Learning by distraction *versus* repeating study in older and younger adults

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# Abstract

In this experiment, we assessed whether the tendency of older people to process distracting information attenuated age-related differences in forgetting when studied items are covertly processed during an unrelated task. This was contrasted to a condition in which studied items were overtly rehearsed. Younger and older adults studied and freely recalled a list of words during an immediate test and again during a delayed test after a 15-min delay. During this delay, participants completed either a 1-back task in which half of the studied words appeared as distractors (covert rehearsal), or a regular repetition of half the studied words (overt rehearsal). The results showed that overt rehearsal lead to overall better performance than covert rehearsal, without any attenuation of age-related differences in either conditions. These results suggest that learning by distraction is not always a reliable method to overcome episodic memory decline in older adults.

Keywords: aging, memory, attention, forgetting, distraction

# Introduction

Changes in episodic memory functioning are observed in healthy aging (Drag & Bieliauskas, 2010). They are characterized by a decrease in the recall and recollection of details from past events (Koen & Yonelinas, 2014), poorer memory for associations between information (Naveh-Benjamin, 2000) and a greater reliance on memory for the gist of previous experiences and feelings of familiarity (Grilli & Sheldon, 2022; Koen & Yonelinas, 2014). Research in cognitive aging has long been interested in identifying conditions in which age-related memory decline can be attenuated (Bastin et al., 2013; Castel, 2005). The endeavor is important because it provides potential leads for interventions in memory-impaired populations, such as patients with Mild Cognitive Impairment, but it also nourishes the understanding of memory functioning and its interactions with other cognitive functions.

One approach to alleviate memory decline in aging consists in taking advantage of the fact that older adults are more sensitive to visual distraction (Amer et al., 2016) and fail to inhibit distractors’ processing during various tasks (Campbell et al., 2020; Lustig et al., 2006). In a seminal study, Biss et al. (2013) asked young and older participants to study a list of 20 words and to freely recall them immediately and after 15 minutes. During the 15-min delay, participants performed a visual 1-back task in which they had to press a key whenever two identical pictures appeared consecutively. Superimposed on the pictures, there were non-words and words, which had to be ignored. Critically, some of these words were a subset of the study list, providing an opportunity for covert rehearsal in case participants failed to ignore them. The results showed that older participants had less forgetting of repeated words from immediate to delayed recall than of unrepeated words. In contrast, younger adults had equivalent forgetting of both types of words. Additionally, there was an age-related difference in delayed recall of unrepeated words, but this difference disappeared for delayed recall of repeated words. This pattern of findings was replicated in further studies (for a review, see Demonty et al., 2022), with variations of the procedure, as well as with other types of materials such as associations. When recognition memory was assessed instead of free recall, learning by distraction occurred specifically for recollection (Biss et al., 2018).

One question yet to resolve is whether covert rehearsal via distraction benefits older adults’ memory more than overt rehearsal. Indeed, the repetition of studied information improves subsequent memory for this information in both young and older adults (Balota et al., 1989) . Nevertheless, sensitivity to agism stereotypes damper older adults’ use of overt memory strategies (Hess & Hinson, 2006; Lemaire et al., 2018) so that a more covert approach may be more efficient in attenuating age-related differences in memory performance.

Therefore, the current study aimed to assess whether older adults demonstrate improved memory for repeated words whether the repetition is overt via restudy or covert via distraction. We adapted the procedure that Biss et al. (2013) used to compare a condition in which studied words were re-exposed with a condition in which studied words appeared as distractors in a 1-back task. Memory performance was tested with immediate and delayed free recall, as well as recognition memory with Remember/Know judgments. We expected that young participants would show better recall and recognition memory for overtly repeated words, but not for words repeated as distractors (covert rehearsal). In contrast, if both types of rehearsal are equally efficient in older adults, they would show less forgetting in free recall and more recollection for repeated words than unrepeated words in both conditions. Alternatively, if covert rehearsal is immune to stereotype threat and difficulties in using memory strategies contrary to overt rehearsal, the beneficial effect of repetition should only be seen in the learning by distraction condition in older participants.

# Methodology

## Participants

We ran an *a priori* power analysis for a repeated measures design with a within-between interaction using the following criteria: two between-subject variables, two within-group variables, α=.05 and an effect size f of 0.27 (Gpower software, Faul et al., 2007), which suggested a 48 subjects’ pool.

In total, 56 participants were tested (28 younger and 28 older adults). In each age group, participants were attributed to one of two experimental conditions (covert or overt rehearsal – see procedure). Four younger adults and one older adult were excluded because they noticed the experimental manipulation in the covert rehearsal condition, which was assessed in the same way as Biss and al. (2018), using a questionnaire. Two older adults were additionally excluded because they did not match the inclusion criteria (both for exclusion-listed medication). One older participant was excluded from analyses because his recognition performance was below chance. So, the analyses were performed on 24 young adults (age range 18- 35 years old, 17 women) and 24 healthy older adults (age range 60- 85 years old, 17 women).

Demographic information is summarized in Table 1. Groups did not differ in age (F=0.01, p=.95) and education level (F=1.39, p=.24) among conditions. As expected (Park et al., 2002), however, older adults had generally higher vocabulary scores on the Mill Hill test (F=6.62, p=.01) and higher Horne (assessing chronotype) scores indicating more morning types (F=5.63, p=.02).

Before the experiment, all participants signed an informed consent form. The study was approved by the ethics committee of the Faculty of Psychology of the University of Liege.

Table 1. Participants’ demographic characteristics

|  |  |  |
| --- | --- | --- |
|  | Younger adults | Older adults |
|  | All | Overt | Covert | All | Overt | Covert |
|  | N=24 | N=12 | N=12 | N=24 | N=12 | N=12 |
| Age (in years) | 22.8 ± 3.03 | 22.92 ± 3.53 | 22.75 ± 2.6 | 68.61 ± 7.72 | 67.64 ± 7.26 | 69.5 ± 8.33 |
| Education | 14.38 ± 1.72 | 14.75 ± 1.86 | 14 ± 1.54 | 14.04 ± 2.71 | 14.45 ± 2.42 | 13.37 ± 2.99 |
| Mill Hill score | 20.58 ± 3.59 | 21.42 ± 2.91 | 19.75 ± 4.11 | 24.04 ± 6.15 | 25.55 ± 5.13 | 22.67 ± 6.88 |
| Horne score | 51.38 ± 10.67 | 52.08 ± 10.23 | 50.67 ± 11.5 | 58.78 ± 10.27 | 62 ± 8.85 | 55.83 ± 10.94 |

##

## Materials

For the memory task, 32 concrete French words were selected and divided into four lists of eight words. The four lists were counterbalanced across participants and served as repeated words (presented in the encoding phase and appearing in the 1-back task), unrepeated words (presented in the encoding phase but not appearing in the 1-back task), filler words (new words appearing for the first time in the 1-back task) and new words (lures in the recognition memory task). The words had an average frequency (M=44.55, STD=14.74) measured by their frequency in movie subtitles by Lexique 311. The four lists did not differ in terms of frequency. All words counted 4 to 7 letters and were unrelated (phonologically and conceptually) to each other and to the 1-back images. Twenty-four non-words were created to serve as fillers for the 1-back task. The non-words were matched with the words in terms of absolute phonotactic frequency (Tubach & Boe, 1990), number of letters, and number of syllables. They were not phonologically similar to the words.

For the 1-back task, 42 black and white line-drawings images were selected from Snodgrass and Vanderwart (1980) based on the norms in the French language created by Alario and Ferrand (1999). Images were selected if they had a name agreement greater than 90 % and if they had image agreement scores (i.e., whether participants estimated that the image matched the idea they had of the object) above or equal to 3 out of 5. Half of the images were manufactured, and the other half were natural; both categories were matched in complexity, familiarity, and age of acquisition. Attempts were made so that the selected images were not too related to each other nor too alike. Items’ complexities in each category were normally distributed to ensure that the images’ visual complexity did not influence words reading in the 1-back task.

## Procedure

Participants were tested individually in a quiet room. Stimuli were presented via a laptop. The experimental tasks consisted in four phases: encoding, immediate free recall, delay, and delayed memory tests (illustrated in Figure 1).

*Encoding phase*

Participants were instructed to study 16 words for a subsequent memory test. The words were presented in lower-case letters at the center of the screen, in red Arial on a white screen. Presentation duration was 3000ms with an inter-stimulus interval (ISI) of 500ms.

*Immediate free recall*

After the encoding phase, participants spent 30 seconds counting backward by 3 from 374 or by 2 from 371 (counterbalanced with delayed recall). Then, they had 60 seconds to recall as many words as possible, no matter their order.

*Delay*

During a 12 to 15 minutes delay, participants performed an overt or covert rehearsal task depending on the condition they were attributed to.

Covert rehearsal: As in Biss et al. (2013), participants had to complete three tasks: one non-verbal filler task (counting backwards for 30 seconds), the 1-back task (preceded by a short training), and another non-verbal filler task (counting backwards for 30 seconds). During the 1-back task, participants were instructed to press a key when two identical images appeared consecutively. They were told that the superimposed letter strings they saw had to be ignored. The images and the superimposed letters-strings were presented simultaneously for 1000ms with an ISI of 500ms. The words appeared in lower-case letters at the center of the screen and were colored in red. Each stimulus appeared twice during the task. Repeated studied words appeared with the same image, while the filler and non-words always were shown on different pictures. The trials including a repeated studied word never needed a one-back answer. There was a total of 84 trials, and the sequence was the following: 4 images alone; 8 images with non-words to serve as buffers; 64 main trials mixing 32 trials with images and non-words, 16 trials with filler words, and 16 trials with repeated studied words; 8 images with non-words as buffers. The images were consecutively identical (and thus required a 1-back response) 15 times throughout the whole phase.

### Overt rehearsal: In this condition, instead of the 1-back task, participants were presented with a list of words and non-words. The sequence of items (target, filler, and non-words) was identical to that of the distractors in the 1-back task. Each item was presented for 1000ms with an ISI of 500ms. Participants were told that some of the words were coming from the encoding phase and that they should consider this task as a sort of repetition.

*Delayed memory tests*

After the delay, participants performed the backward counting task for 30 seconds (different from the one they had done during the immediate recall), and then they had to try and recall as many studied words as possible for a maximum of 60 seconds. Finally, a recognition memory task was proposed. Thirty-two words were presented, 16 being old (8 repeated and 8 unrepeated), 8 filler words from the 1-back, and 8 new words. The participants made an “old/new” judgment for each word. If their answer was “old,” they were asked to specify whether they recollected qualitative details about the encoding of the word (Remember), whether they knew they saw the word without recollecting its encoding context (Know), or whether they were unsure (Guess). The Remember/Know/Guess instructions were given before the start of the recognition phase. Responses were self-paced. Each trial ended with a blank screen for 500ms, and the next one started with a fixation cross for 500ms.

At the end of the experiment, participants’ awareness of the relationship between the tasks was checked. For the covert rehearsal, if they noticed that words were repeated during the 1-back task, they were asked whether they avoided using the words in the memory tests or voluntarily used them. Participants were excluded if they had noticed the relationship and if they had acted upon it (cf. Biss et al., 2013). In the overt rehearsal, participants had to indicate whether they used a strategy to study words. Using a strategy, however, was not an exclusion criterion.

According to Ngo et al. (2018), the time of day impacts younger adults’ task performance using distractors. To control for that variable, half of the participants in each group and each condition were seen in the morning (between 8 A.M. and 11 A.M) and the other half in the afternoon (between 1 P.M to 4 P.M). Moreover, we tested their chronotype using the Horne questionnaire (Horne & Ostberg, 1976) and chose the test sessions time according to the answers, so that some participants were tested in their preferred time of day, while others not.



Figure 1. Experimental design: Participants underwent an encoding phase, followed by an immediate free recall test. Then, an interferent task would be presented, either as an overt rehearsal, or a covert 1 back task, in both cases followed by a delayed free recall test. Finally, a recognition memory task was performed with a R/K/G paradigm.

## Results

We performed Bayesian statistical analyses with JAMOVI. For each analysis, we used a 10000 prior sample as recommended by Ly et al. (2016).

For simple comparisons (i.e., Bayesian independent sample t-tests or post hoc tests), we reported BF10 to indicate the likelihood of our data appearing under H1. For Bayesian multivariate ANOVAS, we used the BF Inclusion from Sebastiaan Mathôt, which is a comparison of all models that include the factor(s) to all models that do not include the factor(s) (Morey et al., 2022; Rouder et al., 2009).

The variables of interest were the number of correctly recalled words during the immediate and delayed free recall tests, recognition accuracy indexed by the proportion of hits minus the proportion of false alarms (FA), and proportion of Remember and Know responses for hits minus for FA, reflecting accuracy of recognition decisions based on recollection and familiarity respectively. For free recall scores, we computed a Bayesian ANOVA in which there were two between-subjects variables: age group (young/older) and condition (overt/covert), and two within-subjects variable: repetition (repeated/unrepeated) and time (immediate, delayed). For recognition accuracy and proportion of Remember and Know responses, we performed age group by condition Bayesian ANOVAs.

All effect sizes have been reported from Raftery (1995) as follows: **BF < 1** - No evidence, **1 < BF ≤ 3** – Weak, **3 < BF ≤ 20** – Positive, **20 < BF ≤ 150** – Strong, **BF > 150** - very strong. Results were interpreted only for BF > 3.

### Free recall

Table 2 presents the number of correctly recalled words as a function of age group, repetition, time, and condition.

The 2x2x2x2 ANOVA showed a positive main effect for age group (older<younger, BFinclusion=6.812), no effect of time (immediate>delayed; BFinclusion=1.142), no effect of condition (BFinclusion =0.772), nor repetition (BFinclusion =0.646). There was no interaction between repetition and group (BFinclusion=0.207), time and group (BFinclusion=0.209), time and condition (BFinclusion=0.219) and group and condition (BFinclusion=0.636).

However, there was a strong interaction between repetition and time (BFinclusion=20.57) indicative of less unrepeated words recalled than repeated words at the delayed test (BF10=4.724) whereas there was no difference between words during the immediate test (BF10=0.204), and less unrepeated words recalled after the delay than before (BF10=9993.601) which was not the case for repeated words (BF10=0.283), independently of condition. There was also a very strong interaction between repetition and condition (BFinclusion=591.86), indicative of more repeated words than unrepeated words recalled in the overt rehearsal condition (BF10=7.334) but not in the covert rehearsal condition (BF10=0.74), and more repeated words recalled in the overt condition than the covert one (BF10=13.381) which was not true for unrepeated words (BF10=0.337).

Table 2 : Mean and standard deviation of number of words recalled during free recall depending on their repetition (repeated vs. unrepeated), time of test (immediate vs. delayed), the age group (older vs. younger), and the condition (overt vs. covert).

|  |  |  |
| --- | --- | --- |
|  | **Repeated** | **Unrepeated** |
| **Immediate** | **Delayed** | **Immediate** | **Delayed** |
| **Older** | **Younger** | **Older** | **Younger** | **Older** | **Younger** | **Older** | **Younger** |
| **Covert** | 2.83±1.40 | 4.25±1.71 | 3.33±1.72 | 5.08±1.38 | 2.83±1.90 | 3.83±1.75 | 1.42±1.68 | 2.58±1.98 |
| **Overt** | 2.58±1.44 | 2.67±1.56 | 2.25±1.54 | 2.50±1.62 | 2.83±1.99 | 3.83±1.19 | 2.17±1.64 | 3.00±1.28 |

To test more specifically our main hypothesis, which is a reduced forgetting at delayed free recall for repeated words in older participants more than in young participant in the covert rehearsal condition, and a possible equivalent reduction of forgetting in both age groups in the overt rehearsal condition, we performed age group x time x repetition Bayesian ANOVAs in each condition (overt and covert rehearsal).

In the overt rehearsal condition, the Bayesian ANOVA reported a positive effect of age group (BFinclusion=7.142) with younger adults recalling more words than older adults, a strong effect of repetition (BFinclusion=62.507) with repeated words being more recalled than unrepeated words, and no effect of time (BFinclusion=0.321). It also reported a positive interaction between repetition and time (BFinclusion=17.095) so that repeated words are better recalled than unrepeated words at the delayed condition (BF10=77.095), but not the immediate condition (BF10=0.229). This is the result of a decrease in recalled unrepeated words after compared to before the delay (BF10=58.162). This effect is not reported for the repeated words (BF10=2.001) (see Figure 2).

In the covert rehearsal condition, the ANOVA reported no effect of time (BFinclusion=1.939), repetition (BFinclusion=1.274), or age group (BFinclusion=0.575), and no interaction between those variables.



*Figure 2: Number of recalled words at the immediate and delayed recall tests, depending on their repetition status represented for each condition (overt vs. covert). Circles represent the means and bars the confidence interval.*

### Recognition memory performance

An age group x condition Bayesian ANOVA on recognition accuracy scores (Hits – FA) reported no main effect of condition (BFinclusion=0.338), age group (BFinclusion=0.670) or interaction between the two factors (BFinclusion=1.558), see Figure 3A.

For “remember” scores (HIT\_R -FA), we computed an age group x condition ANOVA. A positive effect of age group (BFinclusion=3.122) was found, indicating less accurate remember answers in older adults compared to younger adults. There was no effect of condition (BFinclusion=0.319) nor interaction between condition and age group (BFinclusion=0.564), see figure 3B.

Finally, for “know” scores (HIT\_K – FA), the age group x condition ANOVA reported no evidence for a difference between conditions (BFinclusion=2.379), age group (BFinclusion=0.664) or their interaction (BFinclusion=0.539), see figure 3C.



Figure 3 : Recognition accuracy for global performance and Remember and Know responses (Panel A=Hits – FA, Panel B=Hits “Remember” – FA, Panel C=Hits “Know” – FA), depending on the age group (older vs. younger) and the type of rehearsal task (covert vs. overt). Circles represent the means and bars the confidence interval.

**Association between chronotype and memory scores**

From the Horne scores, we computed a “peak” variable with 3 conditions: 1) on-peak when participants were tested at their on-peak period, off-peak when they were tested at their off-peak period, and neither when participants were tested at neither their off nor on peak.

Bayesian ANOVA reported positive evidence towards H0 regarding the link between peak variable and every memory scores of interest (Hits–FA: BF01=4.45; Hits R-FA: BF01=3.65; Hits: K-FA, BF01=4.78; immediate recall scores: BF01 = 2.85; delayed recall scores: BF01 = 4.60).

# Discussion

Our main objective was to assess whether one can improve performance in older adults with a 1-back covert rehearsal, like in Biss et al.’s (2013), as a result of an episodic memory boost. We also wanted to compare this situation to regular overt learning as it has not yet been tested against this specific type of covert learning.

We could not find any evidence of a better free recall nor recollection specific to older adults after the covert re-exposure of studied words, contrary to the results by Biss et al. (2013). The results indicated a typical reduction in free recall and recollection in older adults compared to younger adults, but neither young nor older participants demonstrated reduced forgetting or improved recognition memory for repeated compared to unrepeated words in this condition.

One possible explanation for this lack of benefit of covert rehearsal in older participants could be found in the fact that we counterbalanced the time of the day at which the testing took place, which has been shown to influence learning by distraction (Ngo et al., 2018). Specifically, in Ngo et al.’s study (2018), young adults tested at an optimal time showed no memory benefit for words repeated as distraction (i.e., an expected result in young adults in the covert condition). When young participants were tested at a non-optimal time, however, they showed minimal forgetting of words repeated as distraction (i.e., a pattern nearly like that of older adults in previous learning by distraction studies). This is because there is a variation in attention regulation throughout the circadian cycle, with reduced cognitive control during periods out of the circadian preference (e.g., Intons-Peterson et al., 1998). It is thus possible that no difference could be found between younger and older adults in our study because most participants were tested at neither Off nor On peak (and this was counterbalanced when it was the case). So, a mixture of testing at optimal and less optimal times for young and older participants may have canceled out age differences. Yet, we could not find any significant differences in memory scores as a function of the time of testing, so this interpretation should be further explored. Another explanation for the lack of benefit from learning by distraction in older participants could be that our sample of older adults did not present a sufficient reduction of their inhibition skills. Indeed, for the covert procedure to be successful, participants had to fail to inhibit the processing of the stimuli used as a distraction. The relatively high level of education of our sample (year of education around 14) could indicate a high-functioning group with relatively preserved inhibition skills (Álvares-Pereira et al., 2022). In this sample, there was no significant relation between education and forgetting scores of repeated words in the covert rehearsal condition (BF10=0.180), but participants’ inhibition skills should have specifically been collected to formally support or rule out this hypothesis.

Whatever the exact reason for the lack of learning by distraction in older participants in the current study, this indicates that this type of learning is possibly not as robust as previously suggested and that any improvement in memory in older adults using a learning by distraction procedure could be more dependent on contextual elements than currently thought. More precisely, many parameters (such as those reported here) could affect the emergence of the expected effect by exacerbating or reducing differences between younger and older adults.

In contrast, in the overt condition, free recall performance for repeated words was maintained between the immediate and the delayed test for both younger and older adults, whereas unrepeated words were more forgotten after the delay. This could simply reflect consolidation by repetition and forgetting with passing time, respectively. Alternatively, as there was no such forgetting of unrepeated words in the covert rehearsal condition, the profile of performance could represent a case of retrieval-induced forgetting effect (i.e., the fact that practicing some items of a studied set decreases the recall of other unrepeated items of this set relative to a baseline, Maxcey & Woodman, 2014). This was observed in a comparable way in young and older participants.

To conclude, neither covert rehearsal via distraction nor overt rehearsal via restudy allowed attenuating age-related differences in free recall and recollection. Future studies should assess whether older participants benefited from learning by distraction only under specific conditions, such as being tested during a non-optimal time of day, or when they exhibit a significant reduction in their inhibition skills.

**Acknowledgement**

**Funding**: This work was supported by SAO-FRA (grant SAO-FRA 2019/0022) and the Funds Malou Malou, Perano, Georgette Paulus, JMJS Breugelmans and Gabrielle, François & Christian, managed by the King Baudouin Foundation (grant 2021-J1990130-222080). MG is a research associate at F.R.S.-FNRS and CB is a senior research associate at F.R.S.-FNRS.

**Conflicts of interest/Competing interests:** None

**Ethics approval:** This study has been approved by the ethics committee of the CHU of Liège under the reference 2020-340

**Availability of data and materials**: data can be downloaded at

**Code availability**: All codes used for statistical analysis are open source from Jamovi

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