2024 ■ Vol. 20 ■ no. 1

Articulatory rehearsal and phonological storage in working memory: A replication of Longoni et al. (1993)

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Abstract ■ This study sought to replicate Longoni et al.'s (1993) investigation into the multiple subsystems within the phonological loop, originally proposed by Baddeley et al. (1984). To address the replicability crisis in scientific research, this replication maintains similar methodologies but also features a more diverse sample, characterized solely by advanced French proficiency and increased participant numbers. In addition, this study examined various characteristics of the phonological loop, including the phonemic similarity effect, word length effect, presentation conditions, articulatory suppression effect, and irrelevant sounds. However, the articulatory suppression effect, word length effect, presentation speed effect, and delay effect did not replicate. Notably, an interaction emerged between word length and phonemic similarity, indicating a multiplicative relationship rather than an additive one. The present study emphasizes the importance of further exploration into the factors that influence the non-replicated effects, including the discriminant validity of the variables. Future studies could leverage insights from the phonological loop's characteristics to enhance understanding of the working memory system.

Keywords ■ phonological loop replication, word length effect, phonemic similarity, working memory, replicability predicament.

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10.20982/tqmp.20.1.r001

Acting Editor ■ Denis Cousineau (Université d'Ottawa)

Reviewers
■ No authors from the original article reviewed this article.

Introduction

Memory in its various forms plays a crucial role in the life of human beings, whether for its adaptive role in the environment (Bonin & Bugaïska, 2014), its facilitation of learning, or its involvement in information processing (Malmberg et al., 2019). Among them, short-term memory (STM; Atkinson & Shiffrin, 1968), later renamed working memory (WM; Baddeley & Hitch, 1974), is known as the memory of the present moment. Baddeley and Hitch's (1974) model of WM proposes a multi-component system, distinguishing itself from initial models suggesting a single component: 1) the central executive, which is the attentional control center, 2) the visuospatial sketchpad, which allows the maintenance of visual and spatial information, and 3) the phonological loop, which enables the maintenance of verbal information. A. D. Baddeley (2000) adds a fourth component to the model: 4) the episodic buffer, which would facilitate the coordination of information between WM and long-term memory (LTM).

The phonological loop itself is divided into two components: 1) the phonological store, which is the entry point for auditory information where it is briefly held in a phonological form, and 2) the articulatory loop, which is the entry point for visual stimuli and allows the maintenance of active information in the phonological store through rehearsal (Lemaire & Didierjean, 2018; Fortin & Rousseau, 2015).

One method used to study the phonological loop is the serial recall task, as conducted in the study by Longoni et al. (1993), itself a replication of Baddeley et al.'s (1984) studies. A serial recall task involves the retrieval of information from the participant's memory without the presence of the information during recall (Cleary, 2019). When perform-

ing this task, the participant must recall the information in the order in which it was presented (Hurlstone et al., 2014). In Longoni et al.'s (1993) study, researchers identified and studied five factors that could influence participants' performance, namely (1) the degree of phonemic confusion between items to be recalled (phonological similarity effect; Conrad & Hull, 1964; Baddeley et al., 1984; Page et al., 2007; Roodenrys et al., 2022), (2) the articulatory duration of different items (word length effect; Baddeley et al., 1975; Baddeley & Wilson, 1985; Monnier & Ejarque, 2008; Guitard et al., 2018), (3) the modality of item presentation (visual or auditory; Foxe et al., 2021), (4) asking participants to repeat the syllable or word aloud (articulatory suppression effect; Norris et al., 2018; Baddeley & Hitch, 2019), and (5) the presentation of sounds to be ignored (irrelevant speech effect; Murray, 1968; Colle & Welsh, 1976). These five different factors come into play in specific regions of the articulatory loop. The phonological similarity effect, auditory presentation, and irrelevant speech effect occupy the phonological store, while the word length effect, visual presentation, and articulatory suppression effect occupy the articulatory loop.

The present study is a replication of Longoni et al.'s (1993) studies, conducted by changing the language of the stimuli from Italian to French, as a change in language can result in differences in certain aspects of serial recall (Amici et al., 2019). This new moderating variable will further generalize the initial results (Asendorpf et al., 2013).

Longoni et al.'s (1993) 5 studies and hypotheses

Experiment 1. The word length effect and articulatory suppression were used as indicators for the articulatory loop, while the phonological similarity effect was indicated for the phonological store. The nature of the chosen stimuli was auditory; consequently, articulatory suppression should eliminate the word length effect but should not abolish the phonological similarity effect. However, in Longoni et al.'s (1993) Experiment 1, there seemed to be a relationship between similarity and word length that was potentially due to a plateau effect.

Experiment 2. Explores the relationship between similarity and word length by adding one extra word to the serial recall task. In Longoni et al.'s (1993) Experiment 2, the phonological similarity effect and word length effect were demonstrated to be independent of each other. Using a similar protocol for both experiments should yield similar results.

Experiment 3. The word length effect was contrasted with the irrelevant speech effect as an alternative indicator for the phonological store. The nature of the chosen stimuli was visual. Based on the results obtained by Longoni et al. (1993), the two effects are expected to be independent.

Experiment 4. This experiment examines the effect of articulatory suppression on phonological similarity when items were presented additively at a conventional speed (0.5 sec/item) compared to a slow speed (5 sec/item). A recall occurred after a delay of 5 seconds. Longoni et al.'s (1993) results suggest that articulatory suppression abolished the phonemic similarity effect at a slow presentation rate.

Experiment 5. In this experiment, the effect of articulatory suppression on phonological similarity was studied when items were presented additively as in Experiment 4. However, recall time was investigated; immediate recall and a delayed recall group (10s). Longoni et al. (1993) observed that articulatory suppression did not influence the similarity effect even after a 10-second delay.

Objectives

Since this study is a replication, the main objective is to reproduce the initial study by Longoni et al. (1993) and obtain similar results. This will support the phonological loop model proposed by Baddeley et al. (1984). It is especially necessary to highlight the results of this study if contradictory results are obtained to question an important model in cognitive psychology that seemed to be perfectly demonstrated in Longoni et al. (1993). In the present replication of the five experiments, different participants were recruited for each experiment. All experiments presented here have an equal or slightly larger number of participants than in the original article.

Experiment 1

The first experiment aimed to test the hypothesis that articulatory control is responsible for the word length effect, while the phonological loop is responsible for the phonemic similarity effect. According to the hypothesis, articulatory control and the phonological loop would be independent, not two indicators of the same theoretical component. The use of articulatory suppression, phonological similarity, and word length should affect working memory.

Methodology

Participants and Recruitment. This study replicates Longoni et al.'s (1993) Experiment 1, with a larger group of participants. A convenience sample was recruited, with the only inclusion criteria being a good understanding of French, comprehension of the task, and the ability to perform it. In total, 30 subjects participated in Experiment 1 (50/50 men and women, aged 15 to 54), compared to 24 participants in the original study. All participants completed a consent form and a demographic questionnaire.

Materials. Four lists of six words in four different conditions were used to evaluate the effects of word length and

Table 1 ■ Average percentage of lists correctly recalled in immediate serial recall, based on phonemic similarity and word length under silent conditions and under articulatory suppression, in Experiment 1 of Longoni et al.'s (1993) study.

	Similar		Dissimilar		
	Short	Long	Short	Long	
Silent	86.2	73.7	63.2	31.2	63.6
Suppression	52.0	49.4	25.0	15.5	36.0
	69.1	61.5	44.1	24.4	
	65.3		34.2		

Note. The left and bottom margins shows the means.

Table 2 ■ Average percentage of lists correctly recalled in immediate serial recall, based on phonemic similarity and word length under silent conditions and under articulatory suppression, in the current replication of Experiment 1.

	Similar		Dissimilar		
	Short	Long	Short	Long	
Silent	88.5	87.5	85.3	67.5	82.2
Suppression	87.0	82.5	74.3	61.3	76.3
	87.5	85.0	79.3	64.4	
	86.4		71.8		

Note. The left and bottom margins shows the means.

phonological similarity. The first list included short similar words, the second list had long similar words, the third list consisted of short dissimilar words, and the fourth list contained long dissimilar words.

The word length effect was evaluated using short (two-syllable) and long (four-syllable) words. Phonological similarity was assessed using similar and dissimilar words. For similar words, the sound "on" was present in the last syllable of short words, and the sound "ment" was present in the last syllable of long words. Following Longoni et al.'s (1993) Experiment 1, four randomly selected words from each list were used to create twelve sequences for each group. Additionally, two training sequences were designed for each of the four lists, with a total of 48 evaluated sequences and 8 practice sequences. The word lists were presented visually on a computer screen and audibly through headphones using E-Prime software.

Procedure. Participants were divided into two equivalent groups. During sequence presentation, one group had to whisper continuously "one, two, three," at a rate of one word per second, during both presentation and recall of sequences, to produce the articulatory suppression effect. The other group remained silent during these tasks.

Eight training sequences were presented, followed by 48 sequences in random order for each participant. Stimuli were presented visually on the screen and audibly through a voice synthesizer. A verbal warning was given three seconds before the experiment's start, followed by the presentation of a sequence of four words at a rate of 1.5 seconds per word. A visual warning was presented 2 seconds after the last word.

After a 20-second retention period, participants had to perform a serial recall: they had to write, in the order of presentation, the words they remembered on a response sheet. If a participant did not remember a word at a certain position, they had to cross out that position to indicate it.

Results

The original study and its replication aim to measure the ability to recall words from a list based on three factors: word length (A), phonemic similarity (B), and articulatory suppression (C). The results obtained from Experiment 1, compared to Longoni et al.'s (1993) study, show both significant similarities and differences. Tables 1 and 2 present the average percentage of correctly recalled lists in immediate serial recall, based on phonemic similarity and word length under silent conditions and under articulatory suppression for Longoni et al.'s (1993) Experiment 1 (their Table 1) and the replication study (Table 2). ANOVA was conducted on the number of correctly recalled sequences per participant in each condition, using articulatory suppression as the between-subjects factor and phonemic similarity and word length as within-subject factors.

In Longoni et al.'s (1993) experiment, the results were consistent with the hypothesis, indicating a word length effect (A): [$F(1, 22) = 35.41$, $p < .001$, $\eta_p^2 = .62$], a phonemic similarity effect (B): [$F(1, 22) = 121.10$, $p < .001$, $\eta_p^2 = .85$], and an articulatory suppression effect (C): [$F(1, 22) = 17.62$, $p < .001$, $\eta_p^2 = .44$]. The authors also reported interactions A × B: $F(1, 22) = 6.30$, $p < .02$, $\eta_p^2 = .22$, and A × C: $F(1, 22) = 14.40$, $p < .001$, $\eta_p^2 = .40$. In the results of the present replication, participants' performance was better, with a nearly 30% higher correct response rate. The results demonstrate a significant main effect of phonemic similarity (B): [$F(1, 28) = 57.30$, $p < .001$, $\eta_p^2 = .67$]. However, although a main effect of word length is detected, the effect size is significantly smaller than in the original study (A): [$F(1, 28) = 3.968$, $p < .001$, $\eta_p^2 = .12$]. Moreover, the effect of articulatory suppression is not significant (C): [$F(1, 28) = 3.223$, $p = .08$, $\eta_p^2 = .10$], unlike the results of Longoni et al. (1993). Finally, the interaction between the word length effect and the phonemic similarity effect proved to be significant A × B [$F(1, 28) = 14.23$, $p = .001$, $\eta_p^2 = .34$], as in Longoni et al.'s (1993) study. However, in-

Table 3 ■ Average percentage of correctly recalled lists in immediate serial recall, based on phonemic similarity and word length without articulatory suppression in Experiment 2 of the study by Longoni et al. (1993).

	Similar		Dissimilar	
	Short	Long	Short	Long
Without suppression	74.5	59.9	20.3	6.8

Table 4 ■ Average percentage of correctly recalled lists in immediate serial recall, based on phonemic similarity and word length without articulatory suppression in the current replication of Experiment 2.

	Similar		Dissimilar	
	Short	Long	Short	Long
Without suppression	80.0	78.2	73.6	62.4

teractions between the articulatory suppression effect and the word length effect (A × C): [$F(1, 28) = 0.02$, $p = .88$, $\eta_p^2 < .001$], and the triple interaction among all three variables (A × B × C) [$F(1, 28) = 1.412$, $p = .24$, $\eta_p^2 = .05$], were all non-significant, contrary to what Longoni et al. (1993) reported. Finally, the interaction between the articulatory suppression effect and the phonemic similarity effect B × C [$F(1, 28) = 1.973$, $p = .17$, $\eta_p^2 = .07$], is not significant, as in Longoni et al.'s (1993) findings.

Discussion

Longoni et al. (1993) hypothesized that the word length effect would result from articulatory control processes, while the phonemic similarity effect would stem from the use of phonological memory. Consequently, they predicted that in silent learning, the two effects should be additive and independent. Articulatory suppression, they reasoned, would eliminate the word length effect but not diminish the phonemic similarity effect. As anticipated, the results of the present study demonstrate that word length and phonemic similarity have a significant impact on recall. Both effects also influence each other significantly. Therefore, in the condition of similar words, shorter words were recalled more accurately than longer words. Furthermore, the results imply that articulatory suppression does not influence recall or have interactions with phonemic similarity. In contrast to Longoni et al. (1993), the present study suggests that the word length effect was not significantly eliminated by articulatory suppression. These findings are inconsistent with the theory that the word length effect is eliminated by articulatory suppression while the phonemic similarity effect is not. This contradicts the hypothesis that word length and phonemic similarity use two independent systems for sequence storage.

According to the results of Longoni et al. (1993), the word length effect is greater when words are similar than when they are dissimilar. This could indicate that phonemic similarity is affected by word length, and consequently, phonetically longer words are not recalled as well as shorter, similar words. This interaction was replicated in the present study, raising the question of why word length and phonemic similarity seem to have a more significant impact in silent conditions. Longoni et al. (1993) interpreted this interaction as a ceiling effect, suggesting that the task might be too easy.

Experiment 2

Experiment 2 was conducted to verify whether the interaction between the word length and phonological similarity effects is related to a ceiling effect for short dissimilar word sequences. To make the task more challenging, the number of words in each sequence was increased, and silent learning was adopted. The original study by Baddeley et al. (1984) suggests that this task was indeed more difficult in silent learning.

Methodology

Eighteen participants (12 women and 6 men, aged 15 to 55) were recruited for Experiment 2 (compared to 16 in the original study). The methodology of Longoni et al. (1993), Experiment 2, is replicated for this experiment. Two modifications are made to the methodology of the first experiment: 1) each sequence contains five words instead of four, and 2) all participants experienced the task in silence. Everything else is identical to Experiment 1.

Results

The analysis of the results of the second experiment was again based on the recall of complete sequences by the participants. Particularly, this recall was performed under conditions without articulatory suppression, aiming to verify if there is indeed an interaction between word length and phonological similarity. Tables 3 and 4 illustrate the average percentage of correctly recalled lists in immediate serial recall, based on phonological similarity and word length without articulatory suppression from the study by Longoni et al. (1993) and this replication, respectively. It is noteworthy that the participants in the present study performed significantly better, with a recall percentage 30% higher than in the original study (average of 73.6% compared to 40.4% in Longoni et al., 1993).

The results of the second experiment in Longoni et al.'s (1993) study demonstrate a significant main effect of word length (A) [$F(1, 15) = 34.34$, $p < .011$, $\eta_p^2 = .70$] as well as an effect of phonological similarity (B) [$F(1, 15) = 214.17$, $p < .001$, $\eta_p^2 = .93$]. The interaction between these two

factors, that was present in the previous experiment, was no longer evident. This indicates that the effects would be additive and independent, as mentioned in their hypothesis. In the present study, a main effect of word length (A): [$F(1, 17) = 9.41$, $p = .007$, $\eta_p^2 = .36$] and of phonological similarity (B): [$F(1, 17) = 936.91$, $p < .001$, $\eta_p^2 = .98$] is present. However, an interaction between word length and phonological similarity is also present, A × B: [$F(1, 28) = 14.23$, $p = .001$]. This suggests that the effect of word length and similarity may not be independent and additive but rather multiplicative.

Discussion

The second experiment was conducted to further explore the ceiling effect observed in the previous experiment; thus, the second experiment was conducted under conditions without articulatory suppression. According to the results of Longoni et al. (1993), the interaction between word length and phonological similarity is eliminated under conditions without articulatory suppression, reaffirming their hypothesis that these effects are independent and additive. However, the results of the present study indicate a significant interaction between the two variables. These findings reinforce the results of the previous experiment, suggesting that the two effects have a more substantial impact on each other than initially suggested. Therefore, data collected may not reveal individual systems of phonological memory but rather converging operations within the same system.

The presence of this interaction led researchers (Salamé & Baddeley, 1982; Baddeley et al., 1984) to revise the concept of the articulatory loop. The articulatory loop is now viewed as a system responsible for storing phonological inputs while influenced by an articulatory process. This may explain the interaction between word length and phonological similarity observed in the results of this replication.

Experiment 3

Experiment 3 aims to investigate the effects of word length and irrelevant stimuli on immediate serial recall. Word sequences were presented either with ambient sound or with irrelevant speech, intending to distract participants during recall. It was demonstrated that serial recall of visual stimuli was significantly influenced when subjects were exposed to speech that needed to be ignored (Colle & Welsh, 1976). According to Baddeley, the articulatory loop represents the coding of auditory information, specifically speech, in working memory. With limited capacity, it would result in the word length effect (Baddeley et al., 1984).

Methodology

Participants. 28 participants (16 females and 12 males; aged 14 to 64) were recruited for this study (compared to 24 in the original study).

Material. Two lists, each containing seven words with the same number of letters, phonemes and syllables, were used. One list comprised words that took longer to pronounce aloud, while the words in the second list took less time to pronounce. The first list included the words cesser, accueil, propos, bambou, alcool, autour and carton. The second list contained the words dehors, souhait, cadeau, chassé, bandit, chaton and soleil. From these two lists, the seven words from both lists were randomly presented in each sequence for a total of ten sequences. An auditory recording (70 decibels) of 400 irrelevant random words was used for the condition involving irrelevant speech, at a rate of 1 word/second.

Procedure. To vary the order of condition administration (described below), participants were divided into two groups of 14 individuals each. Each group underwent one condition with ten sequences (five short words and five long words) before completing the other condition with ten additional sequences.

In the first condition, ambient noise (35 dB) recorded in a quiet room was present in the participant's headphones during the visual and auditory presentation of words and during the recall period. In the second condition, the auditory recording of 400 irrelevant random words was played (70 dB). For both conditions, the seven words in a sequence were presented one at a time at a two-second interval per word. Auditory and visual instructions preceded the start of the presentations. The words were presented both auditorily (via headphones) and visually. To make the procedure as similar as possible to that used by Longoni et al. (1993), Experiment 3, which involved viewing individually displayed words in uppercase (12 × 10 mm) at a distance of approximately 3 meters, participants were positioned 70 cm from the monitor displaying words in a font size of 11 pt.

Following the presentation of each sequence without a delay (for immediate recall), participants had 40 seconds to remember the order of word presentation. A response sheet containing the lists used was provided, as the participants did not have to recall the words but only their order.

Results

The goal of Experiment 3 was to distinguish between the two components of the phonological loop: the articulatory loop and the phonological store. Irrelevant speech (A) and word length (B) were used as operational variables for the sensory store and the phonological loop, respectively. Ta-

Table 5 ■ Average percentage of correctly recalled lists in immediate serial recall, based on word length under silent conditions and under conditions of irrelevant speech in Experiment 3 of the study by Longoni et al. (1993).

	Short	Long
Silent	75.5	65.5
Irrelevant speech	62.4	54.9

Table 6 ■ Average percentage of correctly recalled lists in immediate serial recall, based on word length under silent conditions and under conditions of irrelevant speech words in the current replication of Experiment 3.

	Short	Long
Silent	61.4	55.4
Irrelevant speech	44.0	46.4

bles 5 and 6 reflect the average percentages of correctly recalled lists in immediate serial recall, based on word length under silent conditions and under non-relevant word conditions in Longoni et al.'s (1993) Experiment 3 and its replication, respectively. This time, participants in the replication performed 12% less effectively on average than in the original study.

The results of the original study show a significant main effect of irrelevant speech (A): [$F(1, 22) = 30.80$, $p < .001$, $\eta_p^2 = .58$] as well as an effect of word length (B): [$F(1, 22) = 13.53$, $p < .001$, $\eta_p^2 = .38$]. The interaction between the two factors was non-significant (A × B): [$F < 1$]. The results tend to support the hypothesis that word length and unsupervised speech exert additive and independent effects. In the present study, a main effect of irrelevant speech is observed (A): [$F(1, 26) = 10.24$, $p = .004$, $\eta_p^2 = .28$]. However, a main effect of word length was not replicated; statistical analyses of this effect in the present study were non-significant (B): [$F(1, 26) = 0.567$, $p = .46$, $\eta_p^2 = .02$]. Yet, similar to Longoni et al.'s (1993) study, the interaction between irrelevant speech and word length is non-significant (A × B): [$F(1, 26) = 1.864$, $p = .18$, $\eta_p^2 = .07$].

Discussion

Longoni et al. (1993) hypothesized that irrelevant speech and the word length effect are independent. Thus, irrelevant speech and word length were used as operational variables for the sensory store and the phonological loop, respectively. Since the results of the current replication did not find an interaction between the variables, the data is not interpretable since the word length effect was not significant. In other words, there was no significant difference in performance among participants whether the word is long or short. Longoni et al. (1993) obtained results supporting the hypothesis that word length and irrelevant speech exert additive and independent effects, while the results of the present study lack interpretability. Moreover, the average number of correctly recalled words in each condition of this replication seems to be lower than the data obtained by the original study. Success rates are observed to be 17.6% lower in the condition of long words in silence, and up to 41.8% lower in the condition of short words with irrelevant speech than in the original study. The non-replication of the word length effect in this study is surprising given that a significant part of the concept of the phonological loop and storage concept rests on this key notion (Jalbert et al., 2011). Since this study included more participants than Longoni et al.'s (1993) study, we can exclude the possibility of lower statistical power in the present study than in the original study.

There are two main types of lists to test word length: a list based on the number of syllables and a list based on the time it takes to pronounce the word (Baddeley et al., 1975). The word length effect based on time was established in two initial studies, Experiments 3 and 4 by Baddeley et al. (1975). Several studies, including Longoni et al.'s (1993) study, have replicated the word length effect based on time using the original stimuli; however, no other set of stimuli has produced the same result (Jalbert et al., 2011). For example, Neath et al. (2003) tested different sets of short and long words with corresponding syllables and phonemes but different pronunciation times; only the original stimuli by Baddeley et al. (1975) showed a word length effect. Neath et al. (2003) concluded that the word length effect based on time resulted from an unknown characteristic of the original stimuli. They suggested that unless other sets of stimuli show a recall difference solely related to pronunciation time, the existence of the word length effect based on time may be questioned. This poses a challenge for theories involving concepts such as the phonological loop. The word length effect based on the number of syllables is consistent across various experiments. This means that it is generally more difficult to remember longer words, measured in syllables, compared to shorter ones (Baddeley et al., 1975). Researchers continue to debate the cause of this effect. Replication studies confirm that differences in results depend on the stimuli used (Bireta et al., 2006). Ultimately, much like the word length effect based on time, the word length effect based on the number of syllables seems to vary depending on specific stimuli.

The present study was conducted with a list of words based on the time it takes to pronounce the word, i.e., two-word sequences with the same number of letters and sylla-

Table 7 ■ Average percentage of correctly recalled lists in immediate serial recall, based on phonemic similarity under silent conditions and under articulatory suppression, as well as under slow and fast presentation speed in Experiment 4 of the study by Longoni et al. (1993).

	Silent		Suppressed	
	Dissimilar	Similar	Dissimilar	Similar
Fast	70.0	5l .l	56.9	37.8
Slow	93.6	8l.1	77.8	77.8

Table 8 ■ Average percentage of correctly recalled lists in immediate serial recall, based on phonemic similarity under silent conditions and under articulatory suppression, as well as under slow and fast presentation speed in the current replication of Experiment 4.

	Silent		Suppressed	
	Dissimilar	Similar	Dissimilar	Similar
Fast	7l.2	46.9	65.6	44.5
Slow	69.8	50.8	65.0	49.2

bles; longer words naturally take more time to pronounce than shorter ones. It appears that the format of the list used in the present study had an effect on the non-significant result of word length; a result similar to the studies mentioned earlier.

Experiment 4

The aim of this fourth experiment is to verify the effects and interactions of articulatory suppression, phonological similarity, and word presentation speed. Longoni et al. (1993) demonstrate that articulatory suppression abolishes the phonological similarity effect when items are presented at a slow pace (5 seconds/word) but not at a fast pace (0.5 seconds/word). Since articulatory suppression and phonological similarity occur in two different components of the phonological loop, with a fast presentation rate, the similarity and suppression effects are independent and additive. Thus, similar words are more challenging to remember when participants engage in articulatory suppression. However, it is suggested that a slow presentation rate coupled with articulatory suppression should abolish the phonological similarity effect because the phonological trace of similar and dissimilar words undergoes equal degradation.

Methodology

Participants. The sample consists of 24 participants (12 women and 12 men, aged 15 to 64), the same number as in the original study.

Materials. Two lists of words were used. The first contains six phonetically similar words, and the second contains six phonetically dissimilar words. Phonetically similar words all contain the sound "erre": frère, vert, air, guerre, plaire and serre. The phonetically dissimilar words are pomme, juge, œil, ski, chat and pain. The choice of words was made to eliminate retention strategies, such as grouping. Subsequently, ten random orders of each set were created, and these were divided in half to obtain two groups, each containing five sequences of phonetically similar words and five sequences of phonetically dissimilar words. This process was done randomly using E-Prime software. To measure the effect of presentation rate on recall, two audio recordings of different sequences were designed: one recording at a presentation rate of 0.5 seconds/item, and another at a rate of 5 seconds/item.

Procedure. The sequences are presented visually and auditorily to the participants. After the presentation of each list of six words, participants must remember the order of the twelve presented words and transcribe them on a pre-prepared sheet, which includes the two-word lists. Participants are divided into two groups: the first group initially listens to the word sequence at a fast presentation rate (0.5 seconds/word), while the other group starts with the word sequence at a slow presentation rate (5 seconds/item). During slow-paced listening, for articulatory suppression, participants are required to repeat "one, two, three" one word per second. Following the presentation of the sequences, participants have 30 seconds to transcribe the words they just heard in the order presented.

Results

The objective of Experiment 4 was to analyze phonological similarity, the articulatory suppression effect, and the presentation speed effect. Tables 7 and 8 provide the results of the original study and the current replication, respectively. Participants in the present replication had poorer performance than those in the original study, with an average 10% lower performance

Firstly, the results indicate a significant similarity effect (B; $F(1, 20) = 67.045$, $p < .001$). Next, the reported data do not show a significant effect regarding articulatory suppression (C: $F(1, 20) = 0.378$, $p = .54$). The interaction between the similarity effect and the articulatory suppression effect is not significant (B × C: $F(1, 20) = 0.395$, $p = .54$). Finally, whether the presentation rate is fast or slow, there are no significant differences between these two conditions (D: $F(1, 20) = 0.072$, $p = .79$). That being said, the presentation speed does not attenuate the phonological similarity effect. There is no difference in the presentation rate of words when they are dissimilar or similar (B × D: $F(1, 20) = 1.048$, $p = .32$). In this regard, whether in the silent condition or in the articulatory suppression con-

Table 9 ■ Average percentage of correctly recalled lists in serial recall, based on phonemic similarity under silent conditions and under articulatory suppression, as well as under immediate or delayed recall in Experiment 5 of the study by Longoni et al. (1993).

	Silent		Suppressed	
	Dissimilar	Similar	Dissimilar	Similar
Immediate	59.4	40.6	40.3	27.2
Delayed	79.4	50.3	57.8	38.1

Table 10 ■ Average percentage of correctly recalled lists in serial recall, based on phonemic similarity under silent conditions and under articulatory suppression, as well as under immediate or delayed recall in the current replication of Experiment 5.

	Silent		Suppressed	
	Dissimilar	Similar	Dissimilar	Similar
Immediate	72.8	47.8	68.3	38.0
Delayed	78.1	43.3	68.0	53.3

dition, the presentation speed does not affect participants' performance (C × D: $F(1, 20) = 0.005$, $p = .94$). Thus, the presentation speed has no impact on the suppression effect, and there is no triple interaction between the similarity effect, the articulatory suppression effect, and the word presentation speed (B × C × D: $F(1, 20) = 0.000$, $p = 1$).

Experiment 5

The study by Longoni et al. (1993) examined whether articulatory suppression had an impact on the phonological similarity effect, even when participants had a 10-second interval between the end of the presentation and recall. The obtained results indicate that suppression had very little or no impact on the phonological similarity effect, both for immediate and delayed recall, even when waiting for 10 seconds. These results were consistent with previous experiments in their study. It was suggested that these findings provided evidence of the encoding of auditory information in the phonological store and, that the retrieval of this information did not depend on articulatory rehearsal. This contradicts the theory proposed by Baddeley et al. (1984), which suggests that "coded" information may be forgotten unless it is recalled with the aid of articulatory rehearsal. The fifth experiment aimed to determine if, even in the presence of a delay between presentation and recall of information, articulatory suppression has an impact on phonological similarity, by replicating Longoni et al.'s (1993) Experiment 5. Since the phonological similarity effect is related to the phonological store and suppression occurs in the articulatory loop, the latter should have no effect on phonological similarity.

Methodology

Participants. Twenty-four participants (10 females and 14 males, aged 15 to 64) were recruited for this experiment, which is the same number as in the original study.

Materials. Two lists of words were used: one composed of six phonetically similar words, and the second composed of six phonetically dissimilar words. These two lists are the same as those used in Experiment 4. Ten lists were randomly generated from the two initial lists. These lists were then divided into two blocks, so that each block contains five sequences of phonologically similar words and five sequences of dissimilar words. Audio recordings of these sequences were created. Audio cues signaled the participants about the beginning and end of a list. This procedure was repeated twice, increasing the recall time by 10 seconds.

Procedure. To vary the order of presentation of conditions, participants were divided into two equal groups. The two blocks (0.5 seconds/word and 5 seconds/word) were presented one after the other but in reverse order between the two groups. The presentation of words was done through listening to a recording. For the block with a 0.5-second/word interval, a delay of 0.5 seconds was imposed after each sequence before recall. For the block with a 5-second/word interval, the delay was 10 seconds. Furthermore, all participants were randomly separated again. Half had to repeat "un, deux, trois" ("one, two, three") at a rate of one word per second, while the other half could listen to the words without articulatory suppression. This separation was independent of the two groups separated by word presentation speed. After listening, participants had 30 seconds for recall and transcription of the words (in order) onto a prepared sheet.

Results

Similar to the study by Longoni et al. (1993), data analysis is based on the recall of each list of words by participants under specific conditions. These conditions involved recalling similar and dissimilar words (factor A) either in immediate silence or after a 10-second delay (factor E).

Statistical analyses revealed a significant main effect of phonological similarity [A: $F(1, 20) = 124.61$, $p < .001$], but failed to produce a significant main effect of articulatory suppression [C: $F(1, 20) = 0.83$, $p = 0.37$], or the recall delay effect [G: $F(1, 20) = 0.68$, $p = 0.42$]. This is highly unexpected compared to the original results of Longoni et al. (1993), Experiment 5, where significant main effects of phonological similarity [$F(1, 20) = 55.60$, $p < 0.001$], articulatory suppression [$F(1, 20) = 41.96$, $p < 0.001$], and delayed recall effect [$F(1, 20) = 6.48$, $p < 0.02$] were reported. The present replication study also

examined the interactions between the three effects and found no significant interaction between phonological similarity and articulatory suppression [A × C: $F(1, 20) = 2.71$, $p = 0.12$]. Furthermore, there was no significant interaction between phonological similarity and recall delay [A × G: $F(1, 20) = 0.39$, $p = 0.54$], nor between articulatory suppression and recall delay [C × G: $F(1, 20) = 0.831$, $p = 0.37$]. In comparison to Longoni et al.'s (1993) study, similar interactions were observed, indicating no interaction between delay and the phonological similarity effect [A × G: $F(1, 20) = 2.44$, $p > 0.10$], nor between delay and the articulatory suppression effect [C × G: $F(1, 20) = 0.02$, $p > 0.80$]. Unlike the present study, Longoni et al. (1993) found an interaction between the effects of phonological similarity and articulatory suppression [A × C: $F(1, 20) = 3.54$, $p < 0.10$].

Discussion of Experiments 4 and 5

Longoni and colleagues were able to corroborate this hypothesis since the phonemic similarity effect was abolished under articulatory suppression at a slow rate of presentation (**lr493**). In the present experiment, the phonemic similarity effect was preserved in every condition, notably under articulatory suppression at a slow rate of presentation. Although insignificant, the magnitude of the phonemic similarity effect was reduced at a slow rate of presentation under articulatory suppression, which aligns with the decay hypothesis. Furthermore, Longoni and colleagues found an improvement in overall performance at a slower rate of presentation, which contradicts Baddeley's decay theory, in which a faster rate of presentation would improve overall performance. It might indicate the involvement of semantic encoding processes, beyond the scope of simple phonological encoding (A. Baddeley, 2007; Longoni et al., 1993). In contrast, the present experiment found no significant increase in performance at a slow rate of presentation. On debriefing in Longoni's study, participants under the slow condition reported the use of semantic encoding strategies between the presentation of each item. (Longoni et al., 1993). Experiment 5 was consequently designed to test the decay theory while eliminating the possibility of semantic encoding between items. To that end, all items were presented at a conventional, rapid rate. Instead, the incorporation of a 10-second delay between presentation and recall was implemented to test the effects of temporal decay. According to the decay hypothesis, the phonemic similarity effect should be abolished when the delay is occupied by articulatory suppression, preventing semantic encoding (Baddeley et al., 1984). On the other hand, according to the encoding strategy (interference) hypothesis, the phonemic similarity effect should be preserved under these conditions, since the decay of information is not dependent on time alone, but on the presentation of new interfering information (Nairne, 2002). Longoni and colleagues reported that the 10-second delay failed to abolish the phonemic similarity effect, even when the articulatory loop was suppressed during this period (Longoni et al., 1993). Consistent with these results, the present experiment found that the delay had no discernible effect on phonemic similarity; the effect was notably preserved across all tested conditions. The findings of both experiments support Nairne's interference hypothesis and refute Baddeley's decay hypothesis by showing that memory retention is more significantly affected by the amount of new information encoded (interference) rather than the mere passage of time (Nairne, 2002). Moreover, Longoni and collaborators noted an increase in overall performance with a delay. However, the present study failed to replicate these results. As previously noted, this increase in performance suggests the presence of semantic encoding strategies (Longoni et al., 1993). Overall, the results from Experiments 4 and 5 suggest that the current model in working memory may be overly simplistic in capturing this dynamic. Similar research has prompted the development of more comprehensive theories that incorporate the roles of interference, temporal decay, and long-term memory influences on working memory function, for instance, the Time-Based Resource Sharing (TRBS) theory (Barrouillet et al., 2004). This theory suggests that the persistence of memory over short intervals may rely more heavily on the allocation of attentional resources than time-related decay or interference (Barrouillet et al., 2004).

A limitation of this experiment is that there may be an oversight in assuming that a 10-second interval is sufficient to observe decay, particularly if the actual duration needed for phonological traces to fade might be longer. Future research should explore the specific conditions under which attentional resources are most effective at preserving memory traces and investigate whether these resources are inherently limited or can be enhanced through training to improve memory performance. In conclusion, these experiments have provided further empirical evidence confirming the existence of the phonemic similarity effect and its reliance on the phonological store, whilst adding valuable data to the ongoing research on the decay and interference hypotheses.

General Discussion

In the first experiment, the similarity effect was replicated, the word length effect is mainly present in the similar condition, but the articulatory suppression effect was not replicated. The second experiment shows differences in results compared to Longoni et al. (1993). The similarity effect and the word length effect would not be independent and ad-

ditive, as suggested by the original study, but rather multiplicative. In Experiment 3, the word length effect is not replicated: word length and irrelevant speech would be multiplicative and not independent and additive. The effect of irrelevant speech is less significant than that in the original study. Moreover, the lack of interaction between word length and irrelevant speech is replicated. In the fourth study, the similarity effect is even greater than in the original study. It is noteworthy that in the original study, the similarity effect disappeared in the suppression condition under slow speed. As in the original study by Longoni et al. (1993), there is no articulatory suppression effect. Additionally, there is no speed effect. In the fifth experiment, the similarity effect is present. However, the suppression effect and the delay effect are not replicated.

The replication results are very different from the original study. Several alternative explanations can account for this, with the main one being the validity of the method. The present study was not conducted under optimal laboratory conditions. When the participant was in the computer room, several other people were present at the same time. Additionally, this study was conducted by over 30 experimenters, who may contribute to a small degree of variation to the methodology. However, it is difficult to believe that over 30 experimenters consistently deviated from the method.

The absence of the articulatory suppression effect can be explained by the findings of the Saito (1998) study. According to this study, intermittent articulatory suppression would be the best option to obtain an articulatory suppression effect. The non-replicated effects of similarity and word length can be explained in the findings of the Spurgeon et al. (2014) study. The word list utilized in this study is too short to effectively eliminate the primacy effect, which is present with both similar and dissimilar words.

To address some of our study's limitations, additional steps and modifications to the methodology are necessary. Participants should be placed in an isolated room to minimize external interference. There should be fewer experimenters administering the testing to ensure closest adherence to the method. Some aspects of the method should also be revised to more accurately measure the impact of certain variations. For example, the task used to evaluate the articulatory suppression effect could be changed from a continuous suppression activity to an intermittent articulation suppression task, to compare outcomes. Word lists should be longer to eliminate the primacy effect, allowing for a clearer distinction between similar and dissimilar word conditions.

References

Amici, F., Sánchez-Amaro, A., Sebastián-Enesco, C., Cacchione, T., Allritz, M., Salazar-Bonet, J., & Rossano, F. (2019). The word order of languages predicts native speakers' working memory. *Scientific Reports*, *9*(1), 1124–1124. doi: 10.1038/s41598-018-37654-9.

Asendorpf, J. B., Conner, M., De Fruyt, F., De Houwer, J., Denissen, J. J. A., Fiedler, F., K., S., F., C., D., Kliegl, R., Nosek, B. A., Perugini, M., Roberts, B. W., Schmitt, M., Van Aken, M. A. G., Weber, H., & Wicherts, J. M. (2013). Recommendations for increasing replicability in psychology. *European Journal of Personality*, *27*(2), 108–119. doi: 10.1002/per.1919.

Atkinson, R. C., & Shiffrin, R. M. (1968). Human memory: A proposed system and its control processes. *The psychology of learning and motivation: Advances in Research and Theory*, *2*, 89–195. doi: 10.1016/S0079-7421.

Baddeley, A. (2007). *The phonological loop*. In Working Memory. doi: 10.1093/acprof:oso/9780198528012.003.0003.

Baddeley, A. D. (2000). The episodic buffer: A new component of working memory? *Trends in Cognitive Sciences*, *4*(11), 417–423. doi: 10.1016/S1364-6613(00)01538-2.

Baddeley, A. D., & Hitch, G. J. (1974). Working memory. *The psychology of learning and motivation*, *8*, 47–89. doi: 10.1016/S0079-7421(08)60452-1.

Baddeley, A. D., & Hitch, G. J. (2019). The phonological loop as a buffer store: An update. *Cortex*, *112*, 91–106. doi: 10.1016/j.cortex.2018.05.015.

Baddeley, A. D., Lewis, V., & Vallar, G. (1984). Exploring the articulatory loop. *The Quarterly Journal of Experimental Psychology A: Human Experimental Psychology*, *36A*(2), 233–252. doi: 10.1080/14640748408402157.

Baddeley, A. D., Thomson, N., & Buchanan, M. (1975). Word length and the structure of short term memory. *Journal of Verbal Learning and Verbal Behavior*, *14*(6), 575–589. doi: 10.1016/S0022-5371.

Baddeley, A., & Wilson, B. (1985). Phonological coding and short-term memory in patients without speech. *Journal of Memory and Language*, *24*(4), 490–502.

Barrouillet, P., Bernardin, S., & Camos, V. (2004). Time constraints and resource sharing in adults' working memory spans. *Journal of Experimental Psychology: General*, *133*(1), 83–100. doi: 10.1037/0096-3445.133.1.83.

Bireta, T. J., Neath, I., & Surprenant, A. M. (2006). The syllable-based word length effect and stimulus set specificity. *Psychonomic Bulletin & Review*, *13*(3), 434–438. doi: 10.3758/BF03193866.

Bonin, P., & Bugaïska, A. (2014). "survivre pour se souvenir": Une approche novatrice de la mémoire

humaine : La mémoire adaptative. *L'Année psychologique*, *114*, 571–610. doi: 10.3917/anpsy.143.0571.

Cleary, A. M. (2019). *Handbook of research methods in human memory*. Routledge.

Colle, H. A., & Welsh, A. (1976). Acoustic masking in primary memory. *Journal of Verbal Learning & Verbal Behavior*, *15*, 17–32. doi: 10.1016/S0022-5371(76)90003-7.

Conrad, R., & Hull, A. J. (1964). Information, acoustic confusion, and memory span. *British Journal of Psychology*, *55*, 429–432. doi: 10.1111/j.2044-8295.1964.tb00928.x.

Fortin, C., & Rousseau, R. (2015). *Psychologie cognitive : Une approche de traitement de l'information*. Presses de l'université du Québec (PUQ.

Foxe, D., Cheung, S. C., Cordato, N. J., Burrell, J. R., Ahmed, R. M., Taylor-Rubin, C., Irish, M., & Piguet, O. (2021). Verbal short-term memory disturbance in the primary progressive aphasias: Challenges and distinctions in a clinical setting. *Brain Sciences*, *11*(8), 1–99. doi: 10.3390/brainsci11081060.

Guitard, D., Gabel, A. J., Saint-Aubin, J., Surprenant, A. M., & Neath, I. (2018). Word length, set size, and lexical factors: Re-examining what causes the word length effect. journal of experimental psychology. *Learning, Memory, and Cognition*, *44*(11), 1824–1844. doi: 10 . 1037/xlm0000551.

Hurlstone, M. J., Hitch, G. J., & Baddeley, A. D. (2014). Memory for serial order across domains: An overview of the literature and directions for future research. *Psychological Bulletin*, *140*(2), 339–373. doi: 10 . 1037 / a0034221.

Jalbert, A., Neath, I., Bireta, T. J., & Suprenant, A. M. (2011). When does length cause the word length effect? journal of experimental psychology. *Learning, Memory, and Cognition*, *37*(2), 338–353. doi: 10.1037/a0021804.

Lemaire, P., & Didierjean, A. (2018). *Introduction à la psychologie cognitive*. De Boeck Supérieur.

Longoni, A. M., Richardson, J. T., & Aiello, A. (1993). Articulatory rehearsal and phonological storage in working memory. *Memory & Cognition*, *21*(1), 11–22. doi: 10.3758/BF03211160.

Malmberg, K. ., Raaijmakers, J. G. ., & Shiffrin, R. . (2019). 50 years of research sparked by atkinson and shiffrin (1968). *Memory & Cognition*, *47*(4), 561–574. doi: 10 . 3758/s13421-019-00896-7.

Monnier, C., & Ejarque, L. (2008). Origine de l'effet longueur de mots en mémoire à court terme verbale chez l'enfant. *Psychologie Française*, *53*(3), 343–356. doi: 10.1016/j.psfr.2007.11.002.

Murray, D. J. (1968). Articulation and acoustic confusability in short- term memory. *Journal of Experimental Psychology*, *78*, 679–684. doi: 10.1037/h0026641.

Nairne, J. S. (2002). Remembering over the short-term: The case against the standard model. *Annual Review of Psychology*, *53*(1), 53–81. doi: 10.1146/annurev.psych.53.100901.135131.

Neath, I., Bireta, T. J., & Surprenant, A. M. (2003). The time-based word length effect and stimulus set specificity. *Psychonomic Bulletin & Review*, *10*(2), 430–434. doi: 10.3758/BF03196502.

Norris, D., Butterfield, S., Hall, J., & Page, M. P. A. (2018). Phonological recoding under articulatory suppression. *Memory & Cognition*, *46*(2), 173–180. doi: 10.3758/s13421-017-0754-8.

Page, M. P. A., Madge, A., Cumming, N., & Norris, D. G. (2007). Speech errors and the phonological similarity effect in short-term memory: Evidence suggesting a common locus. *Journal of Memory and Language*, *56*(1), 49–64. doi: 10.1016/j.jml.2006.09.002.

Roodenrys, S., Guitard, D., Miller, L. M., Saint-Aubin, J., & Barron, J. M. (2022). *Phonological similarity in the serial recall task hinders item recall, not just order*. British Journal of Psychology. doi: https://doi.org/10.1111/bjop.12575.

Saito, S. (1998). Phonological loop and intermittent activity: A whistle task as articulatory suppression. *Canadian Journal of Experimental Psychology*, *52*(1), 18–24. doi: 10.1037/h0087275.

Salamé, P., & Baddeley, A. D. (1982). Disruption of short-term memory by unattended speech: Implications for the structure of working memory. *Journal of Verbal Learning & Verbal Behavior*, *21*(2), 150–164. doi: 10 . 1016/S0022-5371(82)90521-7.

Spurgeon, J., Ward, G., & Matthews, W. J. (2014). Examining the relationship between immediate serial recall and immediate free recall: Common effects of phonological loop variables but only limited evidence for the phonological loop. journal of experimental psychology. *Learning, Memory, and Cognition*, *40*(4), 1110–1141. doi: 10.1037/a0035784.

Citation

Couture, C., Veilleux, C., Chinhama, S., Jacot de Boinod, O., Payment, B., Husereau, T., & Ouellette, É. (2024). Articulatory rehearsal and phonological storage in working memory: A replication of Longoni et al. (1993). *The Quantitative Methods for Psychology*, *20*(1), r1–r12. doi: 10.20982/tqmp.20.1.r001.

Received: 15/01/2024 ~ Accepted: 19/02/2024