regardless of whether participants had just previously seen 1- or 3-items. These findings indicate that under some circumstances, reflective and perceptual repetition may have different consequences for later subjective experience during remembering, suggesting differences in their underlying functional mechanisms.

Keywords: Subjective states of awareness; Recognition memory; Recollective experience; Refreshing; Encoding; Remember/know; Attention; Selection

1. Introduction

Many studies (including the classic work of Ebbinghaus, 1885/1964) show that long-term memory often benefits from repetition. We investigated the nature of the long-term memory benefit from a single repetition of two types—perceptual repetition (perceiving an item again immediately) or reflective repetition (perceiving an item and then mentally thinking of it immediately in its absence). These simple acts of briefly looking again

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at something or immediately thinking of it are interesting because they constitute basic perceptual and reflective attentional processes that contribute to conscious experience. We asked what are the relative effects on long-term memory, especially subjective experience during remembering, of a perceptual repetition vs. a reflective repetition?

This question may be addressed in the framework of the Multiple-Entry, Modular Memory framework (MEM) proposed by Johnson and colleagues (e.g., Johnson, 1992; Johnson, Reeder, Raye, & Mitchell, 2002). MEM is a process-oriented model that distinguishes between perceptual component processes and reflective component processes of cognition. Perceptual processes act in response to external stimuli whereas reflective processes allow one to mentally maintain, revive, or act on the products of prior perception or thought. Reflective processes can be thought of as a part of the executive function of working memory (e.g., Baddeley & Hitch, 1974) in that some are recruited to manipulate and organize active information. One of the simplest reflective processes is *refreshing*, that is, thinking of an item that was just perceived and whose representation is still active. It serves to foreground a representation against a background of other active representations, thus making the item a focus of reflective attention (Raye, Mitchell, Reeder, Greene, & Johnson, in press; see also Cowan, 1999) just as selective perceptual attention to a visual display can foreground one of several external stimuli (e.g., Desimone & Duncan, 1995). Refreshing can be considered as an instance of repetition in that the item is processed twice (e.g., the first time perceptually, the second time reflectively); the second processing of the item occurs when the item is not externally present. It can be distinguished from other types of reflective repetition such as rehearsal of active information in a cyclic manner over several seconds, or reactivating information that is no longer active. It can also be distinguished from generation, in which an item is mentally generated in response to a cue but has not just been previously perceived or thought. Ranganath, Cohen, and Brozinsky (2005) proposed that refreshing may operate during the initial stage of working memory maintenance and contribute to successful long-term memory formation over and above processing that occurs later in the memory delay. Thus, one possibility is that refreshing helps transform a temporary perceptual representation in iconic memory into a stable working memory representation that can be maintained for a longer period. Here we investigate whether a reflective act as simple as refreshing contributes to the conscious experience of remembering on a later occasion and whether its effects are comparable to or different from seeing an item again.

Johnson and colleagues (e.g., Johnson et al., 2005) have investigated refreshing by cueing participants to immediately think of an item they just perceived. For example, in one study (Johnson et al., 2002), participants read aloud unrelated words presented one after another on a computer screen. Critical words were presented once (*read* condition), immediately repeated (*repeat* condition), or followed by a dot signalling the participants to think of the just-previous word and to say it again (*refresh* condition). Verbal response times were compared across conditions. This first phase was followed by a surprise recognition memory test in which previously presented words were randomly mixed with new words. In this study and others using a similar experimental procedure, participants typically show a long-term recognition memory benefit for refreshed items relative to read items (Grillon et al., 2005; Johnson, Mitchell, Raye, & Greene, 2004; Johnson, Raye, Mitchell, Greene, & Anderson, 2003; Johnson et al., 2005, 2002; Raye, Johnson, Mitchell, Greene, & Johnson, 2007; Raye, Johnson, Mitchell, Reeder, & Greene, 2002) and repeated items (Johnson et al., 2002; Raye et al., 2002). They also typically show a recognition benefit from perceptual repetition of an item (*repeat* condition compared to items read once) (Grillon et al., 2005; Johnson et al., 2004, 2005, 2002; Raye et al., 2002; but see Johnson et al., 2003). None of these studies (with the exception of Grillon et al., 2005, discussed below) assessed the subjective experience of the participants during long-term recognition; rather, they focused on recognition accuracy.

Recognition memory sometimes involves the experience of consciously recollecting details of a particular event and sometimes involves only a feeling of familiarity (e.g., Gardiner, 1988; Johnson, Hashtroudi, & Lindsay, 1993; Mandler, 1980; Tulving, 1985). Tulving (1985) proposed the Remember–Know procedure to investigate this difference in subjective experience. Participants are asked to make a Remember response if recognition is accompanied by the conscious recollection of some specific feature of the item's presentation (where it was, what they thought, etc.) and a Know response if recognition is associated with feelings of familiarity in the absence of conscious recollection of the item's presentation.

Combining the Remember–Know procedure and the refresh paradigm in patients with schizophrenia and their controls, Grillon et al. (2005) showed that for Remember responses, both groups benefited from processing a word twice (i.e., in the refresh and the repeat conditions) in comparison with reading it once (i.e., the read condition). However, because the experimental procedure had to be adapted to patients with schizophrenia, presentation time of items in the encoding phase was a relatively long 2000 ms. Therefore, participants may have had enough time to engage additional processes at encoding during repeat trials. For instance, some control participants reported that they mentally rehearsed the word during its initial presentation in all conditions. Thus, it cannot be ruled out that the benefit in Remember responses on the perceptual repetition condition might have been due to the fact that participants actively rehearsed the word when it was initially presented rather than to the fact that they perceived the item a second time. In Experiment 1, we used the same experimental procedure as in Grillon et al. (2005) except that words stayed on the screen 1000 ms instead of 2000 ms to reduce the likelihood that participants would engage in additional spontaneous processing, such as mental rehearsing, during the initial stimulus presentation (the interstimulus interval was the same in both experiments, 500 ms). If the mere act of processing twice (either perceptually or reflectively) produces an increment in Remember responses, then we would expect both perceptual repetition and refreshing to increase Remember responses in comparison with reading, even after the opportunity for rehearsing is reduced for both conditions. In contrast, if Remember responses during long-term recognition memory are more likely after mentally foregrounding an active representation of a stimulus that is no longer present (refreshing) than seeing the stimulus again (repeating), this would argue for a special role of reflection in creating memory representations that later result in the subjective experience of recollection.

2. Experiment 1

2.1. Methods

2.1.1. Participants

Thirty French native speaking students (seven men, 23 women) ranging in age from 22 to 34 years (mean age = 25.0, $SD = 2.98$ years) were tested individually. They provided informed written consent and were paid for their participation. The protocol was approved by the Ethical Committee of Pitié-Salpétrière hospital.

2.1.2. Materials

A set of 180 common French two-syllable words, each between four and ten letters in length, with a mean word frequency of 46.24 pm was selected from the Brulex database. This word set was randomly divided into five subsets of 36 items each, which did not differ in terms of mean word frequency or mean number of letters ($F < 1$). Each subset was presented equally often as target items in each experimental condition of the first phase and as new words in the recognition task.

2.1.3. Procedure

During Phase 1, stimuli were displayed on a computer screen at a 1500 ms rate (1000 ms on, 500 ms interstimulus interval). In each of the 108 trials, participants read a word aloud. This word was followed by a new word in the read condition (36 trials), by the same word in the repeat condition (36 trials), and by a dot (•) that signalled participants to think of the word that preceded the dot and to say it aloud in the refresh condition (36 trials). These three types of trials were pseudo randomly mixed. Participants were asked to read or say aloud the words as quickly as possible and were not informed of the subsequent recognition test. Response times (from the onset of the word or dot on the second screen of each trial) were collected via a voice key.

During a 15-min interval separating Phases 1 and 2, participants were given a set of oral and then typed instructions regarding Remember, Know, and Guess responses and the general test procedure. The instructions were closely based on those of Gardiner, Java, and Richardson-Klavehn (1996). A Remember response was defined as conscious awareness of some aspect of what had happened or been experienced when the word was presented. Examples included an association with another list word, an image that came to mind, something about the physical appearance or the position of the word, something of personal significance in autobiographical memory, or something that had happened in the room. A Know response was described as the knowledge that an item had appeared in the study list but without any conscious recollection, the recognition being based primarily on feelings of familiarity. A Guess response was to be used for words that elicited neither the experience of remembering, nor of knowing, but that might have appeared during the learning phase. The participants were asked to read carefully the typed instructions. We discussed these instructions with them, after they had read them, to ensure understanding and trained them to use these instructions on a practice task. They had to explain their responses at the end of this practice task to check that instructions were followed and that the Remember, Know, and Guess responses were properly used. They were informed that they could refer to the typed instructions during the test phase as often as they needed to.

Phase 2 was a recognition memory task consisting of 180 items (the 144 items presented in Phases 1 and 36 completely new items). Each word on the test list appeared on the screen until the participants clicked the button for a Yes response if they recognized the word as having occurred during the learning phase or a No response if they did not recognize the word. If the response was Yes, the participants then clicked one of three other buttons labelled Remember, Know, and Guess. Then the next word appeared. If the response was No, the next word appeared immediately. At the end of the test, participants were asked to report what they did during Phase 1 and then explicitly asked whether they rehearsed or attempted to hold in mind the first item of each trial.

2.2. Results

Significant effects from the analyses of variance were followed-up by Fisher LSD tests to localize differences. Alpha level was set at $p < .05$.

2.2.1. Phase 1

In contrast with Grillon et al. (2005), no participants reported attempting to rehearse or hold in mind any item. Response accuracy in all conditions was 100%. Trials in which the microphone was spuriously triggered (in less than 75 ms) were removed from response time analyses ($p < 1\%$). Mean response times for Phase 1 were computed separately for read, refresh, and repeat conditions (see Table 1) and subjected to an analysis of variance (ANOVA) on repeated measures with Condition of presentation (read, refresh, and repeat) as a within subject factor. There was a significant Condition effect ($F(2, 58) = 64.00$, $p < .0001$): participants read a word faster in the repeat (perceptual repetition) condition than in the read condition ($t = 9.13$, $p < .0001$) and were slower to refresh than to repeat a word ($t = 10.35$, $p < .001$). They were slightly slower to refresh than to read an item, but this difference was not significant ($t = 1.22$, $p = .22$).

2.2.2. Phase 2

Only target items from the second phase of each trial were included in the analyses of recognition responses (i.e., the refreshed item, the repeated item, or the second item presented on read trials). Proportions of Remember, Know, and Guess responses were calculated separately for each condition by dividing the number of responses given by the number of possible responses (e.g., There were 36 test items that had been refreshed. If the participant said "Remember" to 9 of them, the Remember score would have been .25). Corrected proportions were obtained by subtracting false recognition of new items from correct recognition of critical items (see Table 1). These pro-

Table 1
Mean (*SD*) response times (in ms) and mean (*SD*) corrected scores of Yes, Remember, Know, and Guess responses, as a function of conditions in Experiment 1

Word	RT		Yes		Remember		Know		Guess	
	Mean	*SD*	Mean	*SD*	Mean	*SD*	Mean	*SD*	Mean	*SD*
Read	569	75	0.51	0.15	0.22	0.11	0.18	0.10	0.11	0.10
Refresh	578	75	0.58[a]	0.15	0.28[a]	0.13	0.21	0.10	0.09	0.11
Repeat	503[a]	72	0.51	0.15	0.28[a]	0.13	0.17	0.11	0.06[a]	0.09
New			0.15	0.14	0.02	0.03	0.04	0.05	0.09	0.08

[a] Significant difference ($p < .05$) for refresh or repeat words in comparison with read words.

portions were subjected to an analysis of variance (ANOVA) with Condition of presentation (read, refresh, and repeat) and Response type (Remember, Know, and Guess) as within subject factors. There was a significant Condition effect ($F(2, 58) = 10.80$, $p < .001$): participants recognized more words that had been refreshed than words that had been read ($t = 3.89$, $p < .001$) or repeated ($t = 4.14$, $p < .001$). There was also a significant effect of Response type ($F(2, 58) = 18.89$, $p < .001$): Remember responses were more frequent than Know responses ($t = 2.69$, $p = .009$), and Know responses were more frequent than Guess responses ($t = 3.44$, $p = .001$). However, the interaction between Condition and Response type was significant ($F(4, 116) = 5.00$, $p < .001$): Remember, but not Know, responses were significantly more frequent for refreshed ($t = 3.21$, $p = .002$ and $t = 1.79$, $p = .08$, for Remember and Know responses, respectively) or repeated ($t = 3.12$, $p = .002$ and $t = 0.73$, $p = .47$; for Remember and Know responses, respectively) words than for read words, and Guess responses were more frequent for read than for repeated words ($t = 2.64$, $p = .009$).

2.3. Discussion

As in Grillon et al. (2005), relative to the read condition, Remember responses benefited from both refreshing and repeating a word. This benefit in Remember responses occurred under conditions in which, in contrast with Grillon et al. (2005), all participants explicitly reported that given the fast presentation rate and the large number of words, they did not attempt to hold each presented item in working memory until the next one was presented in order to better perform the refresh task. In addition, our data are not consistent with the hypothesis that participants held each item in mind but were unaware of doing so and thus cannot report it. Indeed, holding an item in mind until a second item occurs (a dot in the refresh condition or the same word in the repeat condition) should improve long-term memory performance for repeated words more than for refreshed words because repeated words would have been seen, held in memory from screen 1 to screen 2, seen again on screen 2, and produced aloud whereas refreshed items would have been held but not seen again. This is not consistent with our results since participants overall recognized more refreshed words than repeated words. Furthermore, this hypothesis is not supported by the response time data. A conflict between an active representation being held in mind and reading a new word should be reflected in an increase in response times in the read condition relative to the refresh condition, which would involve no conflict. This was not the case; the response times were not significantly different between these two conditions and rather, as it is typically found, tended to be faster in the read condition than in the refresh condition (569 ms vs. 578 ms). Therefore, our findings provide evidence that the benefit in Remember responses in the perceptual repetition condition arises from the fact that items were seen twice rather than that they were actively held in mind until the second presentation. This is consistent with the increase in Remember responses consistently reported in previous studies that compared recognition for items that have been repeatedly (twice or more) presented at encoding with recognition for an item presented once (Dewhurst & Anderson, 1999; Dewhurst & Hitch, 1997; Gardiner, Kaminska, Dixon, & Java, 1996; Gardiner & Radomski, 1999; Kinoshita, 1997; Mäntylä & Cornoldi, 2002; Parkin, Gardiner, & Rosser, 1995; Parkin & Russo, 1993). Our results confirm that in terms of the effect on subjective experience during later episodic memory, an immediate perceptual repetition may increase Remember responses on long-term memory tests. In addition, under the conditions investigated in Experiment 1, there was no difference between perceptual repetition and refreshing: these two kinds of repetitions were as likely to lead to memory representations stable and distinctive enough to prompt later conscious recollections.

3. Experiment 2

In Experiment 1, as in Grillon et al. (2005), words were presented individually in the center of the screen. However, information rarely occurs in isolation; instead, it is part of a more complex context. Thus, in everyday situations, refreshing and repeating (e.g., seeing a stimulus again) typically occur in an environment of competing active mental representations. Experiment 2 investigates whether repeating and refreshing still produce comparable effects on conscious recollection when an item was initially displayed along with other items. The original refresh paradigm (Johnson et al., 2002) was modified so that the number of active and thus potentially competing representations varied. We compared refreshing or reading again a single item that had just been perceived with refreshing or reading again one from among three items just perceived. Varying the conditions under which refreshing and repeating occur is a way to explore potential differences between these two processes with respect to their impact on later subjective experience. If the mere act of processing twice results in an enhanced level of Remember responses, then we would expect no dissociation in effects on Remember responses for repeated and refreshed words across experimental conditions varying in the potential for interference. Alternatively, some dissociation in effects on subjective experience across experimental conditions between refreshing and repeating would argue for differences in underlying mechanisms. For example, either reflective or perceptual processing may be more vulnerable to the impact of interference. That is, the effect of a repeating an item on Remember responses may be influenced by the vulnerability of the process (i.e., repeating vs. refreshing) to competition from other active representations.

3.1. Methods

3.1.1. Participants

Twenty seven students (seven men, 20 women) ranged in age from 21 to 33 years (mean age = 24.37, $SD = 2.76$ years) were tested individually. They provided informed written consent and were paid for their participation. The protocol was approved by the Ethical Committee of Pitié-Salpétrière hospital.

3.1.2. Materials

A set of 288 common French two-syllable words, each between four and ten letters in length, with a mean word frequency of 47.00 pm was selected from the Brulex database. This word set was randomly divided into sixteen subsets of 18 items each, which did not differ in terms of mean word frequency or mean number of letters ($F < 1$). Each subset was presented equally often as a target (read, refreshed or repeated word), as a distractor and as a new word in the recognition task.

3.1.3. Procedure

The trial structure was the same as in Experiment 1 but the number of items in the first stimulus display was manipulated; for half of the trials (54 trials), 3-words were presented in a column on the screen for 2250 ms. The distance between words was 5 cm. The array subtended an angle of approximately 6°. For the other half (54 trials), a single word was presented for 750 ms in the upper, middle or bottom position. After 500 ms, participants saw, for 1500 ms, either a single word or a dot in one of the three locations. In the read condition, the single word was a new word. In the repeat condition, one of the three previous words was presented in its previous position. In the refresh condition, the dot, by its location, signalled the participants to think of the word that had appeared in that position on the just-previous screen. There were 18 trials of each type, that is, the number of items (1 vs. 3) was orthogonally crossed with condition (read, refresh, and repeat). Participants were asked to read or say aloud all words as quickly as possible and were not informed of the subsequent recognition test. As in Experiment 1, response times were collected via a voice key that was triggered from the critical event on the second slide of each trial (presentation of the dot, the repeated word, or the new word in the read condition).

During a 10-min interval separating Phases 1 and 2, as in Experiment 1, participants were given a set of oral and then typed instructions regarding Remember, Know, and Guess responses and the general test procedure. Phase 2 was a surprise recognition memory task consisting of 144 items (the 108 targets presented in Phases 1 and 36 completely new items) presented in a different random order for each participant. The test procedure was identical to Experiment 1.

3.2. Results

As in Experiment 1, significant effects from the analyses of variance were followed-up by Fisher LSD tests to localize differences. Alpha level was set at $p < .05$.

3.2.1. Phase 1

As in Experiment 1, participants were 100% accurate in responses in all conditions in Phase 1. Trials in which the microphone was spuriously triggered (in less than 75 ms) were removed from response time analyses

($p < 1\%$). Response time data from one participant were excluded because of a recording dysfunction. Mean response times for Phase 1 (see Table 2) were subjected to an analysis of variance (ANOVA) on repeated measures with Condition of presentation (read, repeat, and refresh) and Number of items (1 vs. 3) as within subject factors. There were significant condition ($F(2,50) = 57.5$, $p < .0001$) and number ($F(1,25) = 167.68$, $p < .0001$) effects, and a significant interaction between Number and Condition ($F(2,50) = 30.87$, $p < .0001$). Participants were faster to read ($t = 7.61$, $p < .001$), refresh ($t = 17.56$, $p < .001$), and repeat ($t = 8.31$, $p < .001$) a word on 1-word trials than on 3-word trials. Participants were also faster to repeat a word than to read it on both 1-word and 3-word trials ($t = 7.50$, $p < .001$, and $t = 8.31$, $p < .001$; on 1-word trials and 3-word trials, respectively), but were slower to refresh than to read a word only on 3-word trials ($t = 11.18$, $p < .0001$ vs. $t = 1.24$, $p = .22$ for 1-word trials). This result indicated that the 1 vs. 3 manipulation did not affect the repetition priming effect (mean RT for repeated words minus mean RT for read words = −92 ms for 1-word trials vs. −84 ms for 3-word trials, $t = 0.74$, $p = .47$) but substantially increased the time to refresh a word in comparison with reading it (mean RT for refreshed words minus mean RT for read words = 15 ms for 1-word trials vs. 137 ms for 3-word trials, $t = 6.02$, $p < .001$).

3.2.2. Phase 2

Corrected proportions of Remember, Know, and Guess responses were subjected to an analysis of variance (ANOVA) with Condition of presentation (read, refresh, and repeat), Number of items (1 vs. 3) and Response type (Remember, Know, and Guess) as within subject factors. There were significant Condition ($F(2,52) = 4.87$, $p = 0.011$) and Response type ($F(2,52) = 15.04$, $p < .001$) effects but no significant interaction between Condition and Response type ($F(4,104) = 0.16$, $p = .96$). Post-hoc analyses showed that, as in Experiment 1, participants recognized more words that were refreshed than words that were read ($t = 2.49$, $p = .015$) or repeated ($t = 2.87$, $p = .005$). Here also, Remember responses were more frequent than Know responses ($t = 2.50$, $p = .015$), and Know responses were more frequent than Guess responses ($t = 2.98$, $p = .004$).

The Number effect, and the interaction between Number and Response type were not significant ($F(1,26) = 0.30$, $p = .58$; and $F(2,52) = 0.01$, $p = .98$, respectively) but there was a significant interaction between Number and Condition ($F(2,52) = 3.56$, $p = .035$). Post-hoc analyses showed that participants recognized more words that were refreshed than words that were read or repeated on 1-word trials ($t = 3.42$, $p = .001$, and $t = 2.41$, $p = .019$, respectively) but not on 3-word trials ($t = 0.28$, $p = .78$, and $t = 1.21$, $p = .23$, respectively).

To further understand the close to significant interaction between Number, Condition and Response type ($F(4,104) = 2.07$, $p = .089$), separate analyses were conducted for Remember, Know, and Guess responses.

For Remember responses, an ANOVA on corrected scores revealed no significant Condition or Number effects ($F(2,52) = 0.22$, $p = .80$, and, $F(1,26) = 0.02$, $p = .89$, respectively) but a significant interaction between Number and Condition ($F(2,52) = 4.01$, $p = .024$). Participants reported more Remember responses for refreshed than for read words on 1-word trials ($t = 2.36$, $p = .022$) but not on 3-word trials ($t = 1.21$, $p = .23$). In contrast, Remember responses did not benefit from perceptual repetition in comparison with

Table 2
Mean (*SD*) response times (in ms) and mean (*SD*) corrected scores of Yes, Remember, Know, and Guess responses, as a function of conditions and numbers in Experiment 2

Word	Number	RT		Yes		Remember		Know		Guess	
		Mean	*SD*	Mean	*SD*	Mean	*SD*	Mean	*SD*	Mean	*SD*
Read	1	610	60	0.45	0.14	0.24	0.16	0.16	0.17	0.05	0.09
	3	704	59	0.51	0.17	0.28	0.20	0.18	0.18	0.05	0.08
Refresh	1	625	71	0.54[a]	0.21	0.31[a]	0.24	0.18	0.19	0.05	0.09
	3	841[b]	122	0.51	0.15	0.25	0.21	0.18	0.17	0.08	0.09
Repeat	1	518[a]	61	0.48	0.21	0.26	0.20	0.18	0.17	0.04	0.09
	3	620[b]	56	0.48	0.17	0.29	0.17	0.16	0.15	0.03	0.10
New				0.19	0.15	0.04	0.07	0.04	0.06	0.11	0.08

[a] Significant difference ($p < .05$) in comparison with responses for corresponding read words on 1-item trials.
[b] Significant difference ($p < .05$) in comparison with responses for corresponding read words on 3-item trials.

reading for either 1-word trials ($t = 0.44$, $p = .66$) or 3-word trials ($t = 0.22$, $p > .82$). Furthermore, the proportion of Remember responses for refreshed words from 3-word trials was significantly lower than for refreshed words from 1-word trials ($t = 2.21$, $p = .031$) whereas the 1 vs. 3 manipulation had no significant effect on the proportions of Remember responses for repeated and read words ($t = 1.14$, $p = 0.26$, and $t = 1.35$, $p = 0.18$, respectively). ANOVAs carried out on Know and Guess responses showed no significant results (Fs < 1.08, ps > .34).

Secondary analyses: In addition, we conducted an analysis to assess whether mixing 1-word trials and 3-word trials resulted in a cost on Phase 1 RT performance for single items (Meiran, Levine, & Henik, 2000). The mean response time on 1-word trials preceded by a 3-word trial was compared with the mean response time on 1-word trials preceded by a 1-word trial. The ANOVA showed no effect of the number of words on the preceding trial ($F(1,25) = 0.04$, $p = .83$), and no interaction between this factor and Condition ($F(2,50) = 0.24$, $p = .78$). An ANOVA on corrected recognition scores for single items with Response (Remember, Know, and Guess), Condition (read, refresh, and repeat) and Number of words on the preceding trial (1 vs. 3) as factors showed no significant differences between single items following a 1-word trial and single items following a 3-word trial ($F(1,26) = 0.01$, $p = 0.91$) and no significant interaction between this factor and Condition ($F(2,52) = 0.73$, $p = 0.48$) or between this factor, Response type and Condition ($F(4,104) = 0.64$, $p = 0.63$). The same analysis carried out on Remember responses led to similar results: no significant differences of Remember responses for single items following a 1-word trial relative to a 3-word trial ($F(1,26) = 0.07$, $p = 0.78$) and no significant interaction between this factor and Condition ($F(2,52) = 0.97$, $p = 0.38$).

3.3. Discussion

In Phase 1 response times, the 1 vs. 3 manipulation had an impact on refreshing but did not affect perceptual repetition when these two repetition conditions were compared with a read condition, in which the target item was processed once. Indeed, the repetition priming effect was preserved: participants were faster to read a word just-seen before than to read a new word to the same extent on 3-word trials as on 1-word trials. In contrast, the time to refresh a word increased dramatically from 1-word trials to 3-word trials. The 1 vs. 3 manipulation also had a differential effect on long-term memory in refresh and repeat conditions. Remember responses did not benefit from perceptual repetition in either the 1-word or 3-word conditions. In contrast, Remember responses benefited from refreshing a word initially presented alone (1-word trials) but not from refreshing when the refreshed item had to be selected from among three active representations (3-word trials).

Participants were significantly slower in refreshing a word when the representations of three words had just been activated than a word initially presented alone and this increase in response times was significantly greater in the refresh than in the repeat and read conditions (consistent with the young adults in Raye et al., in press). This disproportionate slowing of response times presumably reflects the fact that active representations produce more need for control in the refresh than repeat or read conditions. That is, refreshing requires participants to select an item from among several active representations whereas the selection is, in effect, accomplished for the participant on read and repeat trials with the visual presentation of the word. Furthermore, since the item to be refreshed is specified with a location cue, an item from a 3-word set requires that items are bound to their locations, at least temporarily, whereas reading a word (as in the *read* and *repeat* conditions) does not.

The greater time to refresh on 3-word trials than 1-word trials might be related to a type of serial, exhaustive scanning process (e.g., Sternberg, 1966), in which internal representations of the 3-words are all successively examined for a match between the location of the dot and the corresponding word. However, when we compared the time to refresh a word as a function of its previous position on the screen (top, middle, bottom), we observed that participants were faster to refresh both first words (primacy effect, mean RT = 821 ms) and last words (recently effect, mean RT = 783 ms) of the list than middle words on 3-word trials (mean RT = 953 ms). Therefore, although some type of scanning process cannot be entirely ruled out, it is unlikely that participants were engaged in exhaustive serial scanning (see Mc Elree & Dosher, 1989). Importantly, even the relatively faster response times for items in the top and bottom position were still dramatically slower than the time to refresh words that were initially presented alone (mean RT = 625 ms). On the other hand, the fact that we did not find significantly faster RTs in the read than the refresh condition for 1-word trials in either Experiment 1 or Experiment 2, as is typically found (e.g., Johnson et al., 2002), suggests that participants may have had a set to be more ready for a refresh cue than a perceptual item, which could have slowed reading responses somewhat. (In comparing instructions between the present and previous experiments, there was somewhat greater emphasis on response speed in the present studies and thus some participants might have been inclined to be ready for the most difficult condition). Such a set would not alone account for the disproportionate (relative to the read condition) slowing during refreshing on 3-word compared to 1-word trials.

Consistent with other findings (Higgins, Johnson, Garoff-Eaton, & Huron, submitted for publication; see also Oberauer, 2002), the disproportionate slowing of refreshing a word from 3-word trials suggests that compared to reading, refreshing requires greater cognitive control to resolve interference from active distractor items in order to select the target item (again, with location information presumably providing a cue for selection). It has been proposed that some types of interference (such as interference in a Stroop task) might be resolved by an amplification of the task relevant information, rather than by inhibiting distracting stimuli (Egner & Hirsch, 2005). The absence of a beneficial effect from refreshing on long-term memory in the 3-item condition relative to the 1-item condition does not provide any support for this hypothesis. An alternative is that interference in the selective refreshing condition (3-word items) may have been resolved by decreasing strength of the unselected words and not by increasing strength of the selectively refreshed word (e.g., Tipper, 2001) as in retrieval induced forgetting in long-term memory (Anderson, Bjork, & Bjork, 1994). Thus, there would be no special benefit for the selected item in long-term memory for refreshed compared to repeated items.

4. General discussion

As in previous studies, long-term, old/new recognition memory was more likely to benefit from a reflective repetition (refresh trials) than a perceptual repetition (repeat trials) (e.g., Johnson et al., 2002). Our primary interest in these experiments was in assessing the effect of a perceptual or reflective repetition (i.e., a brief act of perceptual or reflective attention) on the subjective experience occurring during later long-term recognition memory. In Experiment 1, relative to a word read only once (read condition), both perceptual repetition (repeat condition) and reflective repetition (refresh condition) increased the proportion of items participants assigned a Remember response in long-term recognition memory. Thus, under conditions where the probability of additional spontaneous processing is relatively unlikely (brief presentation of the original display), where there is relatively little competition from currently active representations (only one item in the initial display), and where the perceptual or reflective repetition occurred immediately (after 500 ms), perceptual repetition and refreshing appeared to have an equal impact in producing Remember responses. These results are consistent with previous findings that showed that Remember responses may be affected by perceptual manipulations as well as conceptual ones (Rajaram, 1996, 1998).

In Experiment 2, participants saw a perceptual repetition or were cued to refresh after seeing only a single word (as in Experiment 1) or after seeing three-simultaneously-presented words. Under these conditions, there was some ambiguity in where the original word would be presented in 1-item trials (in contrast to Experiment 1, where the single item was always in the center position). Also, in Experiment 2, there was some ambiguity on the second phase of the 3-item trials about where a word or a refresh cue would appear. Thus, although the participants were focusing on individual words as they read or refreshed them, it is nevertheless reasonable to suppose that to some extent they tended to spread their attention across the whole display more in Experiment 2 than Experiment 1. Under these conditions, in Experiment 2, there was no benefit from perceptual repetition on Remember responses in either 1- or 3-item conditions. Findings from perception studies indicate that if perceptual attention is allocated to a large area, then performance suffers at any single location (Eriksen & St James, 1986). If information within a larger area is processed less efficiently than information presented in a smaller area, it might be less likely later to prompt conscious recollection. Interestingly, in Phase 1, the 1 vs. 3 manipulation did not affect the repetition priming effect: the decrease in time to read a word that had been seen just before in comparison with reading a new word was virtually identical in 1-word and 3-word trials. Furthermore, for 1-item repeat trials, the Phase 1 response times were slower in Experiment 2 than Experiment 1, but the repetition priming effect was larger (92 ms in Experiment 2 vs. 66 ms in

Experiment 1). At the same time, overall long-term recognition accuracy was somewhat less in Experiment 2 (.48 vs. .51). This pattern suggests that on 1-item as well as 3-item trials, the ambiguity in where an item would be presented produced a greater cost to encoding processing that contributes to long-term explicit memory than to encoding processing that produces implicit repetition priming in the short-run.

Another difference between Experiment 1 and 2 was that 3-word trials and 1-word trials were intermixed in Experiment 2 whereas Experiment 1 involved only 1-item trials, raising the issue of a potential task switching cost. However, as reported above, supplementary analyses that revealed the absence of differences in memory performance for single words following a 1-word trial and single words following a 3-word trials argue against this hypothesis. Similarly, analyses of response times that showed an absence of significant differences between response times for 1-word trials preceded by 1-word trials vs. by 3-word trials argues against a cost from switching between 3-word trials and 1-word trials. In addition, in a pilot experiment in which 1-word trials and 3-word trials were blocked rather than mixed, Remember responses increased for refreshed words in comparison with read words but we did not observe an increase in Remember responses from perceptual repetition relative to the read condition. Therefore, it seems that the failure to observe a benefit in Remember responses in Experiment 2 from perceptual repetition does not arise from the mixing between 1-word trials and 3-word trials.

In contrast to the failure of perceptual repetition to increase Remember responses in Experiment 2 in the 1-item condition, refreshing did increase Remember responses relative to the read condition, as it did in Experiment 1. This finding provides additional evidence that refreshing may produce a more reliable benefit than an immediate perceptual repetition for long-term memory (e.g., Johnson et al., 2002). This advantage could result from a number of factors. For example, reflective refreshing might activate different or additional features than does perceptual repeating. It could produce records of the cognitive operations of refreshing along with visual features whereas repeating would produce only records of visual features of the stimulus; either cognitive operations or perceptual features could be later used as evidence that the item had occurred on the list (e.g., Johnson & Raye, 1981). Recent fMRI evidence consistent with the assumption that refreshing results in records of visual properties is that refreshing modulates some of the same posterior visual areas as does perception (Johnson, Mitchell, Raye, D'Esposito, & Johnson, 2007), and that refreshing, like perception, can produce repetition attenuation when the same stimulus is perceived again (Yi et al., in press). With respect to subjective reports of participants' experiences, a more specific characterization of Remember responses involving ratings of various type of details would be required to compare the basis of the Remember responses for refresh and repeat items (e.g., using a Memory Characteristics Questionnaire (MCQ), Johnson, Foley, Suengas, & Raye, 1988; see also Huron, Danion, Rizzo, Killofer, & Damiens, 2003, for such combined approach). An alternative to the possibility that the qualitative characteristics of memorial representations constructed from refreshing and perceptual repetition might differ in features is that the robustness of the representations might differ. Representations constructed from perception might be more vulnerable (e.g., to interference, to divided attention) than representations constructed from refreshing, as suggested by the loss of benefit in Remembering from perceptual repetition on 1-word trials in Experiment 2 compared with Experiment 1.

Finally, refreshing did not increase Remember responses in the 3-item condition. This suggests that increasing the number of active representations during refreshing offset the long-term memory benefits on Remember responses from refreshing observed in the 1-item case. Presumably, this cost is associated with the greater competition during refreshing that arises from the larger number of active items. Consistent with the idea of greater competition and the need for greater cognitive control in Phase 1, increasing the number of active representations from 1 to 3 dramatically increased response times in the refresh condition in comparison with the read condition. Converging evidence from neuroimaging is that there is greater activity in anterior cingulate cortex and lateral PFC during refreshing on 3 vs. 1-item trials (Johnson et al., 2005, Experiment 5), areas associated with competition and cognitive control (e.g., MacDonald, Cohen, Stenger, & Carter, 2000) and resolution of interference (e.g., Jonides, Smith, Marshuetz, Koeppe, & Reuter-Lorenz, 1998). We cannot determine from the present design whether increasing the number of active representations decreases the strength of the memorial representation of the refreshed item, or whether the processes engaged during selection reduce the chances that other processes will be engaged that contribute later to the subjective experience of remembering (e.g., the noting of details that might later serve as the basis of a Remember response).

Both Experiments 1 and 2 used a mixed design in which read, repeat and refresh trials randomly occurred. Therefore, participants might have had a set to expect refresh trials, which might have disrupted their processing on read and repeat trials and thus negatively affected their later memory performance in these two conditions. To avoid such set effects (or other uncontrolled strategies that might differentially favour one condition, such as a tendency to refresh on all trials), the three conditions could be manipulated between subjects rather than within. Comparing conditions in which reading and refreshing trials are randomly intermixed with blocked conditions or independent groups would provide an assessment of reading times in the absence of refresh trials and interesting data concerning the potential costs in RTs and long-term memory in redirecting attention from external to internal stimuli and vice versa.

Overall, our results provide evidence that the subjective state of remembering a specific event is affected both by simple processes engaged right after a stimulus is perceived (i.e., whether it is immediately perceived again or refreshed), and on the specific conditions under which these processes are engaged (i.e., whether the critical item is the only representation active or one of several). Perceiving and refreshing are two mechanisms by which information becomes the focus of attention. Under some conditions, perception and reflection may be functionally similar. However, under other conditions (e.g., increasing interference), they may have differential effects, for example, on the nature of later subjective experience during recognition. Investigating these conditions provides one approach for clarifying the similarities and differences in the contributions of perception and reflection to conscious experience.

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