Gains in language comprehension relating to working memory training in healthy older adults

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Objective: A growing number of studies are focusing on cognitive training procedures to delay age-related decline. Given the crucial role of working memory (WM) in everyday life, some studies have recently analyzed gains deriving from WM training and their transfer and maintenance effects in older adults.

Method: The present study investigates the efficacy of a verbal WM training program in 20 65–75 year old adults with no cognitive impairments, considering the specific training-related gains in a verbal WM task (criterion) and the transfer effects on measures of WM updating, reasoning, and on abilities related more to daily life, that is language comprehension. Maintenance of training benefits was also assessed after 6 months.

Results: The older adults given training performed better than controls in the criterion task and retained this benefit 6 months later. Immediate transfer effects were seen in most of the abilities considered (reasoning and language comprehension performance) and were substantially maintained at the 6-month follow-up.

Conclusion: Our results suggest that WM training is a promising approach for preserving abilities relating to everyday activities, helping to prolong older adults’ independence and well-being. Copyright © 2012 John Wiley & Sons, Ltd.

Key words: working memory; cognitive training; transfer effects; maintenance effects; older adults

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Introduction

There is a broad consensus on the influence of working memory (WM)—the ability to retain and manipulate information for use in complex cognitive tasks—on various skills, such as reasoning, problem solving, and language comprehension, which are related to efficiency in everyday life. Studies are now focusing on the feasibility of increasing WM capacity and the impact of doing so on cognitive processes associated with or implicated in WM. Because of the decline of WM in aging (Park et al., 2002), a growing number of researches are analyzing the benefits of WM training in aging in terms not only of WM but also of other, untrained skills (see Shipstead et al., 2010), to improve older adult functional status and postpone age-related disorders.

Studies on WM training for older adults have generated positive results in terms of specific training benefits, that is, an improved performance in tasks practiced during the training (Richmond et al., 2011; Borella et al., under revision), but transfer effects on untrained tasks are rarely observed (Noack et al., 2009). In the few exceptions, there was evidence of large transfer effects on WM-related mechanisms, such as inhibition and processing speed and on cognitive processes that involve WM, such as fluid intelligence; this happened, for example, in the study of Borella et al. (2010).

The efficacy of the WM training of Borella et al. seems to be due to the types of activity and the schedule for the training sessions. As concerns the types of activity, participants receiving the WM training of Borella et al. were presented with a WM task that combined an adaptive procedure (the task was made more difficult if participants were successful at a given level; if they were not, only the lowest level was presented) with variations in the related maintenance requirements (to avoid simple practice effects). This procedure has several advantages in that it enables participants to be...
trained at a difficulty level close to their capacity limits and it enhances their engagement in the proposed activities because they feel up to the tasks they are presented. In our view, this motivational component is particularly important in the case of older participants because of the well-known inappropriate believes concerning their cognitive abilities (Hertzog and Hultsch, 2000).

As for the schedule for the training sessions, in the light of studies on the positive effects of distributed practice (e.g., Cepeda et al., 2006), the sessions were arranged with a fixed interval between them that left participants sufficient time to consolidate the skills they had acquired and, at the same time, the schedule was tight enough to reduce the risk of them losing the beneficial effects of having practiced with the task.

One of the main goals of cognitive training, and WM training too, is also to consider transfer effects on everyday life activities. To date, apart from the study by Richmond et al. (2011), who found some beneficial influence on tasks more resembling activities of daily living, little is known about WM training impact on everyday cognition in older adults.

The aim of the present study was thus to examine the effect of verbal WM training on processes related to WM (updating and reasoning) and also on an ability that is central to successful daily living, that is, language comprehension, which is needed in various everyday activities and crucial to an individual’s health and well-being. We focused on reading and listening comprehension, using expository texts because they are more liable to age-related decline than narrative texts (De Beni et al., 2007). Texts dealing with history and geography, and texts presenting a spatial description of an environment were administered to reflect situations of everyday life.

The WM training regime was modeled along the lines of the one proposed by Borella et al. (2010). To facilitate transfer effects on language comprehension, the training sessions also included activities requiring that participants update information while reading (several studies have demonstrated that updating is crucial to language comprehension; e.g. Zwaan and Radvansky, 1998).

Transfer effects were sought by administering tasks involving processes similar to the one actually practiced, that is, the WM updating task (near transfer effects), as well as very different processes that are nonetheless related to WM, that is, language comprehension—reading and listening tasks—and fluid intelligence—Cattell Culture Fair test (far transfer effects).

As suggested by the literature, we expected to see gains in WM tasks similar to the one used in the training (criterion). Transfer effects were also expected because the chosen tasks rely on mechanisms relating to the WM process (updating and reasoning), and language comprehension has revealed a close connection with WM (Daneman and Merikle, 1996), even in older age (Borella et al., 2011).

### Method

#### Participants

Forty adults aged 65–75 years took part in the study. All participants were native Italian speakers and volunteered for the study. They were recruited from the University of the Third Age or at social clubs of north-eastern Italy. They were all healthy and active in the cultural and social activities of their neighborhoods.

After a plenary session where the older adults were told about the two different programs, the 40 volunteers were randomly assigned to two groups, 20 to receive training and the other 20 to form the control group.

Three participants assigned to the trained group and one in the control group dropped out. An analysis of their background characteristics (age, years of education, and vocabulary) revealed no differences between those remaining in the study and the dropouts, so our analyses were conducted on the participants involved in all the sessions.

The trained and control groups did not differ by age, years of formal education ($F < 1$), or Wechsler Adult Intelligence Scale-Revised vocabulary score, $F (1, 34) = 1.29; p = .18$ (Wechsler, 1981) (see Table 1).

### Materials

**Criterion task: Categorization Working Memory Span task (CWMS, Borella et al., 2008).** The materials consisted of 10 sets of words, each set comprising 20 lists of words organized in series of word lists of different lengths (from two to six lists). Each list contained five words of high to medium frequency. The lists contained two, one, or no animal nouns, in any position, including the last. Of the total number of words (200) in the task, 28% were animal nouns.

| Table 1  Demographic characteristics of the trained and control groups |
|-------------|-----------------|-----------------|-----------------|-----------------|
|             | Trained group   | Control group   |                 |                 |
| N           | 17, 65% female | 19, 50% female |                 |                 |
| Age         | 69.00           | 70.37           | 3.44            | 3.74            |
| Education   | 8.12            | 9.00            | 3.70            | 4.93            |
| Vocabulary  | 45.82           | 41.05           | 9.01            | 11.33           |

M, mean; SD, standard deviation.
Participants listened to the audio-recorded word lists presented at a rate of 1 s per word and had to tap their hand on the table whenever they heard an animal noun (processing phase). The interval between series of word lists was 2 s. At the end of the series, participants recalled the last word of each string in serial order (maintenance phase). Two practice runs of two words long were administered before the experiment began. The total number of correctly recalled words was used as the measure of WM performance (maximum score 20).

Near transfer effect: Working Memory Updating word span test (Carretti et al., 2010). The task consisted of 10 lists of object words. For each level of WM demand (from 1 to 5), two lists were presented, and participants had to remember an increasing number of items (from 1 to 5) according to the criterion recall the smallest object(s) in each list and in order of presentation. All the words were highly familiar and referred to objects easy to compare for size. Participants listened to the lists of words read aloud by the experimenter at a rate of 1 s per word.

The dependent variable was the number of correctly recalled words (maximum score 30).

Far transfer effect. Language comprehension - Listening comprehension of spatial descriptions (Pazzaglia et al., 2007) Three texts were used, one per session, describing outdoor environments in route perspective (a farm, a countryside with a lake, and a nature park). Each spatial description was 10 sentences long (about 220 words) and mentioned 10 landmarks. The three environments had similar layouts as regards the landmarks’ positions. The experimenter read the text aloud twice, and participants were asked to answer 20 true/false questions (maximum score 20). Then, they had to draw a map of the environment. The dependent variable was the sum of the landmarks recalled, the number of landmarks recalled in the right position, and the number of landmarks recalled in the right correct order (maximum score 30). Map-drawing performance was assessed by two independent judges, who showed a high rate of agreement (r > .90).

Reading comprehension of expository texts. Six texts were used, two per session, adapted from the Nelson-Denny (see Borella et al., 2011). The texts contained about 200 words and dealt with topics of history and geography. Each text was followed by four multiple choice questions with five alternatives. Participants had 4 min for each text, the number of correct answers being the dependent variable (maximum score 8).

Fluid intelligence: Culture Fair Test, scale 3 (Cattell and Cattell, 1963). Scale 3 of the Cattell test consists of two parallel forms (A and B), each containing four subtests to complete in 2.5–4 min (depending on the subtest). The subtest involves (i) completing a series of figures by choosing which of the six options best completes the series, (ii) identifying figures or shapes that differ from the others, (iii) choosing items that correctly complete matrices of abstract figures and shapes, and (iv) assessing relationships between a set of items. The dependent variable was the number of correct solutions obtained across the four subsets (maximum score 50).

For each task, two parallel versions were devised and administered in a counterbalanced order across the training sessions. The only exception concerned the language comprehension tasks, for which three versions were prepared and they were counterbalanced by participant and across the training sessions.

Procedure

Participants attended six individual sessions: the first and fifth were the pretest and posttest sessions, and the last one, 6 months later, was the follow-up; in the other three, the control group was occupied in alternative activities (see Table 2), whereas the trained group attended the training.

The training was completed within a 2-week time frame, with a fixed 2-day break between sessions. The schedule was identical for the two groups, thus enabling a matching amount of social interaction. The WM training consisted of three sessions (sessions 2–4), each comprising two parts: in the first part, lasting about 30–40 min, participants practiced a modified version of the CWMS; in the second, lasting about 20–30 min, they practiced tasks requiring the updating of information while reading (see Table 2).

In the first part, adopting the method used in Borella et al. (2010), the experimenter presented trained participants with lists of audio-recorded words organized in the same way as for the CWMS task. Participants were asked to recall target words and tap their hand on the table when an animal noun was heard. To favor generalized transfer and contain the development of task-specific strategies, the maintenance demand of the CWMS task was manipulated by increasing the number of words to recall if participants succeeded and presenting the lowest memory load if they failed (session 2). The task requirements also varied, involving the recall of (i) the last or first word in each series (sessions 2 and 4) and (ii) words proceeded by a beep sound (session 3). The processing requirement (tapping when
an animal noun occurred) was also manipulated by varying the frequency of these animal words in the lists (session 3).

In the second part of each session, participants were presented with two short texts (of about 14–15 sentences each) describing a character concurrently performing two common activities of daily living (i.e., shopping at a drugstore and thinking about meals to prepare for dinner); participants were asked to remember the character’s two–six actions or thoughts. Texts were presented on a computer screen, sentence by sentence, with a self-paced presentation. To recall relevant items, participants had to update their mental representation, adding or substituting the information to recall.

The control group met the experimenter for the same number of sessions as the trained group and for approximately the same amount of time. Sessions 1, 5, and 6 were the same as for the trained group, whereas in sessions 2–4, participants were asked to fill in paper-and-pencil questionnaires.

For both groups, the sessions were conducted by the experimenter, who explained the activities involved in each session and managed the presentation of materials.

### Results

The two groups did not differ at the pretest session. To assess the effects of training, the measures of interest

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**Table 2: Description of training sessions by groups**

<table>
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<tr>
<th>Session</th>
<th>Trained group</th>
<th>Control group</th>
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<tbody>
<tr>
<td>1. Pretest</td>
<td>Health interview, Vocabulary, CWMS, Reading comprehension, WM updating, <strong>WM training</strong>: sets of different lengths (from 2 to 5) each with three series of word lists. Participants had to recall the target words and tap the hand on the table whenever an animal noun was heard. The WM task included three phases presented sequentially: in the first, participants had to recall the last word of each series of words; in the second, the first, and in the third, again the last. In each phase, for correct recall of words for two of the three series of a given length, the task was increased in difficulty up to length 5. In case of failure in one of the three phases, participants were presented the following phase starting from the easiest level and had to recall either the first (phase 2) or last word (phase 3). <strong>WM updating during reading</strong>: two texts were presented. The first text, 14 sentences long (177 words), required to recall at the end two pieces of information. The second text, of the same length (182 words), required to recall three information. After presentation, participants were presented two open-ended questions on texts content.</td>
<td>Listening comprehension, Cattell test Autobiographic Memory questionnaire (De Beni et al., 2008)</td>
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<tr>
<td>2. Training</td>
<td><strong>WM training</strong>: sets of different lengths (from 2 to 5) each of four series of word lists. Word series of length 2 could contain from two to eight animals noun, length 3 from four to nine, length 4 from six to 11, and length 5 from eight to 17. For each series, participants had to tap the hand on the table whenever an animal noun was heard and to remember each word followed by a sound, in serial order. <strong>WM updating during reading</strong>: two texts were presented. The first text, 15 sentences long (179 words), required to recall at the end four pieces of information. The second text, of the same length (186 words), required to recall five information. After presentation, participants were presented two open-ended questions on texts content.</td>
<td>Need for cognition (adapted from Cacioppo et al., 1996)</td>
</tr>
<tr>
<td>3. Training</td>
<td><strong>WM training</strong>: sets of four series of two word lists. Participants had to tap the hand on the table whenever an animal noun was heard and had to recall in (i) the first series, the last words of each list; (ii) the second, the first words; (iii) the third, the last words; and (iv) the fourth, the first words. <strong>WM updating during reading</strong>: two texts were presented. The first text, 15 sentences long (183 words), required to recall at the end four pieces of information. The second text, of the same length (180 words), required to recall five information. After presentation, participants were presented two open-ended questions on texts content.</td>
<td>Psychological Well-being (De Beni et al., 2008)</td>
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<tr>
<td>4. Training</td>
<td><strong>WM training</strong>: sets of four series of two word lists. Participants had to tap the hand on the table whenever an animal noun was heard and had to recall in (i) the first series, the last words of each list; (ii) the second, the first words; (iii) the third, the last words; and (iv) the fourth, the first words. <strong>WM updating during reading</strong>: two texts were presented. The first text, 15 sentences long (183 words), required to recall at the end four pieces of information. The second text, of the same length (180 words), required to recall five information. After presentation, participants were presented two open-ended questions on texts content.</td>
<td>Memory Sensitivity (De Beni et al., 2008)</td>
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<tr>
<td>5. Posttest</td>
<td>CWMS, Reading comprehension, WM updating, Listening comprehension, Cattell test</td>
<td>Questionnaire on Memory Strategies (adapted from Troyer &amp; Rich, 2002)</td>
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<tr>
<td>6. Follow-up (6 months)</td>
<td>CWMS, Reading comprehension, WM updating, Listening comprehension, Cattell test</td>
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</table>

CWMS, Categorization Working Memory Span test; WM, working memory.
were analyzed with a 2 (group: trained and control) 
3 (session: pretest, posttest, and follow-up) mixed 
design analysis of variance. To test interactions using 
post hoc pairwise comparisons with Bonferroni’s cor-
rection at \( p < .05 \), adjusted for multiple comparisons, 
were run. Descriptive statistics are given in Table 3; 
analysis of variance results are summarized in Table 4.

Criterion task: CWMS

The trained group performed better than the control 
group (MDiff. = 1.81, \( p < .05 \)), and the former’s 
performance improved consistently from pretest to 
posttest (MDiff. = −2.60, \( p < .001 \)) and follow-up 
(MDiff. = −2.30, \( p < .001 \)), with no difference between 
the latter two. Post hoc comparisons showed that trained 
participants performed better at posttest (\( p < .001 \)) 
and follow-up (\( p < .001 \)) than at pretest. The trained 
participants maintained their posttest performance 
at follow-up. No significant difference was found for 
the control group. The trained group outperformed 
the control group at both posttest and follow-up 
(\( p < .001 \)).

<table>
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<th>Table 3</th>
<th>Descriptive data for pretest, posttest and follow-up data by group</th>
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<tr>
<td></td>
<td>Trained group</td>
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<tr>
<td></td>
<td>Pretest</td>
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<td>M, SD</td>
<td>M, SD</td>
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<tr>
<td>CWMS</td>
<td>13.82</td>
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<td></td>
<td>14.58</td>
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<tr>
<td>Updating task</td>
<td>23.82</td>
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<td></td>
<td>22.37</td>
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<tr>
<td>Listening comprehension</td>
<td>13.65</td>
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<td></td>
<td>14.89</td>
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<tr>
<td>True/False</td>
<td>18.71</td>
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<td></td>
<td>22.68</td>
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<tr>
<td>Reading comprehension</td>
<td>3.24</td>
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<td></td>
<td>4.53</td>
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<tr>
<td>Cattell</td>
<td>15.82</td>
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<td></td>
<td>17.47</td>
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M, mean; SD, standard deviation; CWMS, Categorization Working Memory Span test.

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<th>Table 4</th>
<th>Mixed design 2 × 3 ANOVA results for the measures of interest, with group (trained and control) as between-subjects factor and session (pretest, posttest, and follow-up) as repeated measures</th>
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<tr>
<td></td>
<td>Between subjects</td>
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<tr>
<td>Specific effect</td>
<td>CWMS</td>
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<td>Transfer effects</td>
<td>WM updating</td>
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<td>Cattell test</td>
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</table>

ANOVA, analysis of variance; CWMS, Categorization Working Memory Span test; WM, working memory; df, degree of freedom; MSE, mean square error.
p < .05), and the former’s performance improved consistently from pretest to posttest (MDiff. = −1.22, p < .05) and follow-up (MDiff. = −1.62, p < .01), with no difference between the latter two. Post hoc comparisons showed that trained participants performed better at posttest (p < .01) and follow-up (p < .001) than at pretest. The trained participants maintained their posttest performance at follow-up. No significant difference was found for the control group. The trained group outperformed the control group at both posttest and follow-up (p < .001).

Far transfer effect. Listening comprehension of spatial descriptions. In terms of correct answers to true/false questions, performance improved statistically from pretest to follow-up (MDiff. = −2.43, p < .01) but did not differ statistically from pretest to posttest or from posttest to follow-up. Post hoc comparisons revealed that trained participants performed better at posttest (p < .01) and follow-up (p < .001) than at pretest. The trained participants maintained their posttest performance at follow-up. No significant differences emerged in the control group. The trained group outperformed the control group at both posttest (p < .05) and follow-up (p < .01).

In map drawing, performance improved from pretest to posttest (MDiff. = −3.34, p < .05) and follow-up (MDiff. = −4.65, p < .01), with no difference between the latter two. Post hoc comparisons showed that trained participants performed better at posttest and follow-up (for both: p < .001) than at pretest. The trained participants maintained their posttest performance at follow-up. No significant difference was found for the control group. The trained group outperformed the control group at both posttest (p < .05) and follow-up (p < .01).

Reading comprehension of expository text. Follow-up performance was higher than in the pretest (MDiff. = 1.22, p < .01) and posttest (MDiff. = .96, p < .05), with no difference between the latter two. Post hoc comparisons showed that the trained participants’ performance improved at follow-up with respect to pretest (p < .001) and marginally to posttest (p = .06). No statistically significant differences emerged between the groups in any session, however.

Fluid intelligence: Cattell. Performance improved from pretest to posttest (MDiff. = −2.81, p < .05) and follow-up (MDiff. = −2.5, p < .001), with no difference between the latter two. Although the interaction was only marginally significant, post hoc comparisons indicated that the trained participants performed better at posttest (p < .001) and follow-up (p < .001) than at pretest, and their better performance was maintained from posttest to follow-up. No significant differences emerged for the control group. No statistically significant differences emerged between the groups in any session, however.

To analyze training gains and transfer effects from the pretest to the posttest, Cohen’s d (1988) (which expresses the effect size of the comparisons) were computed for within-subjects data (see Morris and DeShon, 2002). When the gains from pretest to posttest were compared within each group, a large (more than .80) effect size emerged for the trained group and a small effect size for the control group (see Figure 1). Benefits were maintained at follow-up by the trained group only (CWMS, d = 1.70; WM updating, d = 1.01; Listening comprehension—true/false questions—, d = 1.16; Map, d = 1.98; Reading comprehension, d = .98; Cattell, d = 0.98).

Figure 1 Effect size for pretest/posttest comparisons for specific and transfer effects by group (trained and control).
Discussion

This study examined transfer effects from a verbal WM training on abilities relating to everyday life (and language comprehension in particular) in healthy older adults. Language comprehension is a crucial skill in everyday life, so demonstrating that it can be improved by means of training on basic cognitive mechanisms affected by aging (such as WM) would open up opportunities for delaying age-related cognitive decline.

To elucidate this issue, a WM training (Borella et al., 2010), already tested for its efficacy, was combined with activities requiring that participants update their information while reading short passages and intended to facilitate the transfer of the benefits of the training to language comprehension because updating processes have also been shown to be implicated in the latter ability (Zwaan and Radvansky, 1998). This modification of the training regimen was designed to link specific WM training with the use of WM resources in contexts mimicking activities of daily living (i.e., reading to remember some relevant information).

Consistently with the literature and our expectations, our results showed that participants benefited immediately after receiving training in the criterion task and WM updating one, and that these improvements were maintained after 6 months. These findings confirm that WM is closely related to updating processes (Schmiedek et al., 2009) and provide further evidence that WM performance is modifiable even in older adults with a normal age-related decline in their cognitive functioning.

We also found far transfer effects on language comprehension. Our training procedure probably engaged multiple processes that are also involved in language comprehension, including encoding, retaining, and inhibiting irrelevant information. All these processes favored a change in the allocation of attentional resources during reading and listening comprehension exercises, generating a better language comprehension performance. The effect was stronger for listening comprehension concerning spatial descriptions, with benefits immediately after the training that increased at the follow-up; the gain in reading comprehension was only evident at the follow-up. This might be due to differences in the content of the texts: the reading comprehension texts required that participants rely on background knowledge more than for the listening comprehension of spatial descriptions. It may also be that the training procedure particularly favored the creation of a spatial mental model because the texts used during the training activities describe character acting in an environment, without providing any spatial references, and this probably facilitates a visual representation of the events. Participants may therefore have refined their ability to integrate the information presented in the text, and this may have had a positive impact on some aspects involved in comprehension processes. However, because of the texts contents (history, geography) in the reading comprehension task, this effect may have interacted with the reader’s background knowledge, reducing the training benefits in the reading comprehension test.

As concerns the transfer effects for the Cattell test, although the group-by-session interaction only approached statistical significance, post hoc analyses showed that the trained group performed better at posttest than at pretest and from pretest to the 6-month follow-up. The more limited transfer effect on the Cattell test may be due to the fact that the two groups’ performance was not completely comparable at pretest (the control group did better) and, although the difference was not statistically significant, this could have emphasized the changes in the trained group. Individual differences analysis might have shed light on this, but our sample size unfortunately prevented us from exploring this issue. It is also possible that modifying the training activities altered the nature of the changes promoted by the original model (Borella et al., 2010). In fact, in another study that used the same procedure of Borella et al. with older adults with mild cognitive impairment, the trained participants achieved an improvement in the Cattell test not observed in the control group (Carretti et al., under review). This prompted us to hypothesize that the WM updating reading task may have somehow induced some participants to find a strategy to complete the task, consequently reducing the transfer power of the training. We unfortunately did not interview participants after the training sessions, so this remains a mere speculation.

Some limits should be considered, however. As suggested by Shipstead et al. (2010), it would have been useful to test transfer effects with multiple tasks tapping the same ability to avoid measurement-related errors. Moreover, although the size of our sample was in line with the one used in other training studies, a larger sample would have enabled us to analyze individual differences in training gains. An effort should be made in future studies to take these aspects into account.

In conclusion, this study confirmed the efficacy of WM training for normally aging older adults. To the best of our knowledge, this is the first study to identify
transfer effects relating to such activities of everyday life as language comprehension. This finding seems particularly important, pointing to the opportunity to extend the gains to other WM-related processes with direct implications for the older adult’s quality of life and functioning. Future studies should try to adopt such a procedure with older adults with mild cognitive impairment with a view to establishing its efficacy.

**Conflict of interest**

None declared.

**Key points**

- The results of the study suggest the efficacy of a verbal WM training for normally aging older adults.
- Near transfer effects were found on WM updating, maintained at the 6-month follow-up.
- The verbal WM training produced transfer effects on reasoning and language comprehension tasks, substantially maintained at the 6-month follow-up.
- WM trainings are a valuable approach to sustain cognitive functioning in older adults also for abilities related to everyday activities.

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