Revisiting backward recall and benchmark memory effects: a reply to Bireta et al. (2010)

Katherine Guérard · Jean Saint-Aubin ·
Samantha C. Burns · Cindy Chamberland

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Abstract When participants are asked to recall lists of items in the reverse order, known as *backward recall*, several benchmark memory phenomena, such as the word length effect, are abolished (Bireta et al. Memory & Cognition 38:279–291, 2010). Bireta et al. (Memory & Cognition 38:279–291, 2010) suggested that in backward recall, reliance on order retention is increased at the expense of item retention, leading to the abolition of item-based phenomena. In a subsequent study, however, Guérard and Saint-Aubin (*in press*) showed that four lexical factors known to modulate item retention were unaffected by recall direction. In a series of five experiments, we examined the source of the discrepancy between the two studies. We revisited the effects of phonological similarity, word length, articulatory suppression, and irrelevant speech, using open and closed pools of words in backward and forward recall. The results are unequivocal in showing that none of these effects are influenced by recall direction, suggesting that Bireta et al.'s (Memory & Cognition 38:279–291, 2010) results are the consequence of their particular stimuli.

Keywords Immediate memory · Backward recall · Phonological similarity · Word length · Articulatory suppression · Irrelevant speech

Immediate memory is typically studied using forward serial recall, in which participants are required to recall lists of items in the same order as that in which they have been presented. Immediate memory is also investigated with a variant of this task, known as *backward recall*, in which participants recall list items in the reverse order (see, e.g., Banken, 1985; Reynolds, 1997). In two articles, Bireta and her colleagues (Bireta et al., 2010; Surprenant et al., 2011) showed that four benchmark memory phenomena—that is, the effects of phonological similarity, word length, articulatory suppression, and irrelevant speech—were abolished or greatly diminished in backward recall. To account for this finding, they suggested that more attention is devoted to order retention in backward recall than in forward recall. The higher level of attention to order retention would come at the expense of item retention, leading to the abolition of item-based phenomena. Guérard and Saint-Aubin (*in press*) tested this hypothesis by manipulating four lexical variables well known to affect item retention (see, e.g., Saint-Aubin & Poirier, 1999). They showed that the effects of semantic similarity, word frequency, word imagery, and lexicality were immune to the influence of recall direction. Guérard and Saint-Aubin suggested that the discrepancy between their results and those of Bireta and her colleagues could be due to the fact that benchmark memory phenomena and long-term effects are based on distinct processes (see Stuart & Hulme, 2009). Another possibility, however, is that this discrepancy is due to methodological differences between the two studies. For instance, Bireta et al. (2010) used closed sets of words or letters in all their experiments,

Katherine Guérard, École de psychologie, Université de Moncton;
Jean Saint-Aubin, École de psychologie, Université de Moncton;
Samantha C. Burns, École de psychologie, Université de Moncton;
Cindy Chamberland, École de psychologie, Université de Moncton.

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K. Guérard (✉) · J. Saint-Aubin · S. C. Burns · C. Chamberland
École de Psychologie, Université de Moncton,
Moncton, New Brunswick E1A 3E9, Canada
e-mail: katherine.guerard@umoncton.ca

whereas Guérard and Saint-Aubin used open sets of words. The objective of the present study was to examine the source of the discrepancy between the two studies to improve our understanding of the processes involved in backward recall. In order to do this, we revisited the effects of phonological similarity, irrelevant speech, articulatory suppression, and word length in forward and backward recall, using open and closed pools of words.

After more than a century of work on the processes involved in forward immediate serial recall, there has been growing interest in understanding the processes involved in backward recall (see, e.g., Lewandowsky & Farrell, 2008). In order to further understand these processes, Bireta et al. (2010; see also Surprenant et al., 2011) tested four benchmark memory phenomena well known to modulate forward serial recall performance in backward recall—that is, the effects of word length, phonological similarity, articulatory suppression, and irrelevant speech. Bireta and her colleagues (2010; Surprenant et al., 2011) showed that the four benchmark memory effects are abolished or greatly reduced in backward recall, as compared with forward recall. They accounted for these results within the scale invariant memory and perceptual learning (SIMPLE) model (Brown, Neath, & Chater, 2007). SIMPLE suggests that benchmark memory effects occur at the level of the item dimension. Bireta et al. (2010) suggested that benchmark memory phenomena were abolished in backward recall because, in this recall condition, more attention is devoted to the order dimension at the expense of the item dimension. As a consequence, the phenomena that occur because of the item dimension are abolished or greatly diminished.

Other factors that are well known to modulate item retention are lexical variables. Lexical variables refer to “word properties, such as word frequency and concreteness, which reflect differences in the way in which words are represented in long-term or lexical memory” (Stuart & Hulme, 2009, p. 157). Lexical effects include the better recall of high-frequency words over low-frequency words (the word frequency effect; see, e.g., Hulme, Stuart, Brown, & Morin, 2003; Roodenrys & Quinlan, 2000), of words over nonwords (the lexicality effect; see, e.g., Hulme, Maughan, & Brown, 1991; Multhaup, Balota, & Cowan, 1996), of concrete words over abstract words (the effect of word concreteness or imageability; see, e.g., Miller & Roodenrys, 2009; Walker & Hulme, 1999), and of semantically related words over unrelated words (the effect of semantic similarity; see, e.g., Poirier & Saint-Aubin, 1995; Tse, 2009). Saint-Aubin and Poirier (1999) showed that lexical variables modulate item retention. Guérard and Saint-Aubin (*in press*) reasoned that if backward recall reduces the availability of resources for the item dimension, lexical effects should

be abolished in backward recall. Contrary to this prediction, they showed that the effects of lexicality, word frequency, word imagery, and semantic similarity were generally unaffected by backward recall (see also Walker & Hulme, 1999).

At first glance, backward recall appears as a further dissociation between short- and long-term memory processes. However, before considering backward recall effects as a new dissociation, some key methodological issues must be addressed. The word pool appears to be a good candidate to account for previous dissociations. With a backward recall procedure, lexical effects were maintained in previous studies using an open word pool in which different words were presented on each trial (Guérard & Saint-Aubin, *in press*; Walker & Hulme, 1999). On the other hand, lexical effects were abolished with a closed pool where the same items were used on every trial (Hulme et al., 1997). Similarly, Bireta and her colleagues (2010; Surprenant et al., 2011) abolished or reduced all benchmark memory effects with closed or semi-closed pools. A semi-closed pool is a word set that is restricted but larger than list length, so that the same items are repeated several times during an experiment. In forward recall, it is well established that set size modulates both lexical (see, e.g., Roodenrys & Quinlan, 2000) and benchmark (see, e.g., Gupta, Lipinski, & Aktunc, 2005) memory effects. For instance, Roodenrys and Quinlan showed that the effect of word frequency was reduced when a closed pool of words was used, as compared with an open pool of words. They suggested that set size influenced item retrieval by reducing the number of competitors during reintegration. Likewise, the phonological similarity effect on item memory has been reduced with a closed pool (Gupta et al., 2005). The different levels of requirements in terms of item memory between open and closed pools might modulate the effect of backward recall and the attentional shift between item and order retention.

In the following series of experiments, we revisited the four benchmark memory phenomena studied by Bireta et al. (2010), using open and closed pools of words. We manipulated phonological similarity, irrelevant speech, articulatory suppression, and word length in both forward and backward recall. Prior knowledge of recall direction was shown not to modulate the effect of recall direction on the benchmark memory effects (see Surprenant et al., 2011) and on the lexical effects (see Guérard & Saint-Aubin, *in press*). Therefore, for the sake of comparability with the previous studies, participants were informed of recall direction only after list presentation. Moreover, in order to compare our results with those of previous studies, an order reconstruction procedure similar to that adopted by Bireta et al. (2010) was used.

Experiment 1: phonological similarity

In Experiments 1A and 1B, we tested the effect of phonological similarity, which is the better recall of dissimilar sounding items over similar sounding items (Baddeley, Lewis, & Vallar, 1984; Conrad, 1964). The effect of phonological similarity was assessed using an open pool of words (Experiments 1A) and a closed pool of words (Experiment 1B).

Experiment 1A

Method

Participants Twenty undergraduate students from Université de Moncton volunteered to participate in this experiment.

Materials A total of 56 lists were assembled. Twenty-eight phonologically similar lists were composed of seven monosyllabic French words that rhymed together. Each word was used only once for phonologically similar lists, and the same rhyme was not used for more than four lists. In order to assemble the lists of 28 dissimilar words, the 28 similar lists were split into four sets of 7 lists, with the constraint that none of the 7 lists could share a rhyme. Seven dissimilar lists were assembled by selecting at random 1 word from each phonologically similar list of a set. With this procedure, each word was used twice: once for a phonologically similar list and once for a phonologically dissimilar list. Therefore, the words in the similar and dissimilar conditions were equated on all possible variables.

Design Each participant underwent one block of 56 experimental trials preceded by 4 practice trials, 2 for each recall direction. The practice trials were done with the experimenter present to ensure compliance with the instructions. The lists in the four conditions (forward dissimilar, forward similar, backward dissimilar, backward similar) were presented in a different random order for each participant. The words within each list were also presented in a different random order for each participant. The two sets of lists used in forward and backward recall were counterbalanced across participants. The experiment lasted about 45 min.

Procedure The words were presented sequentially at the center of the screen at a rate of one item per second (1,000 ms on, 0 ms off). After the presentation of the last word, they all reappeared simultaneously on the screen and were to be clicked on in the correct order—that is, from the first to the last item in forward recall or from the last to the

first item in backward recall. The items reappeared in alphabetical order and were presented in two rows containing three and four items, respectively. Once clicked upon, the words changed from black color to green. The recall direction was indicated by the word “normal” (normal) in blue or “inverse” (reverse) in red capital letters above the symbol “==>” or “<==” presented in black ink in the upper part of the screen, above the to-be-recalled words. The words remained on the screen until each one had been clicked on. The order in which the words were clicked upon was recorded by the computer. Therefore, if, in the backward recall condition, participants started with the first presented word, followed by the second presented word, as in forward recall, those responses would be considered as errors, because the correct answers are the seventh and sixth items, respectively. Participants self-initiated trials by pressing the space bar.

Results

All repeated measures analyses of variance (ANOVAs) conducted on the proportions of correct responses in the following experiments are reported in [Appendix 1](#). In all analyses, the .05 level of significance was adopted, and the Greenhouse–Geisser correction was applied when the sphericity criterion was not met. The two top left panels of [Fig. 1](#) show a phonological similarity effect in both recall conditions. As can be seen in [Appendix 1](#), the recall performance did not vary between the forward recall ($M = .51$, $SD = .13$) and backward recall ($M = .54$, $SD = .17$) conditions. Phonologically dissimilar words ($M = .59$, $SD = .15$) were better recalled than phonologically similar words ($M = .47$, $SD = .13$), and the main effect of serial position was significant. Importantly, there was no significant interaction between recall direction and phonological similarity. The significant interaction between recall direction and serial position corresponded to the typical greater primacy effect in forward recall and to the greater recency effect in backward recall. There was also a significant interaction between phonological similarity and serial position. No other interactions were significant.

Despite the nonsignificant interaction between recall direction and serial position, planned contrasts were carried out in order to confirm the presence of a phonological similarity effect in forward and backward recall. The contrasts for all experiments are reported along with the effect sizes (Cohen's d) and the magnitude of the memory effects (see Surprenant, Neath, Bireta, & Allbritton, 2008) in each of the forward and backward conditions in [Table 1](#). For instance, the magnitude of the phonological similarity effect was given as a percentage by calculating the difference in recall performance between the dissimilar and similar condi-

Fig. 1 Proportion of correct responses as a function of serial position in the forward and backward recall directions in Experiments 1–4. Errors bars represent 95% confidence intervals

tions, divided by recall performance in the dissimilar condition ($[(\text{Dis} - \text{Sim})/\text{Dis}] * 100$). Table 1 shows that the phonological similarity effect was significant in both forward and backward recall.

Discussion

As in previous studies, phonologically similar words were more difficult to recall than dissimilar words (see, e.g., Baddeley et al., 1984; Conrad, 1964). In contrast with the results of Bireta et al. (2010), phonologically similar words were more difficult to recall than dissimilar words for both forward and backward recall: Recall direction had no effect on the phonological similarity effect.

Experiment 1B

The discrepancy between our results and those of Bireta et al. (2010) could be due to their stimuli. First, Bireta et al. (2010) used a closed pool of items, whereas we used an open pool. As was suggested by Roodenrys and Quinlan (2000), decreasing set size might influence memory performance by restraining the pool of candidates that compete for output at recall. This could promote the reliance on order retention in backward recall. Second, Bireta et al. (2010) used letters, which are highly familiar items, whereas we used words. Experiment 1B was designed to control for these two factors. We used a closed pool of words so that for each participant, the same two sets

Table 1 Planned contrasts, Cohen's d and magnitude of the memory effects (%) in each of the forward and backward recall conditions, in Experiments 1–5

Pool (Exp.)		Forward					Backward				
		<i>F</i>	<i>MSE</i>	η_p^2	<i>d</i>	Magnitude (%)	<i>F</i>	<i>MSE</i>	η_p^2	<i>d</i>	Magnitude (%)
Phonological Similarity											
Open (1A)	1, 19	10.72*	.01	.36	0.69	20.8	16.80*	.01	.47	0.91	19.0
Closed (1B)	1, 19	20.98*	.01	.53	0.65	17.9	14.20*	.01	.43	0.62	14.3
Irrelevant Speech											
Open (2A)	1, 19	11.74*	.01	.38	0.61	16.4	9.75*	.01	.34	.56	13.4
Closed (2B)	1, 19	44.97*	.00	.70	1.03	25.1	17.55*	.01	.48	0.70	17.9
Articulatory Suppression											
Open (3A)	1, 19	88.64*	.01	.82	2.41	46.1	67.07*	.01	.78	1.96	37.6
Closed (3B)	1, 19	41.86*	.01	.69	1.64	42.3	78.55*	.00	.81	1.45	32.9
Word Length											
Open (4A)	1, 19	15.05*	.01	.44	0.94	29.9	17.18*	.01	.48	0.67	17.5
Closed (4B)	1, 19	35.96*	.00	.65	0.83	21.9	14.16*	.01	.43	0.78	19.3
Semi-closed (5)	1, 19	26.67*	.01	.58	1.22	29.5	7.75*	.00	.29	0.54	10.7

* $p < .05$

of similar and dissimilar words were presented in every trial, but in a different random order. In order to ensure that the effects are not attributable to the selected stimuli, the stimulus sets were different for each participant. Finally, the effect of familiarity was examined by increasing the number of trials. A total of 80 trials, divided into four blocks of 20 trials, were implemented. If item familiarity modulates the interaction between recall direction and phonological similarity, the similarity effect should decrease as a function of block in backward recall, but not in forward recall.

Method

Participants Twenty undergraduate students from Université de Moncton volunteered to participate in this experiment. None had participated in the previous experiments.

Materials The materials were the same as those used in Experiment 1A. However, to meet the conditions of the closed pool needed for this experiment, the same phonologically similar and dissimilar lists were used throughout the experiment; for each participant, the two lists were chosen from those used in Experiment 1A, with the restriction that one word was not repeated between the phonologically similar and dissimilar lists. On each trial, the same words were presented in a different randomized order. Importantly, the stimulus set was different for each participant.

Design and procedure The design and procedure were the same as those in Experiment 1A, with the exception that the

present experiment consisted of four blocks of 20 trials. In each block, there were 5 trials per condition (forward dissimilar, forward similar, backward dissimilar, backward similar) that were presented randomly. The 80 trials were presented in succession so that participants were not aware that there were four separate blocks of trials. The experiment lasted approximately 1 h.

Results

In order to examine the role of familiarity in the abolition of the phonological similarity effect in backward recall, the 80 experimental trials were divided into four blocks of 20 trials (see Fig. 2). Recall performance was pooled across serial positions. A 2 (recall direction) $\times$ 2 (phonological similarity) $\times$ 4 (block) repeated measures ANOVA showed that dissimilar words were better recalled than similar words, $F(1, 19) = 22.47$, $MSE = .04$, $\eta_p^2 = .54$, and that performance improved as a function of block, $F(3, 57) = 3.47$, $MSE = .02$, $\eta_p^2 = .15$. The effect of recall direction was not significant, $F(1, 19) = 1.57$, $MSE = .03$, $\eta_p^2 = .08$. No interactions were significant.

Since block did not modulate the effect of backward recall on the phonological similarity effect, we analyzed performance as a function of serial position, pooled across the four blocks. The serial position curves illustrated in the two top right panels of Fig. 1 show a phonological similarity effect in both forward recall and backward recall. The repeated measures ANOVA reported in Appendix 1 revealed that the main effect of serial position was

Fig. 2 Proportion of correct responses as a function of block, recall direction, and phonological similarity in Experiment 1B. Errors bars represent 95% confidence intervals

significant but that performance in backward ($M = .64$, $SD = .13$) and forward ($M = .61$, $SD = .12$) recall was not significantly different. Phonologically dissimilar words ($M = .68$, $SD = .18$) were better recalled than phonologically similar words ($M = .57$, $SD = .15$). Once again, there was no significant interaction between recall direction and phonological similarity. Moreover, planned contrasts confirmed that the effect of phonological similarity was significant in both forward and backward recall (see Table 1). Cohen's d s calculated in both conditions suggest that the effect of phonological similarity was similar in the backward and in the forward conditions. The interaction between recall direction and serial position was significant, indicating that the primacy effect was greater in forward recall, whereas the recency effect was greater in backward recall. There were no other significant interactions.

Discussion

Experiment 1B replicates previous studies in showing that phonologically similar items are more difficult to recall than dissimilar items (see, e.g., Baddeley et al., 1984; Conrad, 1964). Most important, the effect of phonological similarity was unaffected by recall direction, irrespective of whether participants were unfamiliar (in Block 1) or familiar (in Block 4) with the stimuli. This suggests that item familiarity does not mediate the abolition of the phonological similarity effect in backward recall.

Experiment 2: irrelevant speech

Experiment 1 showed that, unlike in Bireta et al. (2010), the effect of phonological similarity was observed in forward and backward recall, irrespective of set size and item familiarity. In Experiment 2, we revisited a second benchmark memory effect abolished in backward recall by Bireta et al. (2010)—that is, the effect of irrelevant speech.

This effect is observed when irrelevant tokens presented auditorily during the memory task impair recall performance (Colle & Welsh, 1976; Cowan, Lichty, & Grove, 1990; Jones & Morris, 1992; LeCompte, 1996). The effect of irrelevant speech was tested in forward and backward recall using an open (Experiment 2A) and a closed (Experiment 2B) pool of words.

Method

Participants Forty students from a local college volunteered to participate in this experiment. Twenty took part in Experiment 2A, and 20 took part in Experiment 2B.

Materials In Experiment 2A, two word pools containing 196 monosyllabic French nouns were used; the words within each pool were matched for word frequency. From each pool, 28 lists of seven words were assembled by sampling without replacement, with the constraint that, within each list, there were no rhyming words and no obvious semantic associations between words. For each pool, the 28 lists were randomly split into two sets of 14 lists. At the end of this procedure, we obtained four sets of 14 lists, each presented in one of the four conditions of the experiment (forward/quiet, forward/irrelevant speech, backward/quiet, backward/irrelevant speech). Using a Latin square design, each set was used equally often in each of the four conditions. In order to meet the conditions of a closed pool in Experiment 2B, the lists of words used for each trial of an individual participant were composed of the same seven words in randomized order, the words being taken from an original list randomly chosen from the pool used in Experiment 2A. The stimulus set was different for each participant. A sequence of 27 digits from 1 to 9 presented in random order was used for the irrelevant speech condition of the experiment. The digits were spoken by a male voice through headphones at a rate of one item per 300 ms. The same list of digits was used for all trials and all participants.

Design and procedure The design and procedure were the same as those used in Experiment 1A, with the exception that on 50% of the trials, to-be-ignored digits were presented to the participants over the headphones during the presentation of the words. The presentation of spoken digits began 1,000 ms before the onset of the first word and ended 100 ms after the offset of the last word.

Results

An examination of Fig. 1 shows an irrelevant speech effect for both forward and backward recall conditions. The

pattern of performance was the same in both Experiments 2A and 2B.

Experiment 2A The analysis revealed a significant better recall under quiet ($M = .51$, $SD = .12$) than under irrelevant speech ($M = .44$, $SD = .12$) conditions. Backward ($M = .48$, $SD = .05$) and forward ($M = .47$, $SD = .06$) recall performance was not significantly different, but the effect of serial position was significant. The interaction between recall direction and irrelevant speech was not significant. There was a significant interaction between recall direction and serial position, caused by the greater primacy effect in forward recall and the greater recency effect in backward recall. A significant interaction between irrelevant speech and serial position was also observed. No other significant interactions were found. As is shown in Table 1, planned contrasts confirmed that the effect of irrelevant speech was significant in both forward and backward recall conditions.

Experiment 2B The results of our analysis, reported in Appendix 1, revealed that backward ($M = .45$, $SD = .12$) and forward ($M = .47$, $SD = .12$) recall did not differ significantly but that recall performance was superior in the quiet condition ($M = .52$, $SD = .12$), as compared with the irrelevant speech condition ($M = .41$, $SD = .11$). The main effect of serial position was also significant. It is important to note that no significant interaction was found between recall direction and irrelevant speech. Planned contrasts confirmed that the effect of irrelevant speech was significant in both recall directions (see Table 1). The interaction between recall direction and serial position was significant, confirming the greater primacy effect in forward recall and recency effect in backward recall. The interaction between irrelevant speech and serial position was also significant, but no other interactions were significant.

Discussion In both Experiments 2A and 2B, we replicated the detrimental effect of irrelevant speech on the recall of words (see, e.g., Colle & Welsh, 1976; Cowan et al., 1990; Jones & Morris, 1992; LeCompte, 1996). In opposition to Bireta et al.'s (2010) results, the irrelevant speech effect was found in both forward and backward recall, irrespective of set size.

Experiment 3: articulatory suppression

When participants are asked to articulate irrelevant items during memorization of the list in serial recall, their performance is greatly impaired, as compared with a control condition with no concurrent articulation (the effect of articulatory suppression; see, e.g., Baddeley et al., 1984;

Murray, 1968). Bireta et al. (2010) showed that this effect was reduced in backward recall. The effect of articulatory suppression was tested in forward and backward recall using an open (Experiment 3A) and a closed (Experiment 3B) pool of words.

Method

Participants Forty students from a local college volunteered to participate in this experiment. Twenty took part in Experiment 3A, and 20 took part in Experiment 3B.

Materials The materials in Experiment 3A and 3B were the same as those used in Experiments 2A and 2B, respectively, with the exception that no irrelevant speech was used.

Design and procedure The design and procedure were the same as those in Experiment 1A, with the exception that 1,000 ms before the presentation of the first to-be-remembered word on the screen, participants were presented with either the word “silence” (in the condition without articulatory suppression) or the numbers “1–2–3–4” (in the condition with articulatory suppression) in the center of the screen. Half of the trials were assigned to the quiet condition, and the other half were assigned to the articulatory suppression condition. When submitted to the articulatory suppression condition, participants were required to count from 1 to 4 repetitively during the entire presentation of the to-be-remembered stimuli, whereas during the silence condition, participants were instructed not to count.

Results

As is shown in Fig. 1, forward and backward recall conditions showed an effect of articulatory suppression in both Experiments 3A and 3B.

Experiment 3A The analysis indicated that recall performance did not significantly differ in the backward ($M = .41$, $SD = .17$) and forward ($M = .42$, $SD = .18$) conditions. The absence of articulatory suppression during stimuli presentation ($M = .52$, $SD = .11$) generated better recall performance than did the presence of articulatory suppression ($M = .30$, $SD = .07$). The main effect of serial position was significant. As is suggested by the significant interaction between recall direction and articulatory suppression, the effect of articulatory suppression was greater in forward recall than in backward recall. Planned contrasts showed that the effect of articulatory suppression was significant in both forward and backward recall (see Table 1). The interaction between recall direction and serial position and

the interaction between articulatory suppression and serial position were significant. No other significant interactions were found.

Experiment 3B The analysis confirmed that recall performance was superior in the quiet condition ($M = .45$, $SD = .11$) than in the articulatory suppression condition ($M = .28$, $SD = .09$). Recall performance was not significantly different in the backward ($M = .37$, $SD = .10$) and forward ($M = .36$, $SD = .10$) conditions, but the effect of serial position was significant. Importantly, there was no significant interaction between recall direction and articulatory suppression in this experiment. Planned contrasts confirmed that the effect of articulatory suppression was significant in both forward and backward recall (see Table 1). The interaction between recall direction and serial position was significant, consistent with the greater primacy and recency effects found in forward and backward recall, respectively. A significant three-way interaction between recall direction, articulatory suppression, and serial position was also found, although no other significant interactions were found.

Discussion

An effect of articulatory suppression on recall performance was found in Experiments 3A and 3B (see, e.g., Baddeley et al., 1984; Murray, 1968). In line with previous experiments, backward recall did not modulate the effect of articulatory suppression in Experiment 3B when a closed pool was used. In Experiment 3A, however, when an open pool of words was used, backward recall reduced the magnitude of the effect of articulatory suppression. This diminution was rather weak, however, decreasing from 46.1% in forward recall to 37.6% in backward recall (see Table 1), a reduction of 8.5%. Indeed, in Bireta et al.'s (2010) study, the magnitude of the effect of articulatory suppression went from 54.5% in forward recall to 25.8% in backward recall, a reduction of 28.7%.

Experiments 4 and 5: word length

The effect of word length refers to the better recall of short words over long words (see, e.g., Baddeley, Thomson, & Buchanan, 1975). This effect was abolished in backward recall (Bireta et al., 2010; Surprenant et al., 2011). In the following experiments, word length was reassessed in forward and backward recall, using an open pool of words (Experiment 4A), a closed pool of words (Experiment 4B), and the same semi-closed pool of words as that used by Bireta et al. (2010; Experiment 5).

Experiment 4

Method

Participants Forty students from a local college volunteered to participate in this experiment. Twenty took part in Experiment 4A, and 20 took part in Experiment 4B.

Materials In Experiment 4A, two word pools containing 196 words each were used for this experiment. The first pool, used for the short-word condition, consisted of monosyllabic nouns, whereas the second pool, used for the long-word condition, was composed of three-syllable nouns. Both pools were equated for word frequency and imagery. Each pool was divided to make 28 lists of seven words, with the condition that, within each list, there were no rhyming words or obvious semantic associations between words. The same materials were used in Experiment 4B, except that, in order to meet the conditions of a closed pool, the lists of words used for each trial of an individual participant were composed of the same words in randomized order, the words being taken from an original list randomly chosen from the pool used in Experiment 4A.

Design and procedure The design and procedure were the same as those in Experiment 1A.

Results

An examination of Fig. 1 shows a word length effect in both recall conditions, in both Experiments 4A and 4B.

Experiment 4A The analyses indicated that the main effects of recall direction, word length, and serial position were all significant: Backward recall ($M = .49$, $SD = .13$) resulted in better recall performance than did forward recall ($M = .33$, $SD = .10$), and short words ($M = .46$, $SD = .13$) were better recalled than long words ($M = .36$, $SD = .11$). Of particular importance to our study, there was no significant interaction between recall direction and word length. As is shown in Table 1, the effect of word length was significant in forward and backward recall. There was a significant interaction between recall direction and serial position due to the greater primacy effect in forward recall and recency effect of backward recall. There was also a significant interaction between word length and serial position. No other significant interactions were found.

Experiment 4B The analysis showed that backward ($M = .47$, $SD = .19$) and forward ($M = .45$, $SD = .13$) recall performance were not significantly different. There was a significant main effect of word length, with short words ($M = .51$, $SD = .14$) being better recalled than long words

($M = .41$, $SD = .10$). The main effect of serial position was also significant. There was no significant interaction between recall direction and word length. As is shown in Table 1, planned contrasts showed that the effect of word length was significant in forward and backward recall. Once again, there was a significant interaction between recall direction and serial position, as a direct result of the greater primacy effect in forward recall and the greater recency effect in backward recall. There was a significant interaction between word length and serial position. No other interactions were significant.

Discussion In both Experiments 4A and 4B, we replicated the word length effect, showing a recall advantage for short words, as compared with long words (see also Baddeley et al., 1975). In addition, in contrast with the results of Bireta et al. (2010; Surprenant et al., 2011), the effect of word length was not modulated by recall direction, irrespective of set size. Therefore, the four experiments show that the benchmark memory effects are preserved in backward recall. The Cohen's d s presented in Table 1, however, seem

to suggest that, in most experiments, the benchmark memory effect is reduced to some extent in backward recall, as compared with forward recall.

Combined analysis In order to examine whether increasing power would allow detecting an effect of recall direction on the memory effects, performance was pooled across serial positions, and word pool was used as a between-subjects factor. Therefore, for each benchmark memory effect, we carried out a mixed ANOVA with pool (two levels; open, closed) as a between-subjects factor and recall direction and benchmark memory phenomenon as within-subjects factors. These analyses are presented in Appendix 2. Recall performance for each experiment, pooled across serial positions, is presented in Fig. 3, along with the results of Bireta et al. (2010) to allow a direct comparison between the two studies.

For the phonological similarity effect (Experiments 1A and 1B), only the main effects of phonological similarity and of pool were significant. The interaction between recall direction and phonological similarity was not significant. A

Fig. 3 Proportion of correct responses in the forward and backward recall directions pooled across serial positions, in Experiments 1–5. The left column shows the proportion of correct recall reported in Bireta et al.'s (2010) study

similar pattern was observed for the irrelevant speech effect (Experiments 2A and 2B), showing that only the main effect of irrelevant speech was significant. Indeed, the interaction between recall direction and irrelevant speech was not significant. A different pattern emerged for the effect of articulatory suppression (Experiments 3A and 3B): The main effect of articulatory suppression was significant, as well as the interaction between recall direction and articulatory suppression. Finally, for the word length effect (Experiments 4A and 4B), the main effects of recall direction and of word length were significant. The interaction between recall direction and pool was also significant. As is shown in Fig. 3, this interaction is due to the fact that performance increased in the backward, as compared with the forward, direction when an open pool of words was used (Experiment 4A), but not when a closed pool was used (Experiment 4B). Importantly, the interaction between recall direction and word length was not significant. The combined analyses show that the effects of phonological similarity, irrelevant speech, and word length did not decrease in backward recall. Consistent with the results of Experiment 3A, only the effect of articulatory suppression was reduced in backward, as compared with forward, recall.

Experiment 5

In the previous experiments, we showed that the effects of phonological similarity, irrelevant speech, articulatory suppression, and word length were observed in forward and backward recall. Obviously, item familiarity and set size are not the critical factors responsible for modulating the effect of recall direction on these benchmark memory phenomena. What then, could explain the discrepancy between the present results and those of Bireta et al. (2010; Surprenant et al., 2011)? One possibility is that the effects they observed were due to the specific stimulus set they used. In order to test this possibility, we replicated Experiment 4 using the same pool of words as that used by Bireta et al. (2010).

Method

Participants Twenty students from a local college volunteered to participate in this experiment. All participants were native English speakers, and none had participated in previous experiments.

Materials The materials were the same as those used in the study by Bireta et al. (2010). Two pools were used, the first pool containing 15 monosyllabic words and the second pool containing 15 three-syllable words. The short and long words were equated for frequency, concreteness, imageability, and familiarity (Bireta et al., 2010). On each trial, 7 words were randomly chosen from the pool of the condition for that trial.

Design and procedure The design and procedure were the same as those in Experiment 1A.

Results

As is illustrated in Fig. 4, there appears to be a word length effect in the forward recall condition, which was diminished in backward recall. The analysis indicated that backward recall ($M = .48$, $SD = .09$) was superior to forward recall ($M = .41$, $SD = .10$) and that short words ($M = .50$, $SD = .11$) were better recalled than long words ($M = .40$, $SD = .08$). The main effect of serial position was significant. Of particular importance, the interaction between recall direction and word length was found to be significant. The word length effect was weaker in backward recall for this experiment, but planned contrasts showed that the effect was still significantly present in both forward and backward recall (see Table 1). The interaction between serial position and recall direction was significant, due to the greater primacy effect in forward recall and recency effect in backward recall. The interaction between word length and serial position was also significant, but not the three-way interaction between recall direction, word length, and serial position.

Discussion

Experiment 5 replicated the classic word length effect, with a better recall for short words over long words (see, e.g., Baddeley et al., 1975). Of critical importance, Experiment 5 showed that when Bireta et al.'s (2010) stimuli were used, the effect of word length was almost abolished in backward recall. Indeed, as is shown in Table 1, the magnitude of the word length effect decreased from 29.5% in forward recall to 10.7% in backward recall. This reduction of 18.8% between the two recall conditions is even greater than that observed by Bireta et al. (2010), who observed a reduction of 15.2%.

Fig. 4 Proportion of correct responses as a function of serial position and word length, in the forward and backward recall directions in Experiment 5. Errors bars represent 95% confidence intervals

General discussion

The objective of the present study was to revisit the effects of phonological similarity, irrelevant speech, articulatory suppression, and word length in forward and backward recall using open and closed pools of words. The results showed that all four phenomena were observed in both forward and backward recall, irrespective of set size.

Explaining Bireta et al.'s (2010) results

The results reported in the present study are in sharp contrast with those of Bireta et al. (2010; Surprenant et al., 2011): Bireta et al. showed that the four benchmark memory phenomena were abolished or greatly diminished in backward recall. The abolition of benchmark memory effects cannot be attributed to the use of a closed word pool. Indeed, we showed that the four benchmark memory effects were observed using both an open and a closed pool of words. The discrepancy between our results and those of Bireta and her colleagues, however, might be due to their stimulus set. For instance, because of the selection method used by Bireta et al., it is possible that the stimulus sets they used were much more impoverished in meaning, as compared with our own stimuli, and, as a consequence, participants relied more heavily on seriation in their study. The hypothesis that the discrepancy between our results and theirs is due to the stimulus set was confirmed by our last experiment: When we used the same set of words as that used by Bireta et al., the recall advantage for short words over long words was severely reduced, decreasing from 29.5% in forward recall to 10.7% in backward recall.

For the experiments on irrelevant speech and phonological similarity, Bireta et al. (2010) used closed sets of letters that were the same for all participants. It can be argued that their results with letters were due to the extreme familiarity of letters, as compared with words. However, as was shown in Experiment 1B, increasing familiarity with the stimulus set did not modulate the interaction between recall direction and phonological similarity. Although no definite explanation can be provided for the abolition of phonological similarity and irrelevant speech effects in backward recall using letters, lexical representations are a likely candidate. Indeed, words have a lexical representations in long-term memory, while, to all practical means, letters do not.

The present study is not the first one to suggest that the stimulus set selected is responsible for the effects that are observed. For instance, Bireta, Neath, and Surprenant (2006; see also Jalbert, Neath, Bireta, & Surprenant, 2011) showed that the stimulus set used modulated the word length effect when short and long words were

presented in alternation in a list. On the one hand, this assumption warrants great care when selecting stimuli in order to test memory processes. On the other hand, it does not explain why, when letters or these specific word sets were used, Bireta et al. (2010) abolished the four benchmark memory phenomena.

The presence of results diametrically opposed to those observed by Bireta et al. (2010; Surprenant et al., 2011) in the nine experiments of the present series and the attribution of this difference to the word sets naturally raise the issue of items' representativeness. In both of their articles, Bireta and her colleagues used a total of 54 different words and 15 different letters. In the present series of experiments, we used 980 different words (one set of 196 words in Experiment 1; one set of 392 words in Experiments 2 and 3; and one set of 392 words in Experiment 4). We think that our 980 words are potentially more representative than the 54 words of Bireta et al. and, therefore, that our results are more likely to be replicated in future studies. This idea is comforted by the fact that in addition to the present study, other studies have shown that backward recall had no effect on memory phenomena (see, e.g., Guérard & Saint-Aubin, *in press*; Walker & Hulme, 1999). Undoubtedly, uncovering the key characteristic shared by Bireta et al.'s (2010) stimuli will shed light on the processes underpinning backward recall.

Implications for backward recall

In order to account for the effect of backward recall on the four benchmark memory effects, Bireta et al. (2010) suggested that when participants are required to recall items in the reverse order, attention to the order dimension is increased. Backward recall would necessitate more resources for order processing at the expense of item processing (see also Delosh & McDaniel, 1996). Therefore, the effects found in forward recall that are attributed to distinctiveness along the item dimension would be abolished in backward recall. This interpretation was challenged by Guérard and Saint-Aubin (*in press*), who showed that four phenomena that mainly affect the retention of item information—that is, the effects of semantic similarity, word frequency, lexicality, and imageability—were unaffected by backward recall (see also Walker & Hulme, 1999). According to Bireta et al.'s view, the four benchmark memory effects—that is, the effects of word length, phonological similarity, articulatory suppression, and irrelevant speech—are attributed to the item dimension. The item and order trade-off hypothesis predicts that they should be modulated by recall direction. However, this was not the case in the present study. Therefore, the item and order trade-off hypothesis cannot account for the present results.

In order to explain the discrepancy between Bireta et al.'s (2010; Surprenant et al., 2011) findings and those with

lexical effects, Guérard and Saint-Aubin (*in press*) suggested that the processes underlying benchmark memory effects and lexical effects were modulated differently by recall direction. In agreement with the modal view in the field, lexical effects can be accounted for by calling upon redintegration processes (see, e.g., Hulme et al., 1991; Saint-Aubin, Ouellette, & Poirier, 2005; Stuart & Hulme, 2009). To put it in a nutshell, during recall, degraded phonological representations must undergo a deblurring or reconstruction process before being output as a response. Long-term lexical representations would be used to support this reconstruction process, which would be insensitive to recall direction. The memory processes underlying benchmark memory effects, on the other hand, would be affected by recall direction, since immediate serial recall performance would be based on item and order processes.

The present study does not allow questioning the idea that lexical effects and benchmark memory phenomena depend on distinct processes. It clearly shows, however, that none of these processes are affected by recall direction.

The present study is consistent with previous research showing that memory phenomena, such as the effects of semantic similarity, word frequency, lexicality, and imageability, were unaffected by backward recall (Guérard &

Saint-Aubin, *in press*; Walker & Hulme, 1999). Together, these studies suggest that the processes underlying lexical effects and benchmark memory phenomena are not affected differently by backward recall. One parsimonious explanation that can account for the effect of backward recall is the principle of output interference (see Li & Lewandowsky, 1995): As items are output, the items not yet recalled are degraded and become more difficult to recall. In backward recall, the first items output are the last list's items. Therefore, these items suffer less from output interference, as compared with initial list's items, leading to a greater recency than primacy. In forward recall, recency is weaker than primacy because the last list's items are degraded during the recall of the first list's items.

In conclusion, the present study shows that benchmark memory effects well known to affect forward serial recall are all observed in backward serial recall. We are confident that these results will be easily replicable, since they were found with a large range of words. Overall, the present findings allowed understanding further the mechanisms underpinning backward recall. More precisely, they suggest that a parsimonious account based on the principle of output interference is sufficient to account for the effect of backward recall.

Appendix 1

Table 2 Analyses of variance for the proportion of correct recall in Experiments 1–5

Source	df	Phonological Similarity						Irrelevant Speech					
		Open Pool (Exp. 1A)			Closed Pool (Exp. 1B)			Open Pool (Exp. 2A)			Closed Pool (Exp. 2B)		
		<i>F</i>	<i>MSE</i>	η_p^2	<i>F</i>	<i>MSE</i>	η_p^2	<i>F</i>	<i>MSE</i>	η_p^2	<i>F</i>	<i>MSE</i>	η_p^2
RD	1, 19	1.58	.07	.08	1.54	.05	.08	0.65	.04	.03	0.91	.05	.05
Mem	1, 19	16.52*	.12	.47	22.33*	.08	.54	23.67*	.04	.56	56.81*	.03	.75
SP	6, 114	36.58*	.08	.66	21.70*	.05	.53	38.72*	.08	.67	17.30*	.15	.48
RD × Mem	1, 19	0.03	.03	.00	0.82	.02	.04	0.17	.04	.01	2.55	.03	.12
RD × SP	6, 114	26.38*	.03	.58	38.11*	.04	.67	55.81*	.01	.75	28.30*	.02	.60
Mem × SP	6, 114	2.40*	.01	.11	2.16	.01	.10	2.26*	.01	.11	2.80*	.01	.13
RD × Mem × SP	6, 114	0.63	.01	.03	1.18	.01	.06	0.29	.01	.02	0.28	.01	.01

Source	df	Articulatory Suppression						Word Length								
		Open Pool (Exp. 3A)			Closed Pool (Exp. 3B)			Open Pool (Exp. 4A)			Closed Pool (Exp. 4B)			Semi-closed (Exp. 5)		
		<i>F</i>	<i>MSE</i>	η_p^2	<i>F</i>	<i>MSE</i>	η_p^2	<i>F</i>	<i>MSE</i>	η_p^2	<i>F</i>	<i>MSE</i>	η_p^2	<i>F</i>	<i>MSE</i>	η_p^2
RD	1, 19	0.52	.03	.03	0.98	.02	.05	18.42*	.03	.49	1.70	.05	.08	11.04*	.06	.37
Mem	1, 19	104.86*	.06	.85	70.66*	.06	.79	27.70*	.07	.59	36.02*	.04	.66	28.10*	.05	.60
SP	6, 114	30.90*	.10	.62	44.97*	.06	.70	49.52*	.07	.72	47.97*	.06	.72	31.09*	.10	.62
RD × Mem	1, 19	6.02*	.02	.24	3.10	.02	.14	1.72	.03	.08	0.11	.03	.01	8.68*	.03	.31
RD × SP	6, 114	27.50*	.01	.59	28.70*	.02	.60	39.13*	.01	.67	30.93*	.03	.62	34.50*	.02	.65
Mem × SP	6, 114	3.61*	.03	.16	2.30	.03	.11	3.78*	.01	.17	2.53*	.02	.12	2.15*	.01	.10
RD × Mem × SP	6, 114	1.64	.01	.08	8.09*	.01	.30	0.61	.01	.03	0.39	.01	.02	0.98	.01	.05

Mem = benchmark memory phenomenon, RD = recall direction, SP = serial position

* $p < .05$

Appendix 2

Table 3 Analyses of variance for the combined analyses in Experiments 1–4

Source	<i>df</i>	Phonological Sim. (Exp. 1A & 1B)			Irrelevant Speech (Exp. 2A & 2B)		
		<i>F</i>	<i>MSE</i>	η_p^2	<i>F</i>	<i>MSE</i>	η_p^2
RD	1, 38	3.11*	.01	.08	0.03	.01	.00
Mem	1, 38	37.57*	.01	.50	75.95*	.01	.67
Pool	1, 38	4.66	.08	.11	0.15	.05	.00
RD × Pool	1, 38	0.02	.01	.00	1.56	.01	.04
Mem × Pool	1, 38	0.04	.01	.00	2.72	.01	.07
RD × Mem	1, 38	0.50	.00	.01	1.80	.01	.05
RD × Mem × Pool	1, 38	0.19	.00	.01	0.50	.01	.01

Source	<i>df</i>	Articulatory Supp. (Exp. 3A & 3B)			Word Length (Exp. 4A & 4B)		
		<i>F</i>	<i>MSE</i>	η_p^2	<i>F</i>	<i>MSE</i>	η_p^2
RD	1, 38	0.00	.00	.00	52.78*	.01	.58
Mem	1, 38	174.72*	.01	.82	56.10*	.01	.60
Pool	1, 38	2.92	.03	.07	1.77	.05	.04
RD × Pool	1, 38	1.40	.00	.04	29.15*	.01	.43
Mem × Pool	1, 38	2.88	.01	.07	0.00	.01	.00
RD × Mem	1, 38	8.82*	.00	.19	0.57	.00	.02
RD × Mem × Pool	1, 38	0.19	.00	.01	0.09	.00	.00

Mem = benchmark memory phenomenon, RD = recall direction

* $p < .05$

Lists used in Experiment 1

nb. Lists in the similar conditions are presented horizontally (e.g., paix, craie, frais, mets, plaie, vraie, trait). Lists in the dissimilar conditions are presented vertically (e.g., paix, grue, joint, nuit, banc, veau, toux)

Set 1

paix	craie	frais	mets	plaie	vraie	trait
[peace]	[chalk]	[expenses]	[dish]	[wound]	[truth]	[feature]
rue	lu	fût	vue	nue	bru	pus
[street]	[read]	[barrel]	[sight]	[nude]	[daughter-in-law]	[pus]
grain	loin	fin	train	frein	nain	lien
[grain]	[far]	[end]	[train]	[brake]	[dwarf]	[bond]
banc	dent	gant	plan	rang	vent	sang
[bench]	[tooth]	[glove]	[map]	[rank]	[wind]	[blood]
maux	tôt	chiot	saut	lot	flot	chaud
[pain]	[early]	[pup]	[jump]	[batch]	[flood]	[heat]
froid	plat	drap	joie	poids	proie	moi
[cold]	[dish]	[cloth]	[joy]	[weight]	[prey]	[ego]
blé	clef	dé	gai	fée	nez	quai
[wheat]	[key]	[dice]	[gay]	[fairy]	[nose]	[wharf]

Set 2

plein	mien	lin	thym	clin	saint	rien
[load]	[mine]	[linen]	[thyme]	[fillet]	[saint]	[naught]
prêt	fait	grès	jet	lait	guet	raie
[loan]	[fact]	[sandstone]	[fountain]	[milk]	[lookout]	[stripe]
frit	gui	plie	fruit	bruit	mie	brie
[fried]	[mistletoe]	[plaise]	[fruit]	[noise]	[crumb]	[brie]

grand	plant	sans	gens	cran	temps	dans
[senior]	[seedling]	[without]	[people]	[notch]	[time]	[in]
trou	coup	flou	loup	moue	sous	cou
[hole]	[knock]	[vagueness]	[wolf]	[pout]	[cash]	[neck]
vœu	pieux	vieux	queue	jeu	mieux	deux
[wish]	[pious]	[old]	[tail]	[game]	[best]	[two]
blond	long	jonc	prompt	rond	thon	pont
[blond]	[length]	[rush]	[swift]	[circle]	[tuna]	[bridge]
<i>Set 3</i>						
près	taie	quiet	muet	laid	niais	fouet
[near]	[slip]	[calm]	[mute]	[ugly]	[simpleton]	[whip]
joint	pin	vin	foin	sain	point	coin
[joint]	[pine]	[wine]	[hay]	[lard]	[point]	[corner]
nuit	riz	vie	ski	nid	prix	lit
[night]	[rice]	[life]	[ski]	[nest]	[price]	[bed]
franc	clan	quand	blanc	lent	gland	chant
[franc]	[clan]	[when]	[white]	[slow]	[acorn]	[song]
toux	roux	goût	clou	boue	doux	joue
[cough]	[red]	[taste]	[nail]	[mud]	[goy]	[cheek]
gras	bas	spa	tas	bras	gars	trois
[fat]	[sock]	[spa]	[heap]	[arm]	[guy]	[three]
fond	don	mont	bond	lion	nom	pion
[bottom]	[gift]	[mount]	[jump]	[lion]	[name]	[pawn]
<i>Set 4</i>						
grue	cru	but	glu	flux	jus	dru
[crane]	[vineyard]	[goal]	[glue]	[flow]	[juice]	[thick]
veau	sceau	peau	mot	gros	haut	dos
[calf]	[seal]	[skin]	[word]	[bulk]	[top]	[back]
pneu	feu	yeux	dieu	bleu	creux	lieu
[tire]	[fire]	[eyes]	[god]	[blue]	[hollow]	[place]
puis	ouïe	truie	scie	gris	suie	cuit
[then]	[hearing]	[sow]	[saw]	[gray]	[soot]	[cooked]
ton	son	front	ion	plomb	scion	tronc
[pitch]	[noise]	[forehead]	[ion]	[lead]	[scion]	[trunk]
chat	noix	croix	doigt	foie	loi	soie
[cat]	[nut]	[cross]	[finger]	[liver]	[law]	[silk]
bain	chien	pain	main	vingt	gain	rein
[bath]	[dog]	[bread]	[hand]	[twenty]	[profit]	[kidney]

Lists used in Experiments 2 and 3

Set 1

bond	cap	lord	joueur	fer	lot	rat
[jump]	[cape]	[lord]	[player]	[iron]	[batch]	[rat]
ciel	os	gag	short	muet	prix	coup
[sky]	[bone]	[gag]	[knickers]	[mute]	[price]	[knock]
veuf	clic	noix	sketch	vis	duo	coin
[widower]	[click]	[nut]	[sketch]	[screw]	[duet]	[corner]
punch	nerf	fleur	plein	gras	rond	dieu
[punch]	[nerve]	[flower]	[load]	[fat]	[circle]	[god]
jazz	oie	lard	bail	loup	tri	blond

[jazz]	[goose]	[bacon]	[lease]	[wolf]	[sorting]	[blond]
ion	gel	quai	sac	foi	biais	tour
[ion]	[frost]	[wharf]	[bag]	[faith]	[slant]	[turn]
chips	tronc	golf	trait	chant	mat	bout
[chips]	[trunk]	[golf]	[feature]	[song]	[checkmate]	[tip]
air	foie	but	raie	chic	vers	sueur
[air]	[liver]	[goal]	[stripe]	[knack]	[rhyme]	[sweat]
pro	gaz	sou	frais	flirt	watt	pois
[pro]	[gas]	[penny]	[expenses]	[flirting]	[watt]	[pea]
bloc	clair	pieu	sang	stress	son	prêt
[block]	[light]	[stake]	[blood]	[stress]	[noise]	[loan]
steak	lieue	fée	loft	soir	pin	bal
[steak]	[league]	[fairy]	[loft]	[evening]	[pine]	[ball]
troll	nu	soif	pif	fait	voix	haut
[troll]	[nude]	[thirst]	[nose]	[fact]	[voice]	[top]
mer	moi	baie	dent	toast	star	coach
[sea]	[ego]	[bay]	[tooth]	[toast]	[star]	[coach]
grue	sir	chat	soin	cour	fil	char
[crane]	[sir]	[cat]	[care]	[yard]	[wire]	[tank]
banc	vif	bas	tout	zoom	pneu	sens
[bench]	[raw]	[sock]	[whole]	[zoom]	[tire]	[way]
snob	grain	pic	bac	vol	gris	toux
[snob]	[grain]	[peak]	[tub]	[flight]	[gray]	[cough]
pont	gong	mur	yeux	toit	grill	arc
[bridge]	[bell]	[wall]	[eyes]	[roof]	[steakhouse]	[bow]
court	rhum	cent	rue	ail	drap	corps
[course]	[rum]	[hundred]	[street]	[garlic]	[cloth]	[body]
train	dos	roue	art	gens	duc	long
[train]	[back]	[wheel]	[art]	[people]	[duke]	[length]
ouest	tas	pot	fruit	roux	pour	paie
[west]	[heap]	[pot]	[fruit]	[red]	[pro]	[pay]
grand	vœu	nord	jus	vie	greffe	cil
[senior]	[wish]	[north]	[juice]	[life]	[transplant]	[lash]
dard	coq	mort	droit	tic	roc	lien
[dart]	[rooster]	[death]	[right]	[tic]	[rock]	[bond]
max	veau	tank	lait	non	match	test
[max]	[calf]	[tank]	[milk]	[no]	[match]	[test]
franc	sourd	gain	saut	suie	hall	plus
[franc]	[deaf person]	[profit]	[jump]	[soot]	[hall]	[plus]
bien	scout	yacht	clan	poids	surf	vert
[good]	[boy scout]	[yacht]	[clan]	[weight]	[surfing]	[green]
cieux	rein	mai	ours	rap	joie	trueie
[heaven]	[kidney]	[May]	[bear]	[rap]	[joy]	[sow]
tir	pain	flanc	est	rock	coût	sot
[shooting]	[bread]	[side]	[east]	[rock]	[cost]	[zany]
stop	cuir	job	moeurs	cou	bar	sol
[stop]	[leather]	[job]	[customs]	[neck]	[bar]	[ground]
<i>Set 2</i>						
sort	noir	chair	nul	soie	taux	bras
[fate]	[black]	[flesh]	[idiot]	[silk]	[rate]	[arm]
peur	fort	stock	plant	voie	pré	lion
[fear]	[fort]	[stock]	[seedling]	[way]	[meadow]	[lion]

trip	coeur	mal	front	nain	script	pie
[trip]	[heart]	[pain]	[forehead]	[dwarf]	[script]	[magpie]
col	tien	chou	deuil	bouc	vue	fil
[collar]	[yours]	[cabbage]	[mourning]	[goat]	[sight]	[son]
goût	flux	club	set	mois	tag	fouet
[taste]	[flow]	[club]	[set]	[month]	[graffiti]	[whip]
sport	parc	patch	plat	scotch	tract	craie
[sport]	[park]	[patch]	[dish]	[scotch]	[pamphlet]	[chalk]
souhait	don	haie	joue	or	chaud	rail
[wish]	[gift]	[hedge]	[cheek]	[gold]	[heat]	[rail]
vent	joug	plaie	joint	blé	flair	lieu
[wind]	[yoke]	[wound]	[joint]	[wheat]	[intuition]	[place]
gros	mets	bain	feu	cri	boeuf	froid
[bulk]	[dish]	[bath]	[fire]	[shout]	[beef]	[cold]
pli	gang	pet	mot	pub	fin	scalp
[fold]	[gang]	[fart]	[word]	[saloon]	[end]	[scalp]
lac	moins	rot	brun	choc	ouïe	pouls
[lake]	[minus]	[burp]	[brown]	[shock]	[hearing]	[pulse]
brin	paix	duel	seau	jet	bord	thé
[strand]	[peace]	[duel]	[bucket]	[fountain]	[edge]	[tea]
volt	daim	gym	doigt	pion	lit	blanc
[volt]	[deer]	[gym]	[finger]	[paw]	[bed]	[white]
boue	tin	cran	zinc	poil	nuit	pleur
[mud]	[keelblock]	[notch]	[zinc]	[hair]	[night]	[tear]
pou	chiot	bruit	fax	bec	foin	ton
[lice]	[pup]	[noise]	[fax]	[beak]	[hay]	[pitch]
mars	rien	champ	doux	pied	thon	poing
[March]	[naught]	[field]	[goy]	[foot]	[tuna]	[fist]
proie	vin	gant	plouc	creux	pair	talc
[prey]	[wine]	[glove]	[idiot]	[hollow]	[peer]	[talc]
chef	frein	scie	jeep	gré	punk	trou
[chief]	[brake]	[saw]	[jeep]	[liking]	[punk]	[hole]
quart	chien	grec	fou	choeur	clef	jouet
[quarter]	[dog]	[greek]	[bishop]	[choir]	[key]	[toy]
guet	bol	spot	teint	queue	riz	cas
[lookout]	[bowl]	[spot]	[complexion]	[tail]	[rice]	[case]
ski	point	tact	part	peau	tort	sud
[ski]	[point]	[tact]	[portion]	[skin]	[wrong]	[south]
four	plomb	puits	cerf	juin	mont	round
[oven]	[lead]	[well]	[stag]	[June]	[mount]	[round]
clin	froc	tard	proue	dur	ranch	juif
[fillet]	[trousers]	[evening]	[prow]	[tough nut]	[ranch]	[jew]
flash	lin	gourd	oeuf	ruée	clip	sel
[flash]	[linen]	[heavy hand]	[egg]	[rush]	[clip]	[salt]
sceau	fonds	rush	rang	seuil	porc	clou
[seal]	[fund]	[dash]	[rank]	[threshold]	[pig]	[nail]
soeur	août	as	trac	jeu	beau	dé
[sister]	[August]	[ace]	[jitters]	[game]	[beauty]	[dice]
nez	pas	kit	bois	saint	port	nid
[nose]	[step]	[kit]	[wood]	[saint]	[port]	[nest]
sein	croix	tiers	mou	flot	lueur	nom
[breast]	[cross]	[third]	[wimp]	[flood]	[gleam]	[name]

Lists used in Experiment 4

Short words

saint	bond	fruit	coq	bouc	flot	four
[saint]	[jump]	[fruit]	[rooster]	[goat]	[flood]	[oven]
mets	suie	sou	fonds	gain	creux	chaux
[dish]	[soot]	[penny]	[fund]	[profit]	[hollow]	[lime]
soie	parc	tiers	frais	bol	char	ouest
[silk]	[park]	[third]	[expenses]	[bowl]	[tank]	[west]
roux	star	pair	lion	zinc	bœuf	jet
[red]	[star]	[peer]	[lion]	[zinc]	[beef]	[fountain]
tic	plein	club	tronc	lait	chaud	fût
[tic]	[load]	[club]	[trunk]	[milk]	[heat]	[barrel]
rail	loi	moue	clou	craie	poil	ver
[rail]	[law]	[pout]	[nail]	[chalk]	[hair]	[worm]
clown	foie	grain	proue	but	rang	puits
[clown]	[liver]	[grain]	[prow]	[goal]	[rank]	[well]
haie	juin	bac	jazz	gris	pif	clerc
[hedge]	[June]	[tub]	[jazz]	[gray]	[nose]	[clerk]
oie	fée	cran	rat	rein	chou	chœur
[goose]	[fairy]	[notch]	[rat]	[kidney]	[cabbage]	[choir]
cap	arc	jus	frein	saut	lourd	cent
[cape]	[bow]	[juice]	[brake]	[jump]	[heavy]	[hundred]
noix	rien	œuf	plomb	bar	cil	clair
[nut]	[naught]	[egg]	[lead]	[bar]	[lash]	[light]
nerf	sport	jouet	blé	gant	duc	scie
[nerve]	[sport]	[toy]	[wheat]	[glove]	[duke]	[saw]
doux	fric	golf	lard	froc	bloc	proie
[goy]	[money]	[golf]	[bacon]	[trousers]	[block]	[prey]
joint	tsar	vis	clef	fou	lieue	plaie
[joint]	[tsar]	[screw]	[key]	[bishop]	[league]	[wound]
rond	veau	sud	fouet	pli	août	pieu
[circle]	[calf]	[south]	[whip]	[fold]	[August]	[stake]
guet	jonc	trot	soif	pic	flux	mœurs
[lookout]	[rush]	[trot]	[thirst]	[peak]	[flow]	[customs]
gré	prêt	vol	croc	riz	nain	plus
[liking]	[loan]	[flight]	[fang]	[rice]	[dwarf]	[plus]
pois	mai	teint	match	cerf	clé	gaz
[pea]	[May]	[complexion]	[match]	[deer]	[key]	[gas]
lot	tir	boue	clan	mie	choix	seuil
[batch]	[shooting]	[mud]	[clan]	[crumb]	[choice]	[threshold]
grec	lien	seau	bus	queue	mars	roc
[greek]	[bond]	[bucket]	[bus]	[tail]	[March]	[rock]
croix	pin	veuf	raie	pneu	pleur	bourg
[cross]	[pine]	[widower]	[stripe]	[tire]	[tear]	[town]
pré	trac	baie	mât	sel	lin	cru
[meadow]	[jitters]	[bay]	[mast]	[salt]	[linen]	[vineyard]
lac	nid	brin	vif	roue	porc	dé
[lake]	[nest]	[strand]	[bait]	[wheel]	[pork]	[dice]
bec	ours	mont	bal	moins	faux	gel

[beak]	[bear]	[mount]	[ball]	[minus]	[false]	[frost]
chant	joueur	choc	daim	toux	gras	pot
[song]	[player]	[shock]	[deer]	[cough]	[fat]	[pot]
loup	ail	ski	as	foin	flanc	vœu
[wolf]	[garlic]	[ski]	[ace]	[hay]	[side]	[wish]
don	test	thé	souhait	os	tort	pou
[gift]	[test]	[tea]	[wish]	[bone]	[wrong]	[lice]
crin	pion	sort	tract	gars	vrai	deuil
[horsehair]	[pawn]	[fate]	[pamphlet]	[guy]	[truth]	[mourning]
<i>Long words</i>						
pharmacie	peuplier	chirurgien	chevalet	paysan	punition	arsenal
[pharmacy]	[poplar]	[surgeon]	[easel]	[peasant]	[punishment]	[arsenal]
olivier	ornement	poésie	éventail	ensemble	pantalon	procureur
[olive tree]	[ornament]	[poetry]	[range]	[set]	[pants]	[prosecutor]
ingénieur	incendie	document	garage	division	écureuil	déjeuner
[engineer]	[fire]	[document]	[garage]	[division]	[squirrel]	[breakfast]
caméra	aliment	barrage	agonie	escabeau	bataillon	entrevue
[camera]	[food]	[dam]	[agony]	[stepladder]	[battalion]	[interview]
écrivain	assistant	cardinal	réception	inspecteur	cheminée	harmonie
[writer]	[assistant]	[cardinal]	[reception]	[inspector]	[chimney]	[harmony]
industrie	professeur	commerçant	élection	musicien	araignée	lavabo
[industry]	[professor]	[trader]	[election]	[musician]	[spider]	[sink]
ascenseur	accident	capuchon	estomac	barbelé	détenu	biographie
[elevator]	[accident]	[hood]	[stomach]	[barbwire]	[inmate]	[biography]
atelier	argument	carillon	amateur	gouverneur	citoyen	capital
[workshop]	[argument]	[bells]	[amateur]	[governor]	[citizen]	[capital]
alibi	carnaval	irruption	robinet	syndicat	bouclier	océan
[alibi]	[carnival]	[irruption]	[faucet]	[union]	[shield]	[ocean]
producteur	policier	éléphant	énergie	pyjama	construction	inconnu
[producer]	[policeman]	[elephant]	[energy]	[pyjama]	[construction]	[stranger]
instrument	rédaction	embarras	entretien	ouvrier	cabaret	travailleur
[instrument]	[essay]	[embarrassment]	[maintenance]	[workman]	[cabaret]	[worker]
cinéma	radiateur	compliment	hôpital	horizon	cavalier	colonie
[cinema]	[radiator]	[compliment]	[hospital]	[horizon]	[horseman]	[colony]
cyindre	chemisier	champignon	oasis	tragédie	tremblement	parasol
[cylinder]	[blouse]	[mushroom]	[oasis]	[tragedy]	[tremor]	[parasol]
projecteur	parapluie	jardinière	réservoir	colonel	collection	restaurant
[projector]	[umbrella]	[gardener]	[reservoir]	[colonel]	[collection]	[restaurant]
moniteur	bâtiment	hiérarchie	haricot	examen	chevalier	destruction
[monitor]	[building]	[hierarchy]	[bean]	[exam]	[knight]	[destruction]
officier	appareil	étalon	étudiant	aquarium	vendredi	voyageur
[officer]	[apparatus]	[stallion]	[student]	[aquarium]	[friday]	[traveller]
illusion	paradis	canapé	visiteur	oreiller	hurlement	tabouret
[illusion]	[paradise]	[sofa]	[visitor]	[pillow]	[scream]	[stool]
agenda	explosion	festival	combattant	comédie	couturier	directeur
[agenda]	[explosion]	[festival]	[fighter]	[comedy]	[designer]	[director]
habitant	compagnon	univers	maladie	cabinet	serviteur	prisonnier
[resident]	[companion]	[universe]	[disease]	[office]	[servant]	[prisoner]
casino	mercredi	majesté	spectateur	monument	saucisson	corridor
[casino]	[Wednesday]	[majesty]	[spectator]	[monument]	[sausage]	[corridor]
pistolet	passager	historien	parlement	étendue	fondation	fantaisie
[pistol]	[passenger]	[historian]	[parliament]	[area]	[foundation]	[fantasy]

chocolat	animal	retenue	papillon	cuisinier	épaisseur	artisan
[chocolate]	[animal]	[restraint]	[butterfly]	[cook]	[thickness]	[artisan]
citation	conducteur	abolement	amoureux	bourgeoisie	écolier	candidat
[quote]	[driver]	[barking]	[lover]	[gentry]	[schoolboy]	[candidate]
testament	autobus	mélodie	avenue	tablier	magasin	réunion
[testament]	[bus]	[melody]	[avenue]	[apron]	[store]	[meeting]
infirmier	profondeur	librairie	émission	souterrain	scénario	continent
[nurse]	[depth]	[library]	[broadcasting]	[tunnel]	[scenario]	[continent]
appétit	terminus	tourbillon	commandant	banane	escargot	cendrier
[appetite]	[terminus]	[vortex]	[commander]	[banana]	[snail]	[ashtray]
meublier	invention	numéro	tribunal	président	opéra	perroquet
[furniture]	[invention]	[number]	[court]	[president]	[opera]	[parrot]
pharmacien	sifflement	pavillon	écurie	entonnoir	pâtissier	avocat
[pharmacist]	[whistle]	[pavilion]	[stable]	[funnel]	[baker]	[lawyer]

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