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Improvement of working memory performance by training is not transferable

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Abstract
Working memory (WM) usually refers to a cognitive system devoted to the simultaneous maintenance and processing of information which plays a crucial role in high-level cognition. Recently, Barrouillet and collaborators showed the importance of controlling the time course of cognitive activities to assess WM capacities. Therefore, they developed a new paradigm to systematically explore the functioning of WM that involved simple but time-constrained activities as processing component. In comparison with traditional tasks, these computer-paced span tasks provide a more accurate evaluation of WM capacities and turned out to be the most predictive of complex cognitive achievements. The present study was the first attempt to evaluate the improvement of working memory resulting from training by repetition of this type of span tasks. Participants were trained during twelve sessions with a span task in which the duration of the concurrent activity was varied to ease the implementation of an attentional refreshing mechanism. The transfer effects were evaluated with a similar span task with a different type of material to be memorized. Results showed a significant effect of training, but no transfer effect: trained participants did not outperform a control group, and their performance in the second task did not differ from the first task. Thus, we suggested that the improvement in recall performance does not rely on an increased efficiency of a domain-general process (i.e., refreshing), but on the discovery and use of more efficient encoding strategies.

Key words: Working Memory, Training, Transfer, Computer-Paced Span Tasks

Working memory (WM) is a capacity limited system devoted to the simultaneous maintenance and processing of information. WM is involved in a wide range of complex cognitive activities, such as reasoning, problem solving, planning, and learning (Baddeley & Hitch, 1974; Barrouillet, 1996; Conway, Kane, Bunting, Hambrick, Wilhelm, & Engle, 2005; Daneman & Carpenter, 1980). Because WM capacity is a major determinant in achieving complex cognitive activities, researches on training of WM received recently a growing interest. Within the literature about WM training, two streams of research could be distinguished according to their focus on domain-general or domain-specific components of the WM system. On the one hand, in several studies, WM is enhanced through the repetition of mental activities, and this training improves performance in other cognitive tasks such as cognitive control, fluid intelligence, or reasoning (Chein & Morrison, 2010; Jaeggi, Buschkuehl, Jonides, & Perrig, 2008; Klingberg et al., 2005; Persson & Reuter-Lorenz, 2008). On the other hand, other studies are interested by the improvement in WM performance through training based on encoding strategies (Bailey, Dunlosky, & Kane, 2008; Caretti, Borella, & De Beni, 2007; McNamara & Scott, 2001; Turley-Ames & Whitfield, 2003).

The present study aimed at filling the gap between these two streams and evaluated the impact of domain-general mechanism and encoding strategies in the improvement of WM resulting from training by repetition. Moreover, because WM capacities are related to performance in complex cognitive activities, traditional WM span tasks included as concurrent activities tasks that are thought to require a high level of executive control (e.g., problem solving, reading comprehension, reasoning, mental calculation). However, recent studies have shown that very simple but time-constrained activities (e.g., reading or judging the parity of digits or the location of squares) could have an equally detrimental effect on recall as complex activities (Barrouillet & Camos, 2001; Barrouillet, Bernardin, & Camos, 2004). Therefore, Barrouillet and collaborators have developed a new paradigm to systematically explore the functioning of WM using WM span tasks that were not self-paced, as traditional tasks, but computer-paced (Barrouillet et al., 2004; Barrouillet, Bernardin, Portrat, & Camos, 2007; Camos, Lagner, Barrouillet, 2009; Vergauwe, Barrouillet and Camos, 2010). Moreover, it was been demonstrated that these new computer-paced span tasks provide a more accurate evaluation of WM capacities than the more classical span task and are better predictor of cognitive achievement (Barrouillet, Camos, Morlaix, & Suchaut, 2008; Lépine, Bernardin, & Barrouillet, 2005). The assumption is that the temporal constraints of this type of task reduce the use of possible strategies for coping with the specific demands of the dual-task paradigm. Thus, the present study was also the first attempt to evaluate training effects with such span tasks.

Within the domain-general stream of research, WM performance was improved through the repetition of either a WM span task (e.g., reading span task, operation span task or n-back task) or an immediate serial recall task (e.g., letter or digit span tasks). Moreover, the positive effect of such training could transfer to other cognitive tasks such as general fluid intelligence, cognitive control, reasoning or reading comprehension (Chein & Morrison, 2010; Jaeggi et al., 2008; Klingberg et al., 2005; Verhaeghen, Cerella & Basak, 2004). To account for transfer effects, these studies targeted domain-general processes that support complex cognition. For example, Verhaeghen, Cerella and Basak (2004) proposed that WM training increases recall performance by expanding the capacity of the focus of attention. Recently, transfer to multiple and disparate measures of complex cognition (e.g., reading comprehension, verbal or spatial reasoning) was taken as evidence by Chein and Morrison (2010) that training has an impact on a domain-general mechanism, probably by improving cognitive control (see also Klingberg et al., 2005). More especially, they suggested that the coordination of information maintenance in the face of additional processing demands would be enhanced. This suggestion echoes what we describe in the Time-Based Resource-Sharing (TBRS) model as the main mechanism responsible for performance in WM complex span tasks (Barrouillet & Camos, 2007; Barrouillet et al., 2004, 2007). In the TBRS model, attention is a limited resource, which is continuously switched between maintenance and processing to permit the maintenance of memory traces in face of concurrent processing in complex span tasks. When attention is required by some processing steps, memory traces fade away, because of a time-based decay. As a consequence, increasing the duration during which attention could be dedicated to maintenance, i.e., switched away from processing, should result in better recall performance. For example, we asked young adults to maintain letters while judging either the location of a digit (up or down) on a screen or its parity. As expected and for both tasks, recall performance decreased when the proportion of time during which attention could be dedicated to maintenance was reduced (Barrouillet et al., 2007, Exp. 3). Thus, this refreshing of the memory traces could be the locus of the change induces by training.

However, other studies showed that recall performance in span tasks are dependent on encoding strategies. Individual differences in strategy use can account for some of the performance variance in complex span tasks (Bailey, et al., 2008). Indeed, WM spans were higher when individual reported using effective strategy (e.g., sentence generation, imagery) than less effective ones. In another study focused also on individual differences, Engle, Cantor and Carullo (1992) found that resource allocation at encoding correlated with WM spans. High-span adults devoted more time at encoding the target words when recall was required than when it was not.

Participants are then able to adapt strategically their encoding of the memory items. When trained to use encoding strategy like mental images, old and young adults improved memorization of words compared to a control group without any training (Caretti et al., 2007). Similarly but only through instructions to use an encoding strategy (chaining) on a immediate recall task, young adults improved recall performance in this task, but also in a WM span task for which the memory items were similar (Mc Namara & Scott, 2001).

The aim of the present study was to evaluate the effects of training through repetition of the new computer-paced WM span task. According to the first stream of research, improvement in recall performance could result from a more efficient refreshing of the memory traces. However, in accordance with the work on encoding strategies, this improvement could also result from changes in encoding strategy, at least partially. To train participants, we used the parity judgment span task, i.e., a computer-paced WM span task in which letters have to be maintained while judging the parity of digits. To ensure that improvement in WM performance relies on domain-general maintenance mechanism, participants have to read aloud the digits, which impedes subvocal rehearsal. Moreover, the rates of presentation of the digits to be processed varied, either 800, 1200 or 1500 ms per digit. This increase in duration would ease the switching of attention from processing to maintenance and the implementation of refreshing. As already reported in the literature, recall performance should increase across the training sessions. However, if this improvement relies on an increasing efficiency of the refreshing, performance on a similar WM span task should benefit from this training. On the contrary, if the improvement in recall performance depends even partially on discovery and use of efficient encoding strategy, this effect being material-specific should disappear for a second WM task in which a different type of material (numbers instead of letters) had to be maintained. To evaluate the transfer effect, a second WM span task, the location judgment span task, was presented to the same participants (i.e., experimental group) and to a control group who had no prior training. In this span task, numbers were maintained while the location (up or down) of letters was judged. The overall structure of this second task was similar to the task used in the training phase, with three different durations for the presentation of letters and participants reading aloud the letters to impede subvocal rehearsal. To reduce both potential representation-based interference between the material to maintain and the one to process and practice effect on the processing component, different judgment tasks were inserted in the two WM span tasks. If the improvement in WM performance relies on the increased efficiency of the refreshing, the experimental group should outperform the control group. However, if the improvement observed in the training phase depends on encoding strategy, the recall performance of the two groups should not differed, and both groups should benefit from the repetitions of the second WM span task. Finally, we evaluated long-term impact of training by asking the experimental group to perform one more time the parity judgment span task one month after their last training session.

Method

Participants

Eight adults[1] (6 Females; mean age = 30; 5 years; SD = 5;3 years) participated as volunteers. Four of them were assigned to the experimental group (3 Females; mean age = 30;9 years; SD = 6;5 years) and the four other were assigned to the control group (3 Females; mean age = 30;0 years; SD = 4;9 years), as such the two groups were broadly matched in age and sex.

Material and procedure

Two complex span tasks were used. The parity judgment task was presented to the experimental group to evaluate practice effects. The location judgment task was administrated to both the experimental and control groups for accessing transfer effects.

The parity judgment span task

Participants of the experimental group performed the parity judgment span task in which they had to memorize series of eight consonants while judging the parity of digits. Four digits were sequentially presented after each consonant. These digits were randomly selected from 1 to 9, except 5 to have as many even as odd digits. The immediate repetition of the same digit was avoided. The digits were presented at three different rates: 800 ms per digit in the fast rate, 1200 and 1600 ms for the medium and the slow rates, respectively. The consonants of the memory lists were randomly selected among all consonants in the alphabet except W, which is trisyllabic in French. No consonant was repeated among a list. The size of the lists exceeded the size of the sequences classically presented in working memory span tasks. In a pre-test with lists of six consonants, our participants reached more than 90% of correct recall (mean = 94%; SD =1.3%). Because such a high rate of recall would not allow for much improvement, we choose to present longer lists.

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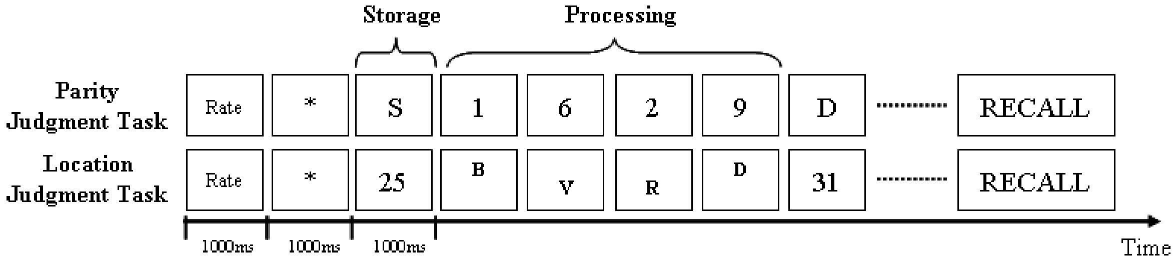
[1] The two authors and 6 volunteers from the department participated. In the results, no difference appeared between the authors and the other participants.

The course of events for each trial was as follows: the temporal condition was announced in the middle of the screen (e.g., “Fast rate: 800ms”). Next, a ready signal (an asterisk) centered on the screen for 1000 ms was followed by the first consonant presented for 1000 ms. This letter was immediately followed by the first digit to be processed. Each of the four digits was presented for 800 ms, 1200 ms, or 1600 ms for the fast, medium, or slow rate, respectively. When the fourth digit was presented, the next consonant appeared, and so on. At the end of the trial, the word Rappel [recall] was displayed on screen (Figure 1).

Participants were asked to read aloud each letter and each digit, to judge the parity of each digit as fast as possible without sacrificing accuracy by pressing either a left or a right key for odd or even, respectively, and to write down the remembered letters in correct order at the recall signal. They recalled the letters by filling out frames containing the appropriate number of boxes. They had to leave a blank box if they do not remember a letter. Five series were created for each temporal condition, and the 15 trials were randomly presented. Recall performance was computed as percentage of letters correctly recalled in the correct position. Response time and accuracy during the parity judgment task were also recorded. For the whole experiment, participants were tested 13 times with this parity judgment span task. They first performed 12 sessions, once a day, over a period of 15 consecutive days and were then tested one more time, one month after their last training session, for the post-test session.

Figure 1: Schematic depiction of the WM span tasks



The location judgment span task

The experimental and control groups performed the location judgment span task which had the same structure as the parity judgment span task (Figure 1). In this task, participants had to memorize series of eight numbers while judging the location of consonants presented. Each number was followed by a series of four consonants sequentially displayed on the screen at three different rates of presentation (800, 1200 and 1600 ms per letter of the fast, medium, and slow rates, respectively). These consonants were randomly selected from all the consonants of the alphabet except

W, and immediate repetition of the same letter was avoided. The consonants were centered and randomly presented on one of two possible locations 15 mm apart either in the upper or the lower part of the screen. Participants judged the location of each consonant by pressing either a left or a right key for lower and upper location, respectively. The numbers to be remembered were randomly selected among a set of 19 possible numbers. Because numbers in the first decade are irregular in French and made of one or two words, we choose to use the regular second and third decade (from 21 to 39), in which the length of number words is constant. The repetitions of numbers among a list were avoided.

Participants were asked to read aloud each number and each letter, to judge the location of each letter as fast as possible without sacrificing accuracy, and to write down the remembered numbers in correct order by filling out frames containing the appropriate number of boxes. A box was left blank if a number could not be remembered. Five series were created for each temporal condition, and the 15 trials were randomly presented. Recall performance was computed as percentage of numbers correctly recalled in the correct position. Response time and accuracy during the location judgment task were also recorded. Participants were tested with this procedure six times once a day over a period of eight consecutive days.

Results

We first accessed the training effects on the experimental group, which performed 12 times the parity judgment span task. Then, we analyzed the transfer effects by comparing the performance in the location judgment span task of the experimental group to the control group, and by comparing the performance of the experimental group in the two span tasks. Finally, we evaluated long-term effects of training in the experimental group.

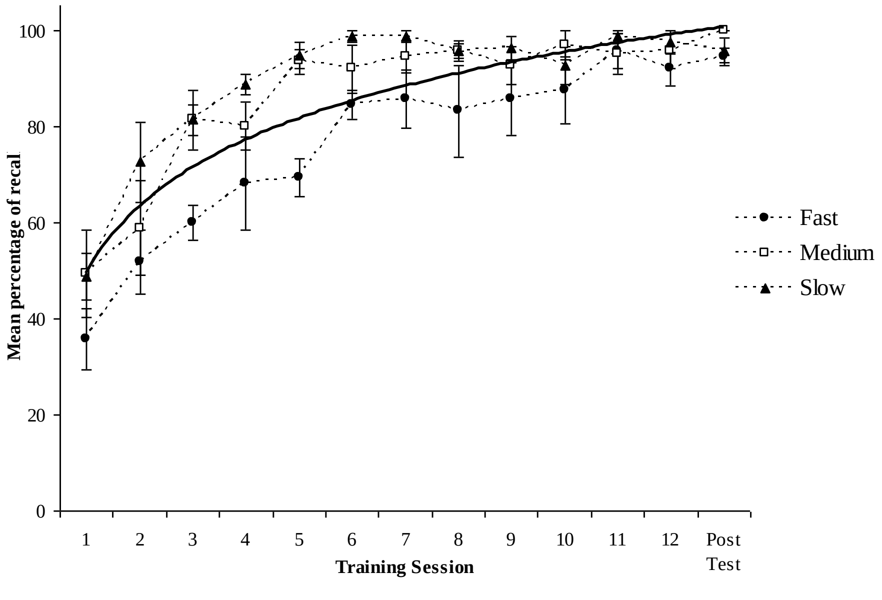
Training Effects

Participants paid sufficient attention to the parity judgment task during the experimental sessions, because all of them achieved at least 80% correct responses on the parity judgment task in all the sessions. The percentage of errors (3%) and the response time (554 ms) did not differ across the training sessions, $F(11,33) = 1.29$, $p > .10$, $\eta^2_p = .30$, and $F(11,33) = 1.36$, $p > .10$, $\eta^2_p = .31$, respectively. Participants committed slightly more errors in the fast rate (6%) than in the two other rates (2%), $F(1,3) = 21.34$, $p < .05$, $\eta^2_p = .88$, although this difference failed to reach significance in response time, $F(1,3) = 6.57$, $p = .08$, $\eta^2_p = .69$.

A 12 (session 1 to 12) x 3 (rates: fast, medium, or slow) analysis of variance (ANOVA) was performed on the mean percentage of recall. Recall performance increased across the sessions from 45% for the first session to 95% for the last session, $F(11,33) = 31.04$, $p < .0001$, $\eta^2_p = .91$. This increase of recall performance was very strong especially at the beginning of training because the performance reached 91% in only six sessions, $F(5,15) = 21.92$, $p < .0001$, $\eta^2_p = .88$. From the seventh session, this increase of recall performance slowed down towards a plateau, and the effect of the training sessions became non significant, $F(5,15) = 1.1$, $p > .10$, $\eta^2_p = .26$, (Figure 2).

Increasing the duration available to process the digits resulted in significantly higher spans (75%, 85% vs. 89% for fast, medium, and slow rates, respectively), $F(2,6) = 18.75$, $p < .01$, $\eta^2_p = .86$. However, this effect was mainly due to the significant difference between the fast rate and the other two rates, $F(1,3) = 26.64$, $p < .05$, $\eta^2_p = .90$, whereas the medium and the slow rates did not differ, $F(1,3) = 2.93$, $p > .10$, $\eta^2_p = .49$. The interaction between the sessions and the rates of presentation was not significant $F < 1$. Furthermore, the curve of mean recall performance according to sessions showed a significant logarithmic fit typical for learning curves, $F(1,10) = 19.80$, $p < .005$, whose equation is $y = 48.85 + 47.19 \times \log10(x)$ and $r^2 = .66$. This logarithmic trend was also confirmed for each rate ($r^2 = .78$, $p < .001$, $r^2 = .62$, $p < .005$, and $r^2 = .52$, $p < .01$, for fast, medium, and slow rates, respectively). Moreover, the learning curve was steeper for the fast rate; the slope of the logarithmic fit decreasing for the medium and the slow rates (55, 45, and 42 for fast, medium, and slow rates, respectively).

Figure 2: Mean percentage of recall according to the training sessions and the rates. The plain line represents the logarithmic fit

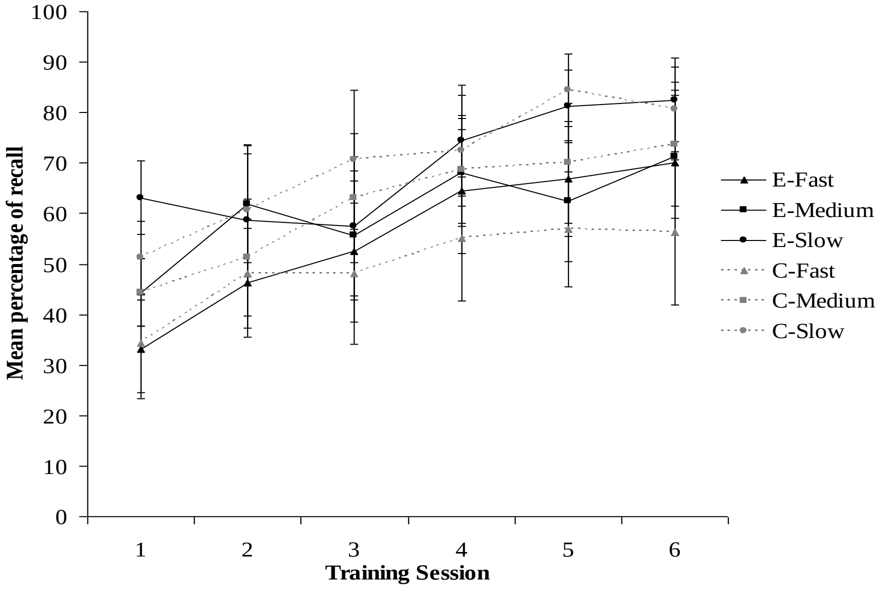


Transfer Effects

The percentage of errors (5%) and the response time (517 ms) for the location judgment task did not differ between the groups (experimental vs. control), *F*s < 1. Participants made slightly more errors and were faster in the fast rate (9% and 477 ms) than in the two others (4% and 536 ms), $F(1,6) = 9.37$, $p < .05$, $\eta^2_p = .61$ and $F(1,7) = 14.73$, $p < .01$, $\eta^2_p = .68$, respectively. Whereas the response time and the percentage of errors significantly decreased across sessions, $F(5,30) = 12.55$, $p < .0001$, $\eta^2_p = .68$, and $F(5,30) = 4.13$, $p < .01$, $\eta^2_p = .41$, respectively. However, none of these effects interacted with the groups, *p*s > .29.

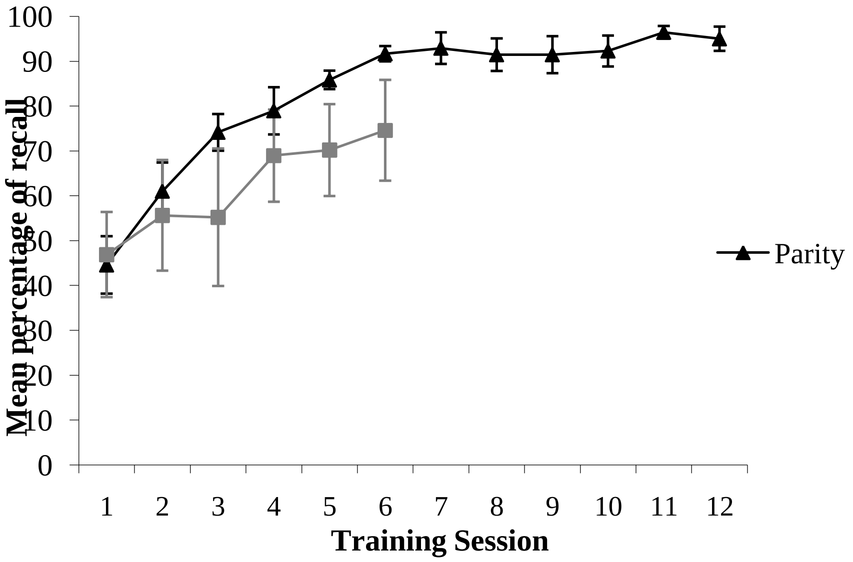
To compare the performance of the two groups, a 2 (groups: experimental vs. control) x 6 (session 1 to 6) x 3 (rates: fast, medium, or slow) ANOVA was performed on the mean percentage of recall. As for the parity judgment span task, recall significantly increased across sessions, $F(5,30) = 12.0$, $p < .0001$, $\eta^2_p = 0.67$, and with the increasing duration to process the location, $F(2,12) = 27.68$, $p < .0001$, $\eta^2_p = 0.82$,. However, the recall performance of the control group that did not benefit from any training on a complex span task did not differ from the experimental group, $F < 1$. Moreover, neither the effect of the training session nor the effect of the rate of presentation varied across the groups, as none of the interactions was significant, ps >.10 (Figure 3). Finally, the curve of mean recall performance according to training sessions showed a significant logarithmic fit in each group, $F(1,4) = 46.97$, $r^2 = .92$, $p < .005$ for the experimental group and $F(1,4) = 31.80$, $r^2 = .86$, $p < .005$ for the control group, and their equations are very similar, $y = 44.87 + 35.78 \times \log10(x)$ and $y = 43.09 + 36.68 \times \log10(x)$, respectively.

Figure 3: Mean percentage of recall according to the training sessions, the rates and the groups (E-: Experimental group and C-: Control group)



To evaluate the potential transfer effect between the two complex span tasks, we compared the recall performance of the experimental group on the first six sessions of the parity judgment span task with the six sessions of the location judgment span task. A 2 (tasks: parity vs. location) x 6 (session 1 to 6) x 3 (rates: fast, medium, or slow) ANOVA was performed on the mean percentage of recall. As already mentioned, recall performance significantly increased across the sessions, $F(5,15) = 20.46$, $p < .0001$, $\eta^2_p = 0.87$, and with the increasing rates of presentation, $F(2,6) = 20.86$, $p < .0001$, $\eta^2_p = 0.87$. More interestingly, the recall performance of the experimental group did not differ between the parity judgment span task and the location judgment span task, $F(1,3) = 1.45$, $p > .10$, $\eta^2_p = 0.32$. Finally, none of the interactions was significant, *ps* >.10 (Figure 4).

Figure 4: Mean percentage of recall of the experimental group according to the training sessions and the tasks



Long-Term Effects

For this last session of the parity judgment span task, the mean error rate (3%) and the mean response time (558 ms) did not differ from the mean error rate and the mean response time of the twelve training sessions, Fs < 1. Mean recall performance for this session was slightly higher but not significantly different from the mean recall performance of the last training session of this task (97% vs. 95%), F < 1 (Figure 2). To test this difference, we applied a logarithm transformation to the data from the 12 training sessions and then performed a linear regression which allowed to compute the predicted values for this post-test, i.e., thirteenth session. Recall performance observed at post-test fell into the expected 95% confidence interval [94% to 138%] on average, as well as for each rate ([94%, 140%], [94%, 139%], and [93%, 140%] for the fast, medium, and slow rates, respectively). Although this last session was performed one month after the end of training, recall performance remained unchanged.

Discussion

The aim of this study was to evaluate whether the increasing efficiency of a domain-general mechanism, namely refreshing, or the use of encoding strategy could account for improvement of WM span tasks through training by repetition. It was also the first try to use the new computer-paced WM span tasks in a training study and to evaluate if performance in such time-constrained tasks could be improved. Although this study was mainly exploratory and on a small sample of participants, it gave some interesting insights on the potential sources of training effects. Indeed, after being trained with a computer-paced WM span task for which their performance increased up to 100% correct recall, young adults did not show any difference with a control group in another WM span task that involved a different type of memoranda. Moreover, the increase of recall performance through repetition was similar for the two WM span tasks.

This lack of transfer between two tasks of the same structure contrasts with previous findings in which transfer was observed between tasks that greatly differed, and for which a change in attention control was put forward as explanation of such a effect (Chien & Morrison, 2010; Klingberg et al., 2005). However, the current findings perfectly fit with the assumption that the repetition of the WM span task allows participants to discover more efficient encoding strategies. The informal verbal report at the end of the experiment confirmed that participants used specific encoding strategies. They reported using sentence generation for the parity judgment task (each letter primed a word they used to create sentences), and various strategies all necessitating long-term memory knowledge for the parity judgment span task (mostly based on idiosyncratic meaning of some numbers). Across the training sessions, participants became more and more efficient in using these strategies. Because encoding strategies are material dependent, no transfer is possible between two tasks that did not share the same type of memoranda. As a consequence, the presentation of a new WM span task implies to discover a new strategy adapted to the type of items to maintain. Our findings were consistent with this interpretation because (1) the performance for the first session of the second WM span task was not better that for the first session of the first WM span task, and (2) the repetition of the second WM span task showed a similar increase of performance as for the first WM span task.

Two main reasons could have favored the fact that WM span was improved through encoding strategies in the present study. First, because the aim was to contrast two sources of improvement, we created a situation that constrained strongly participants. The WM span task we used was computer paced, thus leaving little possibilities to develop strategies to deal with the dual task, like postponing the processing of incoming information. We impeded the use of subvocal rehearsal, which is probably the most commonly used mechanism to maintain verbal information. We presented long lists of items, beyond average span of young adults. The second reason is that our participants were high span individuals as shown in the pre-test. As a consequence, they have most probably efficient control of attention (Engle, Kane, & Tuholski, 1999), which reduced possibilities to increase this capacity any further. Moreover, they are also more akin to rely on efficient encoding strategies. Indeed, whereas individual with low span use mainly on rehearsal, individuals with a high span use elaborative encoding strategies such as semantic elaboration, chaining or imagery (Dunlosky & Kane, 2007; Mac Namara & Scott, 2001; Turley-Ames & Whitfield, 2003).

It has generally been claimed in the literature that in a WM span task where the presentation rate is controlled by the experimenter, the high attentional demand of the task prevents or at least reduces the use of coding and maintenance strategies that are often employed for short term memory tasks, yielding a more pure measure of individuals' WM capacity (e.g., Dunlosky & Kane, 2007; Engle, Cantor, & Carullo, 1992; Lépine et al., 2005). However, our results contrast with this assumption because they suggested that, WM performance is not strategy free, even with a computer-paced span task. Although the temporal constraints of this type of tasks reduce the use of possible strategies, they do not completely impede them. These results strengthen those previously found in the literature on WM training, which have shown that training based on mnemonic strategies can improve WM performance (Carretti et al., 2007; McNamara & Scott, 2001). Moreover, in the literature, the claim that the strategy does not influence WM task performance is primarily supported by the fact that the processing task occurs too quickly, and the participants have no time to develop any strategy. However, our results showed that even in the fast rate condition, participants improved their performance with training. Therefore, the present study suggests that, even under strong time-constraints, participants are able to develop alternative strategies for coping with the specific demands of the dual-task paradigm. However, we also showed that the implementation of mnemonics strategies seems to be time-dependent: the more participants have time to perform the processing task and the more they could implement strategies and improve their performance.

This question of the effect of practice on computer-paced WM span task also has a methodological interest. Indeed, WM span tasks are central research tools in all areas of psychology. Thus, in many research areas researchers are often led to do several measures of memory capacities on the same participants (for example in pre- and post-test). However, our study emphasizes the fact that we must be very careful when we want to test several times the WM capacities since any repetition of the same task leads to a significant change in recall performance and implementation of strategies. Moreover, even after one month, effects of training are still manifest. Results of other studies also point in the same direction. For example, Klein and Fiss (1999) found that scores on a self-paced operation span task markedly increased from the first to the second administration of the test, indicating a practice effect even over 3 months. Barrouillet and Camos (2001, Exp. 1) also found a strong learning effect in their control group which perform the same computer-paced, the "baba" span task, two times with a delay of 3 weeks between. So, to test several times the WM capacities the method which consists in leaving a long interval of time between the first and the second session is not a good technique to avoid practice bias. However, according to our results on the transfer effect, it is possible to neutralize the effects of learning (increased performance through the implementation of alternative strategies) by changing the material to be memorized in the task.

Finally, this study provided interesting preliminary results on the training and transfer effects in our new computer-paced span task, and gave the first cornerstone for further investigations. For example, these results should be replicated on a larger and more heterogeneous sample. It would also be interesting to further explore this effect of training and transfer with other computer-paced span tasks which involve other types of items to be memorized (in verbal or spatial domain) and other types of processing task. In the present study we investigated the transfer effects between two similar WM span tasks (« near transfer »). Therefore, it would be interesting to investigate the transferability of the benefits of a computer-paced WM span task training in other more general cognitive tasks such as fluid intelligence tasks (« far transfer »).

To conclude, the present study did not discard the possibility that a domain-general mechanism, like refreshing the memory traces, could be trained, and thus explaining the transfer effects on different cognitive tasks. However and contrary to previous works on encoding strategies that used either training of strategies or instructions, this study showed that even a mere repetition of a time-constrained WM span task allowed participants to discover more efficient ways to encode the memoranda.

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