Age differences in proactive interference in verbal and visuospatial working memory

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Age differences in proactive interference in verbal and visuospatial working memory

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The current study examined the benefit of reducing proactive interference in verbal and visuospatial working memory tasks in young (25–30 years), young-old (65–75 years), and old-old (older than 75 years) adults. To reduce proactive interference, the verbal and visuospatial working memory tasks were administered in an ascending (the shortest lists presented first) or in descending (the longest lists presented first) format. Results showed that whereas old-old adults benefit from decreased exposure to proactive interference in working memory independently from the task content, young-old adults benefited only in the verbal task, and young adults did not show any benefit. Overall, these findings suggest that the ability to resist proactive interference in working memory tasks depends on the task content and is particularly impaired in late adulthood.

Keywords: Ageing; Proactive interference; Working memory.

There is consensus regarding functionally defining working memory (WM) as the ability to temporarily maintain information for use in ongoing mental operations (e.g., Miyake & Shah, 1999). It is also well accepted that WM capacity limitations are due to a variety of factors, including resistance to interference (see Miyake & Shah, 1999). In particular, proactive interference (PI) occurs when information that has previously been remembered or processed interferes with memory for new and task goal information. The build-up of PI usually leads to a decrease in recall and an increase in memory errors due to interference of no-longer relevant information, usually termed intrusion errors. Considering a classic WM task such as the listening span test by Daneman and Carpenter (1980), poor WM performance is associated with an increase in the number of intrusion errors (i.e., words that are no longer relevant for the task goal). These errors indicate impairment in deleting no-longer relevant interference and, therefore, a lower efficiency in inhibitory mechanisms (e.g., De Beni, Palladino, Pazzaglia, & Cornoldi, 1998; Friedman & Miyake, 2004). Different studies have observed an increase in intrusion errors, leading to poor WM performance, in verbal and visuospatial WM tasks in different categories of individuals also of different ages (verbal WM tasks: poor comprehenders, Carretti, Borella, Cornoldi, & De Beni, 2009; poor problem-solvers, Passolunghi & Pazzaglia, 2005; older adults, Borella, Carretti, & De Beni, 2008; Borella, Ghisletta, & de Ribaupierre, 2011; visuospatial WM tasks: children with nonverbal learning disabilities, Mammarella & Cornoldi, 2005; older adults, Cornoldi, Bassani, Berto, &
Susceptibility to interference is often called on to explain age-related differences between young and older adults (Hasher, Lustig, & Zacks, 2007). Researchers have demonstrated higher susceptibility to PI in older adults in different types of WM tests (e.g., Bowles & Salthouse, 2003; Emery, Hale, & Myerson, 2008; Lustig, May, & Hasher, 2001). For instance, Emery et al. (2008) presented a modified version of the classic WM operation span task (adapted from Bunting, 2006), in which the level of PI (low–medium–high) was manipulated, to young, older adults and very old adults. Their results showed that older adults were more susceptible to PI in high than low proactive interference trials. Moreover, they also found that participants older than 70 years of age showed more PI build-up than those in their 60s. More recently, Robert, Borella, Fagot, Lecerf, and de Ribaupaperre (2009) showed that older adults are more prone to PI, showing more susceptibility to intrusion in WM recall of information from past trials than children or young adults. Similarly, using a visuospatial WM task, Cornoldi et al. (2007) found that older adults produced a higher number of intrusion errors than young adults, and that this result is consistent across various manipulations of the visuospatial WM task (see also, Fiore, Borella, Mammarella, & De Beni, in press). Moreover, susceptibility to PI in WM tasks appears to be amplified in late adulthood: Old–old adults (older than 74 years) have been systematically shown to commit a larger number of intrusion errors than young–old adults (65–74 years old) (Borella, Carretti, Cornoldi, & De Beni, 2007; Borella, Carretti, & Mammarella, 2006; De Beni, Borella, & Carretti, 2007; Palladino & De Beni, 1999). Overall, this pattern of results suggests that the ability to clear no-longer relevant information from WM—resistance to PI—accounts for individual and age-related differences in WM performance.

To gain a better understanding of the role of PI in WM performance in older adults, some studies using verbal (Lustig et al., 2001; May, Hasher, & Kane, 1999) or visuospatial tasks (Rowe, Hasher, & Tourcotte, 2008, 2009) manipulated the presentation of WM tasks. In those studies, using a between-subject design, the conventional order of presentation was reversed by starting the WM task with the longest rather than shortest set sizes (i.e., the descending task version). The rationale was that if older adults are more susceptible to PI, then starting a WM task with longer sets could improve the participants’ performance, lowering the build-up of PI from earlier sets. May et al. (1999) and Lustig et al. (2001) in a group of older adults demonstrated that this manipulation reduced the effects of no-longer relevant, prior-trial information during recall of the longest set sizes. Indeed, age differences between younger and older participants in verbal WM performance were no longer significant in the descending version of the reading span task (Lustig et al., 2001; May et al., 1999). Furthermore, Lustig et al. also found that, in the descending version only, the difference in the percentage of intrusion errors committed by the two age groups was no longer significant. Similarly, Rowe and colleagues (2008; see also Rowe et al., 2009), using two visuospatial short-term tasks (the Corsi block task and a matrix task), found that the descending version improved only older adults’ performance, increasing the number of correctly recalled positions. Nonetheless, in this study, young adults outperformed older adults regardless of task presentation version.

In summary, the review of the literature seems to suggest that older adults’ WM performance is particularly sensitive to PI; in fact, procedures aimed at reducing interference generally produced an increase in older adults’ WM performance and a lower number of intrusion errors. However, such a conclusion is based on studies that have analysed the role of PI in verbal WM tasks. In fact, Rowe et al. (2008, 2009) examined this issue in a visuospatial task—the Corsi test—which cannot be considered a WM task, but rather a short-term memory one (e.g., Berch, Krikorian, & Huha, 1998; Farrand & Jones, 1996; Kessels, van Zandvoort, Postma, Kappelle, & de Haan, 2000). One of the aims of the present research was thus to determine whether PI is a contributing factor to age differences in WM independently of the task nature (i.e., not only in verbal but also in visuospatial WM tasks).

Moreover, with the exception of Emery et al.’s (2008) study—which, however, used verbal material—results on age-related differences in PI are based on older adult samples in which the mean age was around 70 (third age). Adults older than 75 (fourth age) are characterised by a more pronounced general decline compared to the third age (young–old adults) (Baltes, 1997; Baltes & Smith, 2003). Various studies have revealed the existence of a life-long decline in performance on verbal and visuospatial WM tasks (e.g., Park et al., 2002), as well as in inhibitory efficiency. Borella
et al. (2008), for instance, found that the decline in inhibitory efficiency (i.e., intrusion errors) is particularly evident from the age of 74 on. Consistent with this result, most studies showed that only old–old adults (aged older than 75 years) commit a larger number of intrusion errors compared to young–old (aged between 65 and 74 years) and young adults; in contrast, young–old have been shown to produce a nonsignificant number of intrusion errors compared to young adults (Borella et al., 2006, 2007; De Beni et al., 2007).

Therefore, a further aim of this study was to examine whether old–old adults also could benefit from manipulations designed to reduce the amount of PI in verbal and visuospatial WM tasks.

To these ends, verbal and visuospatial WM tasks (one of each) were selected and presented to young and older adults. Older participants were split in two age groups—the young–old (60–74 years old) and the old–old (over 75 years old)—to investigate the effect of PI on WM performance also in late adulthood. The WM tasks were presented in two versions: the standard classical ascending format (starting from the shortest set sizes and proceeding up to the longest ones) and an interference-reducing version (longest set sizes presented first; the descending version). Although manipulation of the presentation format presents some methodological limits (see Emery et al., 2008), we used this approach to compare the current results to those already collected in the literature. Since all the studies manipulating the presentation format adopted a between-subject design, we did the same, presenting the ascending or descending version of the verbal and visuospatial WM tasks to different groups of participants.

To define the impact of PI on WM tasks, we considered the number of correctly recalled words/positions, but also intrusion errors (representing the inability to resist proactive interference; e.g., Borella et al., 2008), which have been analysed only in Lustig et al.’s (2001) study. If PI contributes to age-related differences in WM tasks, we would expect older adults to benefit from the descending condition in the verbal and visuospatial WM tasks. In addition, if old–old adults are particularly vulnerable to no-longer relevant information, then they are expected to make a higher number of intrusion errors than young–old and young adults, which, however, should decrease in the descending versions of WM tasks.

**METHOD**

**Participants**

Participants were 40 young adults aged up to 30 years, 40 young–old adults aged 60–74, and 40 old–old adults aged 75–89 years. All were native Italian speakers and volunteered for the study. The older adults were selected based on a physical and health questionnaire. Any participant meeting the exclusion criteria proposed by Crook et al. (1986) (i.e., history of head trauma; any neurological or psychiatric illness; history of brain fever; dementia or any other state of consciousness alteration; use of benzodiazepines in the previous 3 months; use of illicit drugs; visual, auditory, or motor impairment; any symptomatic cardiovascular condition, breathing problems, or pathologies causing possible cognitive impairments) was excluded from the study. The older participants were healthy. They were recruited from the University of the Third Age in Verona and from social clubs, and were active in their neighbourhood cultural and social activities. Three participants (one young–old and two old–old) were excluded from the analysis because they failed to complete the requests of the WM tasks. In fact, to ensure that participants were not trading off between the processing and maintenance phases of the two working memory tasks, an 85% accuracy criterion on the processing phase (tapping) was required (see Conway et al., 2005).

The three groups did not differ in vocabulary score ($F < 1$). Educational level, measured in years of education, was significantly different across age groups, $F(2, 114) = 97.01, p < .001$, $\eta_p^2 = .63$; the young adults had a higher educational level than the young–old (Mdiff = 5.36, $p < .001$) or old–old adults (Mdiff = 9.11, $p < .001$). This latter group in turn had a lower educational level than the young–old adults (Mdiff = −3.74, $p < .001$).

All participants performed the verbal and visuospatial WM tasks, but half of the participants were randomly assigned to either the standard ascending or the descending version, as done in previous studies (see Lustig et al., 2001; May et al., 1999; Rowe et al., 2008, 2009). Characteristics of the sample are summarised in Table 1. There was no difference in age, years of education, or vocabulary score within age groups in the two task versions.
**Materials**

*Categorisation Working Memory Span Test (CWMS; Borella et al., 2008, adapted from De Beni et al., 1998).* This task is similar to classic WM tasks such as the listening span test (Borella et al., 2008) and can be considered for measuring WM capacity, as it has been shown to correlate strongly with classical verbal and visuospatial WM tasks (see Borella et al., 2008), with fluid intelligence (see Borella et al., 2006), and with complex cognition such as reading comprehension (see Carretti et al., 2009). The only difference is that the CWMS test involves processing lists of words rather than sentences, thus limiting the role of semantic processing.

The material consisted of a series of word lists containing five words of high–medium frequency. Word lists were organised in sets of different lengths (i.e., from two to six words to be recalled). Each set was composed of three trials. Participants were required to read aloud each word and press the space bar when an animal noun was presented (processing phase). After each set, they had to recall the last word of each list following the presentation order (maintenance phase). The material was programmed using E-Prime software (Psychology Software Tools, Inc., Pittsburgh, PA, USA) and presented on a computer screen. Each word remained visible for 1000 ms and was separated from the next word by a blank screen shown for 500 ms. The interval between each trial within the same set was 2000 ms. The end of a list was signalled by a change in screen colour. The words were not repeated across the trials. Lists contained zero, one, or two animal nouns, presented in various positions, including the final position. An example of a list is “house, mother, dog, word, night”. Two practice trials of two words each were administered before the experiment started.

Word recall was transcribed by the experimenter onto a dedicated protocol. Participants were told to remember the words in correct serial order. Nonetheless, the total number of correctly recalled words independently of the presentation order was considered the measure of the participant’s WM capacity. The maximum score was 60. The percentage of intrusions errors (i.e., nonfinal words incorrectly recalled, derived from either the same set or from previous sets) was calculated by dividing the total number of intrusions by the total number of correctly recalled words (see Borella et al., 2007; Robert et al., 2009).

*Matrix task (adapted from Cornoldi et al., 2007; Mammarella & Cornoldi, 2005).* The material consisted of a series of positions presented on $4 \times 4$ matrices; the to-be-recalled positions were organised in sets of two to six. Each set was composed of three trials of the same length. In each matrix, three positions were displayed, one at a time, and participants had to recall only the third position of each matrix (the maintenance phase). Thus, for example, nine positions were presented in the set requiring recall of three positions, 12 in the set requiring recall of four positions, and so on. All matrices consisted of black lines on a white background; each position was indicated by a black dot that appeared in the centre of the cell. Within each trial, each dot was presented for 1000 ms and separated by an empty matrix that was shown for 500 ms. Moreover, within the same set, matrices (each involving three positions) were separated by a grey screen.

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**Table 1**

<p>| Participant characteristics by age group and task version (ascending vs. descending) |</p>
<table>
<thead>
<tr>
<th>Age</th>
<th>Education</th>
<th>Vocabulary</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>M</td>
</tr>
<tr>
<td>Young Ascending</td>
<td>20</td>
<td>26.10</td>
</tr>
<tr>
<td>Young Descending</td>
<td>20</td>
<td>25.90</td>
</tr>
<tr>
<td>Young-old Ascending</td>
<td>19</td>
<td>66.47</td>
</tr>
<tr>
<td>Young-old Descending</td>
<td>20</td>
<td>66.95</td>
</tr>
<tr>
<td>Old-old Ascending</td>
<td>19</td>
<td>78.79</td>
</tr>
<tr>
<td>Old-old Descending</td>
<td>19</td>
<td>78.95</td>
</tr>
</tbody>
</table>

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1As suggested by one of the reviewers, the verbal and visuospatial WM tasks were also scored using the partial-credit unit-weighted (PCU) scoring procedure suggested by Conway et al. (2005). The PCU scores were highly correlated with the mean number of information correctly recalled (for verbal WM task, $r = .98$; for visuospatial WM task, $r = .96$). As a consequence, the results of the analyses did not change when they were run using the PCU scores in both verbal and visuospatial WM tasks.
appearing for 500 ms to indicate that a new trial would appear. In each matrix, one row and one column were shaded grey, and participants had to press the spacebar when the dot fell in a grey cell (the processing phase). Within each trial, the grey row and column remained fixed. Moreover, a random procedure was used to decide which row and column to shade grey between sets. When a set ended, participants were shown a screen with an empty matrix, and the experimenter asked them to use a mouse to indicate the third position of each presented matrix. The matrix remained on the screen until the positions were given. The start of a new set was indicated by the presentation of a new fixation point. Two practice trials in a set of to-be-recalled positions were given before the experiment started.

The total number of correctly recalled positions was considered the measure of the participant’s WM capacity (see Footnote 1). The maximum score was 60. The percentage of intrusion errors was calculated (i.e., nonfinal positions incorrectly recalled derived from the same set of matrices).

Procedure

The tasks were presented in a single session lasting approximately 1 hour. All participants took the vocabulary test; only the older adults completed the health questionnaire. Then, the WM tasks were administered. A short break was taken between each task. Verbal and visuospatial WM tasks were presented in counterbalanced order across the participants.

RESULTS\(^2\)

First, correlation analyses between the verbal and visuospatial WM tasks were run. Results indicated that the two tasks in the ascending and descending versions were strongly correlated, \(r = .68, p < .001\), and \(r = .72, p < .001\), respectively. Second, for the CWMS and the matrix tasks, univariate analyses of variance (ANOVAs) with group (young, young–old, old–old) and version (ascending, descending) as between-subject factors were run on the dependent variables of interest. Interactions were decomposed using post hoc pairwise com-

\(^2\)ANCOVA analyses with educational level as covariate on the measures used showed that this did not affect performance.

\[ \text{Correctly recalled words. The main effects of group, } F(2, 111) = 68.67, p < .001, \eta^2_p = .55, \text{ and of version, } F(1, 111) = 21.86, p < .001, \eta^2_p = .16, \text{ were significant. The young recalled a higher number of correct words than the young–old (Mdiff. = 7.36, } p < .001) \text{ and the old–old (Mdiff. = 17.84, } p < .001). \text{ Furthermore, the young–old outperformed the old–old (Mdiff. = 10.49, } p < .001). \text{ Participants in the descending version benefitted more than those in the ascending version (Mdiff. = 5.83, } p < .001). \]

The Group \times Version interaction was also significant, \( F(2, 111) = 3.96, p < .05, \eta^2_p = .07. \) Post hoc comparisons showed that the young participants in the ascending version outperformed the young–old and old–old participants (Mdiff. = 10.66, \( p < .001, \) and Mdiff. = 22.06, \( p < .001, \) respectively), and the young–old outperformed the old–old (Mdiff. = 11.89, \( p < .001). \) By contrast, in the descending version, young and young–old did not differ from each other, whereas old–old demonstrated a poorer performance than both young (Mdiff. = –13.63, \( p < .001) \) and young–old (Mdiff. = –9.08, \( p < .001; \) see Figure 1A). Furthermore, only young–old and old–old (not the young adults) in the descending version performed better than those in the ascending version (Mdiff. = 6.77, \( p < .01, \) and Mdiff. = 9.58, \( p < .001, \) respectively).

Comparisons conducted on the number of correctly recalled words for a larger set size (four, five plus six) for the two versions indicated no significant differences in the young group. In the descending version, performance was better than that of participants in the ascending version for the young–old group, \( t(37) = 2.72, p < .05 \) (ascending: \( M = 25, SD = 6.92; \) descending: \( M = 30.45, SD = 5.51), \text{ and for the old–old group, } t(36) = 5.01, p < .001 \) (ascending: \( M = 16.31, SD = 3.63; \text{ descending: } M = 22.63, SD = 4.11). \)

\[ \text{Intrusion errors. For intrusion errors, the main effects of group, } F(2, 111) = 31.65, p < .001, \eta^2_p = .36, \text{ with young and young–old participants committing fewer intrusions than old–old (Mdiff. = –0.21, } p < .001, \text{ and Mdiff. = –0.17, } p < .001, \text{ respec-} \]
tively), and of version, $F(1, 111) = 20.88$, $p < .001$, $\eta^2_p = .16$, with more intrusions in the ascending version than in the descending version ($M_{\text{diff.}} = 0.10$, $p < .001$), were significant.

In addition, the Group × Version interaction, $F(2, 111) = 9.86$, $p < .001$, $\eta^2_p = .15$, was significant. Post hoc comparisons showed that old–old participants in the ascending version made a higher number of intrusion errors than young and young–old ($M_{\text{diff.}} = 0.33$, $p < .001$, and $M_{\text{diff.}} = 0.27$, $p < .001$, respectively), who did not differ from each other; in the descending version, however, the old–old group differed from the young group ($M_{\text{diff.}} = 0.10$, $p < .05$) but not from the young–old group. Only the old–old adults in the descending version showed an advantage, with higher resistance to irrelevant information, than those in the ascending version ($M_{\text{diff.}} = -0.25$, $p < .001$; see Figure 2A).

To better understand the benefit of the descending format in reducing interference, we distinguished errors within the category of intrusion between animal words and all other words. It has been indeed demonstrated that in the CWMS the activation of animal nouns is usually higher than that of other words (see Carretti, Cornoldi, De Beni, & Palladino, 2004). A $3 \times 2 \times 2$ repeated measure ANOVA with mixed design was conducted, with group (young, young–old, old–old) and version (ascending, descending) as between-subject factors, and type of intrusion (animal words vs. nonanimal words) as the within-factor.

Results showed the main effects of group, $F(1, 111) = 28.05$, $p < .001$, $\eta^2_p = .34$, with young and young–old participants committing fewer intrusions than old–old ($M_{\text{diff.}} = -0.11$, $p < .001$, and $M_{\text{diff.}} = -0.09$, $p < .001$, respectively), and of version, $F(1, 111) = 18.96$, $p < .001$, $\eta^2_p = .15$, with more intrusions in the ascending version than in the descending version ($M_{\text{diff.}} = 0.06$, $p < .001$), were significant. The main effect of type of intrusion was not significant ($F < 1$) (Table 2).

The Group × Version interaction, $F(2, 111) = 9.43$, $p < .001$, $\eta^2_p = .15$, was significant. Post hoc comparisons showed that old–old participants in the ascending version made a higher number of intrusion errors than young and young–old

![Figure 1. Verbal (A) and visuospatial (B) working memory task: Mean number of recalled words by age group and version (ascending vs. descending) (bars correspond to standard errors).](image-url)
diff. /C30 0.17, p < .001, and Mdiff. /C30 0.14, p < .001, respectively), who did not differ from each other; in the descending version, no significant differences were found. Moreover, only the old–old adults in the descending version showed an advantage, with higher resistance to irrelevant information, than those in the ascending version (Mdiff. = −0.13, p < .001; Table 2).

The Age × Type of intrusion interaction was also significant, F(2, 111) = 11.63, p < .001, ηp2 = .17. Post hoc comparisons showed that old–old participants made a higher number of intrusion errors of animal words than young and young–old (Mdiff. = 0.16, p < .001, and Mdiff. = 0.13, p < .001, respectively); the three groups did not differ in intrusion errors for nonanimal words. Moreover, only old–old adults committed more intrusion of animal words than nonanimal words (Mdiff. = 0.06, p < .001). The Type of intrusion × Version interaction was not significant, F(2, 111) = 1.20, p = .27, ηp2 = .01. However, the Age × Type of intrusion × Version interaction was significant, F(2, 111) = 2.25, p < .04, ηp2 = .06 (Table 2). Post hoc comparison showed that the old–old committed more errors than the young and young–old for both types of intrusions in the ascending version (all comparisons, p < .001), but not in the descending version; moreover, for the old–old, animal word intrusion was higher than for nonanimal words in the ascending version (p < .001), but not in the descending version.

**TABLE 2**

<table>
<thead>
<tr>
<th>Age Group</th>
<th>Type of Intrusion (animal vs. nonanimal)</th>
<th>Version (ascending vs. descending)</th>
<th>M</th>
<th>SD</th>
<th>M</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Young</td>
<td>Nonanimal</td>
<td>Ascending</td>
<td>0.06</td>
<td>0.08</td>
<td>0.05</td>
<td>0.06</td>
</tr>
<tr>
<td></td>
<td>Animal</td>
<td>Ascending</td>
<td>0.02</td>
<td>0.03</td>
<td>0.02</td>
<td>0.03</td>
</tr>
<tr>
<td>Young–old</td>
<td>Nonanimal</td>
<td>Ascending</td>
<td>0.09</td>
<td>0.07</td>
<td>0.06</td>
<td>0.06</td>
</tr>
<tr>
<td></td>
<td>Animal</td>
<td>Ascending</td>
<td>0.06</td>
<td>0.04</td>
<td>0.04</td>
<td>0.04</td>
</tr>
<tr>
<td>Old–old</td>
<td>Nonanimal</td>
<td>Ascending</td>
<td>0.16</td>
<td>0.10</td>
<td>0.07</td>
<td>0.07</td>
</tr>
<tr>
<td></td>
<td>Animal</td>
<td>Ascending</td>
<td>0.27</td>
<td>0.21</td>
<td>0.09</td>
<td>0.06</td>
</tr>
</tbody>
</table>

Figure 2. Verbal (A) and visuospatial (B) working memory task: Proportion of intrusion errors by age group and version (ascending vs. descending) (bars correspond to standard errors).
**Matrix task**

**Correctly recalled positions.** The main effect of group was significant, $F(2, 111) = 53.15, p < .001$, $\eta^2_p = .50$, with the young group recalling more correct positions than the young–old and old–old groups ($M_{diff} = 8.00, p < .001$, and $M_{diff} = 16.12, p < .001$, respectively), which differed from each other ($M_{diff} = 8.12, p < .001$). Participants in the descending version also recalled a higher number of correct positions than those in the ascending version ($M_{diff} = 3.43$), as revealed by the significant main effect of version, $F(1, 111) = 7.20, p < .01, \eta^2_p = .06$.

The Group × Version interaction, $F(2, 111) = 3.52, p < .05, \eta^2_p = .06$ was significant (see Figure 1B). Post hoc comparisons showed that, in the ascending version, the young outperformed the young–old and old–old participants ($M_{diff} = 10.20, p < .001$, and $M_{diff} = 20.26, p < .001$, respectively). In addition, the young–old group performed better than the old–old group ($M_{diff} = 10.53, p < .001$). The same pattern of results was obtained for participants in the descending version: The young performed better than the young–old and old–old ($M_{diff} = 5.8, p < .05$, and $M_{diff} = 11.98, p < .001$, respectively), and young–old recalled a higher number of positions than old–old ($M_{diff} = 6.18, p < .05$). Further, only old–old participants in the descending version performed better than those in the ascending version ($M_{diff} = 7.40, p < .001$).

Comparisons conducted on the number of correctly recalled positions for larger set sizes (four, five plus six) in the two versions indicated that only the old–old group in the descending version outperformed the old–old group in the ascending version, $t(36) = 2.43, p < .05$ (ascending $M = 17.10$, $SD = 3.49$; descending $M = 20.63$, $SD = 5.27$).

**Intrusion errors.** For intrusion errors, the main effects of group, $F(2, 111) = 33.20, p < .001$, $\eta^2_p = .37$, and of version, $F(1, 111) = 5.24, p < .05$, $\eta^2_p = .05$, were significant. The young committed fewer intrusion errors than the young–old and old–old ($M_{diff} = −.05, p < .01$, and $M_{diff} = −.10, p < .001$, respectively), and the young–old committed fewer than the old–old ($M_{diff} = −.05, p < .001$). Independent of age group, participants in the descending version made fewer errors than participants in the ascending version ($M_{diff} = −0.02, p < .05$).

The Group × Version interaction was also significant, $F(2, 111) = 4.77, p < .05, \eta^2_p = .08$. Post hoc comparisons showed that old–old participants in the ascending version made a higher number of intrusion errors than young and young–old participants ($M_{diff} = 0.13, p < .001$, and $M_{diff} = 0.07, p < .001$, respectively), who differed from each other ($M_{diff} = −0.07, p < .01$). However, in the descending version, the old–old group differed from the young group ($M_{diff} = 0.06, p < .01$) but not from the young–old group. The only group to benefit from the version with reduced interference was the old–old group in the descending version, showing higher resistance to irrelevant information than those in the ascending version ($M_{diff} = −0.06, p < .01$) (see Figure 2B).

**DISCUSSION AND CONCLUSION**

The current study investigated the impact of an interference-reducing procedure on verbal and visuospatial WM performance in young, young–old, and old–old participants. In particular, the study had different objectives. The first was to replicate previous results on reduction of PI when a verbal WM task is presented in a descending version, and to determine whether the benefit of the task version can be extended when a visuospatial WM task is used. To compare our results to those already collected, a between-subject design was adopted and we considered not only correct recall but also intrusion errors within the WM tasks. Intrusion errors, being a measure representing inhibitory efficacy, can indeed give complementary information on the role of PI susceptibility in WM in ageing.

Another objective was to assess whether old–old adults—characterised by a more accentuated decline compared to young–old adults in several cognitive processes, including in WM and in the efficacy of inhibitory mechanisms (Borella et al., 2008)—would benefit to the same extent as young–old adults from an interference-reducing procedure. In fact, older adults are known to have difficulty suppressing irrelevant items from the past (e.g., Borella et al., 2008; Borella, Ghisletta et al., 2011; Hartman & Dusek, 1994), and often show more pronounced PI effects than young adults (Winocur & Moscovitch, 1983). Some authors (e.g., Hasher, Goldstein, & May, 2005; Hasher et al., 2007) have attributed older adults’ higher vulnerability to interference to the
The differential effect of the presentation format in reducing interference in both young and old groups (but not the young group) performing one, led to an improvement in the performance in young adults. However, extending the previous finding, we found that the descending version increased the ability to resist to no-longer relevant information. By contrast, in the case of old adults, the descending condition, decreasing the amount of interfering information, produced a benefit, with an increase in the performance in young–old participants.

As regards the verbal WM task, consistent with previous evidence, our current results showed that the descending version, compared to the ascending one, led to an improvement in the performance of older adults. However, extending the previous finding, we found that the descending set-size manipulation produced an increase in WM recall not only in the young–old participants, as shown in the literature, but also in the old–old participants. This result is confirmed by analysis on larger set size (four, five, and six) performance; in fact, it emerged that there was an advantage of the descending presentation format in reducing interference, with both the young–old and old–old groups (but not the young group) performing better than their peers in the ascending version. Nevertheless, only the performance of the young–old group (not of the old–old group) in the descending version was no longer significantly different from that of the young group. In other words, the young–old performance was positively affected by the presentation format manipulation, allowing them to reach the young adults’ level. By contrast, in the case of old–old participants, the performance in the descending version was still below that of both young and young–old adults. The differential effect of the presentation format manipulation for young–old and old–old participants can be due to the smaller basic WM capacity of the old–old with respect to the young–old group. In fact, with ageing, a linear decline in WM performance due to a reduction of cognitive resources has been reported (e.g., Borella et al., 2008; Baltes & Smith, 2003). In the descending version, old–old participants—though they still had a poor performance compared to the others two age groups—recalled a higher number of correct words and produced a lower percentage of intrusion errors than the old–old group in the ascending version. This result supports the idea that WM tasks probably involve multiple processes, one being PI (Borella, Ludwig, Dirk, & de Ribaupierre, 2011; Emery et al., 2008). By contrast, young–old adults did not show a reduction of intrusion errors in the descending version; however, it is notable that in the ascending format, young–old and young adults did not differ in intrusion errors, a result that is consistent with previous studies (Borella et al., 2006, 2007; De Beni et al., 2007). Thus, overall the results confirmed that susceptibility to interference, measured through intrusion errors, is more pronounced only in late adulthood when verbal WM tasks are considered (Borella et al., 2008).

This pattern of findings can also be interpreted referring to the distinction between interference and inhibition (see Borella, Delaloye, Lecerf, Renaud, & de Ribaupierre, 2009). Whereas interference refers to the susceptibility to distracting stimuli (leading to a decrement in performance), inhibition requires the active suppression of information. It can be hypothesised that the descending version produces a benefit in performance because of the lower amount of interfering information in comparison to the ascending version. In the case of young–old, the lowest number of disturbing information may have allowed them to focus on relevant information while ignoring irrelevant information (intrusion errors) and thus blocking the latter from entering and cluttering WM. Therefore, young–old participants benefited from a reduction of distractors, reaching a performance, in terms of correctly recalled words, comparable to that of young adults. In the case of the old–old, the descending condition, decreasing the amount of interfering information, permitted participants to better control for irrelevant information, even when this was particularly activated in memory. In other words, the descending version increased the ability to resist to interference in both young–old and old–old; in
addition, the decrease of interfering information allowed old–old to better control for no longer relevant information.

Though this interpretation is speculative, it is supported by analyses on intrusion errors in the CWMS, which have been distinguished, on the basis of their activation in memory, between intrusion errors of animal words and of other words. It has been demonstrated that in the CWMS task the request to press the spacebar when animal words appeared assigns a higher activation rate to animal nouns with respect to other words in the task (see, for example, Carretti et al., 2004; De Beni et al., 1998). To keep these items from intruding in the recall, a person should be able to actively exclude them from WM with a considerable involvement of cognitive resources. Since these operations are particularly wasteful for old–old adults, the consequence would be that these items might not be suppressed and remained in the WM workspace. In fact, the analysis on intrusion errors demonstrated that only the old–old committed more intrusion errors of animal words than nonanimal words in the ascending version; however, this was not the case in the descending presentation format. Therefore, this interference-reducing procedure produced an increase in the number of words recalled and a decrease of memory errors with regard to old–old WM performance.

In the visuospatial WM task, the advantage of the descending version was significant only for the old–old participants, who showed an improvement in performance, recalling a higher number of correct positions and making a lower percentage of intrusions compared to the old–old participants in the ascending version. Analysis of the performance for the larger set size confirmed the benefit for the old–old adults in the descending version. For the other two age groups, by contrast, no significant effects emerged, even if the inspection of Figure 1 suggests that for young–old participants there was also a tendency to improve their performance. However, the benefit obtained by the old–old participants alone might result from their performance being much lower than that of the young and young–old participants on both task versions. Moreover, despite such an increase in performance and decrease in intrusion errors for the old–old participants in the descending version, they still had a poorer WM performance and committed more intrusion errors than the other two groups. The absence of the benefit for the young–old participants in the descending presentation format could be attributed to the characteristics of the task. Since perceptual organisation influences visuospatial WM (Woodman, Vecera, & Luck, 2003), the perceptual cues are very salient, and the higher effort required in the identification process may impair young–old adults (Sharps & Gollin, 1987), even in the more advantageous version. This may prevent young–old adults from discriminating between patterns, as also shown by Cornoldi et al. (2007). Task characteristics may also account for the discrepancy in results relative to Rowe et al. (2008, 2009). In fact, Rowe et al. (2008, 2009) used the Corsi blocks task (Corsi, 1972) to test the impact of PI on age differences. The Corsi blocks task is a measure of visuospatial short-term memory (Berch et al., 1998; Farrand & Jones, 1996; Kessels et al., 2000), requiring serial recall of spatial information: Various studies have shown that complex span tasks can be dissociated from simple span tasks (i.e., serial recall tasks without additional processing demand; Cantor, Engle, & Hamilton, 1991; Conway, Cowan, Bunting, Therriault, & Minkoff, 2002; Engle, Tuholski, Laughlin, & Conway, 1999; Kail & Hall, 2001). By contrast, the matrix task used in the current study required processing and maintenance of visuospatial positions. Considering the percentages of correct responses in the Rowe et al. (2008) study and in our data, our visuospatial WM task was clearly more difficult for the young and older participants (young–old and old–old). In this task, the benefit of the descending presentation format may have become significant only in the old–old group because of their particularly poor WM performance (in fact, there is also a slight but not significant benefit observed in the young–old group). Nonetheless, in our research, as in Rowe et al. (2008, 2009), age-related differences remain significant independent of the task presentation format.

Qualitatively comparing the results obtained with the verbal and visuospatial WM tasks, which were strongly correlated, the effect of task version appears to be nonhomogeneous and dependent on the age group considered. Overall, indeed, our results suggest that only the old–old, but not the young–old, showed a benefit for the descending version independently of the task content (i.e., verbal, visuospatial) when trials with the longest series, for which PI may be the highest, are also considered.

Nonetheless, the implication on age differences was different depending on task content. In fact,
in the verbal WM descending version, only young-old performance was no longer significantly different from that of young participants. By contrast, in the old-old group, this was not the case, as their performance was still below that of the other age groups. In the visuospatial WM task, the descending procedure was not sufficient to produce the reduction of the age-related differences between young and young-old groups, in fact the young-old did not show a significant benefit; indeed, as for the verbal task, the old-old were still different from the two other groups. Therefore, in the case of young-old participants, the descending format had the effect of causing age differences to vanish in the verbal WM task, but little/null effect in the visuospatial domain. The clear nonbenefit in terms of age-related differences for the visuospatial WM task (in contrast to the verbal task) between the young and young-old adults can be due to the fact that older adults are more impaired on visuospatial WM tasks than on verbal tasks. Older adults have been shown to be more impaired in tasks requiring temporary storage and active manipulation of visuospatial as opposed to verbal information (e.g., Myerson, Emery, White, & Hale, 2003; Vecchi & Cornoldi, 1999). Therefore, the visuospatial task may require more attentional processes independently of the version used, compared to the verbal one. Furthermore, the maintenance of verbal abilities (crystallised intelligence) in young-old, but not in old-old adults, may have also allowed the young-old to compensate for any age-related decline in the verbal task (see Baltes, 1997), thus enhancing their performance in the descending version.

Concerning the effect of version manipulation on old-old performance, the beneficial effect of format manipulation was not so strong as to reduce age differences in comparison either to young or to young-old participants. This result may indicate that procedures to reduce PI are partially advantageous for increasing old-old adults’ WM performance.

In contrast to older adults, and in line with the literature (Lustig et al., 2001; May et al., 1998; Rowe et al., 2008), the young adults’ performance was not sensitive to the format manipulation, independent of the WM task content (verbal or visuospatial) (Lustig et al., 2001; May et al., 1998; Rowe et al., 2008).

The current results are limited by the use of a single verbal and visuospatial WM task to determine the role of PI according to task version presented. To give a clearer picture of the role of PI in WM performance with aging, future studies should address this issue, using more indicators of WM and a within-subject design (administration of the two task versions to the same participants). Furthermore, determining to what extent WM performance on the ascending and descending versions is related to external measures of proactive interference (i.e., Brown-Peterson task) should be examined in further studies.

To conclude, our current results confirmed that PI can play a role in explaining part of the variation due to age in WM task performance (Hasher et al., 2007). Therefore, variations in ability to maintain the focus of attention on goal-relevant stimuli—also avoiding intrusion errors—can determine age differences in WM, but not over and above age-related differences in WM capacity. This finding is in line with other studies showing that resistance to PI accounted for a limited part of the variance in WM compared to age (see Borella et al., 2008). However, and in line with Emery et al.’s (2008) findings, our results demonstrate that, although the WM performance of young-old and old-old adults can benefit from procedures designed to reduce the level of PI, age-related differences remain significant. Therefore, a crucial question concerning the manipulation of the WM task version, in view of the PI, is whether it is useful in increasing WM performance per se or in attenuating age-related differences. The task format (descending version) clearly produces a higher WM performance in older adults and is particularly advantageous for old-old adults. However, in terms of age-related differences, the task version is useful in annulling age-related differences only for young-old in the verbal task. Another interesting point is indeed that procedures for limiting PI cannot be fully compared through the use of verbal and visuospatial WM tasks; the beneficial effect, in fact, is more evident in the former. In conclusion, our results suggest that resistance to PI differently accounts for age effects in verbal and visuospatial WM task performance.
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