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Implementation Intentions Improve Prospective Memory and Inhibition Performances in Older Adults: The Role of Visualization

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ABSTRACT

Implementation intentions have been shown to be a very effective strategy in improving prospective memory in older adults. However, their efficacy in improving inhibition has never been assessed in aging. We thus examined the efficacy of implementation intentions in a prospective memory task and an inhibition task in 87 older participants. Following a crossover design, half of the participants were instructed to form an implementation intention in the prospective memory task, the other half in the inhibition task. The moderating role of working memory, visualization and verbalization habits, and impulsivity were also assessed. Regression analyses revealed that for both tasks, participants benefited from implementation intentions but only if they were used to using visual strategies in daily life. The efficacy of implementation intentions was not moderated by working memory, impulsivity, or the use of verbal strategies in everyday life.

Remembering to transmit a message to someone at the appropriate occasion, to take a new medication, or to stop eating a favorite snack because the physician recommends it—such goals can represent a challenge for everyone, especially with increasing age, as processing resources weaken. Implementation intentions (Gollwitzer, 1993, 1999) are defined as a self-regulatory planning strategy, one that has been shown to be very effective in improving goal-directed behaviors (Gollwitzer & Sheeran, 2006). Formulating implementation intentions implies specifying when, where, and how one will perform a specific action in as much detail as possible. The plan has to be formulated in the form of an if-then contingency using the structure, 'if situation *x* arises, then I will perform behavior y ', for example, 'if I have brushed my teeth, then I will take my medication'.

Prospective memory and implementation intentions in older adults

Prospective memory can be defined as the ability to remember to perform an intended action at the appropriate time (time-based prospective memory) or occasion (event-based prospective memory).

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Prospective memory constitutes an important function in aging, as it contributes to instrumental activities of daily living (remembering to pay bills, buy bread, and switch off the oven), health needs (remembering to take one's medication), and social relations (remembering to call a friend back or to send a birthday card; McDaniel, Einstein, & Rendell, 2008).

Recent meta-analyses have shown that older adults perform worse than younger adults in event-based (Uttl, 2008, 2011) and in time-based laboratory prospective memory tasks (Henry, MacLeod, Phillips, & Crawford, 2004). In a questionnaire study (Smith, Della Sala, Logie, & Maylor, 2000), older individuals reported more frequent difficulties in remembering tasks to be performed in the near future than in remembering past events. Importantly, prospective memory errors were rated as significantly more disruptive in everyday life than retrospective failures. Indeed, prospective memory difficulties are associated with a decline in the performance of instrumental activities of daily living in aging (Woods, Weinborn, Velnoweth, Rooney, & Bucks, 2011).

Recently, several studies have examined the efficacy of implementation intentions in improving prospective memory in older participants. Most of these studies assessed the efficacy in event-based and time-based prospective memory laboratory tasks (Chasteen, Park, & Schwarz, 2001; McFarland & Glisky, 2011b; Schnitzspahn & Kliegel, 2009; Zimmermann & Meier, 2009), although Liu and Park (2004) and Brom et al. (2014) used more ecological tasks, which consisted of remembering to monitor one's glucose four times a day for 3 weeks and to monitor one's blood pressure three times a day for 5 days. In these studies, implementation intentions were more effective than standard instructions, in particular for the young-old participants (aged about 60-75 or 80 years). Depending on the study, forming implementation intentions improved participants' performance by factors of between 1.2 and 2.6 in comparison with the control group or reduced the number of forgotten tasks by a factor 5.

Implementation intentions seem to be a generally effective strategy in improving prospective memory in older adults. However, one limitation of the studies described earlier lies in the representativeness of the included populations. At least two of these studies recruited participants from senior education programs of universities or recreation centers for senior citizens (Schnitzspahn & Kliegel, 2009; Zimmermann & Meier, 2009). These participants may present a higher cognitive functioning level than that in the general population. In order to ensure a broader vision of aging, the studies should also include participants who do not participate in special programs and/or who present subjective memory complaints despite globally preserved cognitive functioning.

Implementation intentions and inhibition

No study has yet examined the efficacy of implementation intentions for inhibition performance in older adults. Inhibition, the ability to suppress responses that are no longer required or are inappropriate (Verbruggen & Logan, 2009), is essential in the performance of goal-directed behaviors. Concurrent, easier, or habitual behaviors have to be inhibited, distractors must be ignored, and second thoughts must be overcome at the critical implementation moment, for example, if the goal includes long-term benefits but short-term costs (Gollwitzer & Sheeran, 2008). Inhibition deficits are related to dysfunctional, impulsive behaviors, to problems with completing activities of daily living, and to inadequate social interactions. Examining the efficacy of

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implementation intentions for inhibition performance in older adults is particularly relevant because lower inhibition abilities have been observed in older adults than in younger adults (e.g., Bedard et al., 2002; Belleville, Rouleau, & Van der Linden, 2006; Fournet, Mosca, & Moreaud, 2007; Potter & Grealy, 2008).

Although the efficacy of implementation intentions in inhibition performance has not been assessed in older adults, implementation intentions have been shown to be effective in improving inhibition performance in a sample of young adults on a task that generates conflicts between spatial localization of stimuli and spatial localization of answer keys (Simon task, A. L. Cohen, Bayer, Jaudas, & Gollwitzer, 2008). In another study, implementation intentions also helped adults who had first undergone a self-regulation task to improve their performance on the subsequent Stroop task (Webb & Sheeran, 2003). Several experiments support the efficacy of implementation intentions in attenuating or compensating for inhibition deficits in children diagnosed with attention deficit hyperactivity disorder in an adaptation of a stop-signal task (Gawrilow & Gollwitzer, 2008; Paul et al., 2007). In young adults, several studies have also shown the efficacy of the technique in real-world behaviors that rely, in all probability, on inhibition, such as dieting (Adriaanse, Vinkers, De Ridder, Hox, & De Wit, 2011), stopping smoking (van Osch, Lechner, Reubsaet, & De Vries, 2010), and diminishing alcohol intake (Armitage, 2009; Murgraff, White, & Philips, 1996).

Moderators of implementation intentions: urgency and visualization habits?

In the general population, some moderators have been shown to limit the applicability of implementation intentions. Thus, Churchill and Jessop (2010, 2011) demonstrated in two studies investigating dieting behaviors that impulsive persons did not benefit from implementation intentions. More precisely, these individuals were high in urgency, that is, with a high tendency to commit rash or regrettable actions as a result of intense negative affect (Whiteside & Lynam, 2001). Interestingly, urgency is positively related to difficulties in inhibiting prepotent responses (Gay, Rochat, Billieux, d'Acremont, & Van der Linden, 2008). Because implementation intentions had been effective in several populations known for their difficulties in self-regulation (e.g., in individuals diagnosed with schizophrenia; or in opiate addicts under withdrawal, Brandstatter, Lengfelder, & Gollwitzer, 2001; or in individuals with cerebral lesions, Lengfelder & Gollwitzer, 2001), these results were unexpected. According to Churchill and Jessop (Churchill & Jessop, 2011), the results could be related to the fact that urgency is not defined as difficulty in regulating behavior in general but as difficulty in regulating behavior *in the context of negative emotion.* Indeed, a study of Burkard, Rochat and Van der Linden (2013) showed that implementation intentions were efficient in individuals with high urgency, as long as they were not emotionally aroused. An alternative hypothesis is that urgency interacts with task difficulty. In this case, implementation intentions would be effective if the task is considered difficult and urgency is low or if an easy task must be achieved by participants with high urgency (who may perceive an easy task as more difficult or too difficult). Implementation intentions would thus not be effective for impulsive people confronted with difficult tasks. However, the potential moderating role of urgency in the efficacy of implementation intentions has not yet been assessed in older adults.

According to A. L. Cohen and Gollwitzer (2008), implementation intentions do not typically involve

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an explicit imagery component: 'Use of imagery techniques [...] is optional, and it may be a good technique for some people (those high in imagery) and for some "if" and "then" components that are easy to imagine' (p. 379). Several studies did, however, include visual components in the implementation intentions, consisting of visualizing oneself in the situation while performing the intended action (e.g., Chasteen et al., 2001; Liu & Park, 2004; McDaniel, Howard, & Butler, 2008; McFarland & Glisky, 2011a; Schnitzspahn & Kliegel, 2009). Despite A. L. Cohen and Gollwitzer's commentary underlining a possible interaction with visual habits, the interaction between the efficacy of implementation intentions with visual components and imagery habits has never been assessed.

In addition, some studies show that adding a visual component to verbal implementation intentions improves performance (Knauper et al., 2011; Knauper, Roseman, Johnson & Krantz, 2009), whereas other studies show no improvement (McFarland & Glisky, 2011a). These inconsistent findings could result from interindividual differences in imagery abilities, a further argument for considering imagery use as a possible moderator of implementation intentions. Depending on their degree of imagery use, the participants in these studies may or may not have benefited from the addition of a visual component to the implementation intentions. Following the definition of Gollwitzer (1993), a key element of implementation intentions is the creation of a cue-action link. In this sense, imagery encoding conditions that associate the cue and the to-be-performed action (e.g., Brewer, Knight, Meeks, & Marsh, 2011; Potvin, Rouleau, Sénéchal, & Giguère, 2011) are comparable with visual implementation intentions. Other mental imagery conditions, such as imagining the positive effect of the outcome of the task (e.g., the guided imagery condition in Andersson & Moss, 2011), may also be effective but probably rely on mechanisms other than implementation intentions (e.g., motivational processes).

Automaticity of implementation intentions

Different arguments support the view that the efficacy of implementation intentions depends in large part on reflexive-automatic, nonvoluntary, uncontrolled cognitive processes. In particular, the effect of implementation intentions is not diminished by the presence of an interfering cognitive load, and ongoing secondary tasks are performed as well or even better by individuals who use implementation intentions than by those who do not (e.g., Brandstatter et al., 2001; Brewer, Hunter Ball, Knight, Dewitt, & Marsh, 2011). Another argument is that executive abilities or working memory do not moderate the efficacy of implementation intentions. However, data differ across studies regarding this question, as some studies found a more important benefit of implementation intentions in individuals with low executive functioning (Allan, Sniehotta, & Johnston, 2013; Brom et al., 2014; Lengfelder & Gollwitzer, 2001), whereas other studies found a more important benefit in individuals with high executive functioning (Burkard, Rochat, Juillerat Van der Linden, Gold, & Van der Linden, 2014; Hall, Zehr, Paulitzki, & Rhodes, in press), and still, others found no difference in benefit with either type of functioning (McFarland & Glisky, 2011b).

The current study

In the current study, we aimed to extend previous results regarding the efficacy of implementation intentions in prospective memory and to assess the efficacy of these intentions in an inhibition task

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in an older population. Because there is no consensus about the most effective form of implementation intentions (e.g., verbal vs. visual) and because most studies in aging used verbal-visual implementation intentions (Brom et al., 2014; Chasteen et al., 2001; Liu & Park, 2004; Schnitzspahn & Kliegel, 2009), participants in the experimental condition of our study used a combination of verbal and visual implementation intentions.

Open questions remain regarding the influence of some moderators on the efficacy of implementation intentions. Indeed, impulsivity (which is related to poorer inhibition performance, Gay et al., 2008) limited the applicability of the strategy (Churchill & Jessop, 2010; 2011), whereas the role of executive functioning and working memory is not clear. In addition, no study has investigated the potential moderating role of verbalization and visualization habits in everyday life for the efficacy of combined verbal and visual implementation intentions. Consequently, these questions were addressed in the current study.

In the present study, we were interested in recruiting older adults with a wide range of cognitive scores. Indeed, one aim was to assess the efficacy of implementation intentions in individuals with a variety of performances in the outcome measures, prospective memory, and inhibition. In addition, in order to test whether the effect of implementation intentions depended on working memory abilities, some variability in the performances was needed. For these reasons, we chose to include in our sample participants of the community and individuals who consulted a memory clinic but did not receive a diagnosis of dementia.

METHOD

PARTICIPANTS

We recruited 87 older individuals living in the region of Geneva, Switzerland, for our study. Inclusion criteria were age older than 60 years, mini mental state examination (MMSE; Folstein, Folstein, & McHugh, 1975) >20, Dementia Rating Scale (DRS; Mattis, 1973) >120, and good mastery of the French language. Exclusion criteria were institutionalization (living in a nursing home) and a history of neurological conditions (e.g., traumatic brain injury and stroke) or decompensated psychiatric problems (acute major depression, anxiety disorder or psychosis, etc.). Participants all had normal or corrected-to-normal vision and hearing. Note that the cognitive inclusion criteria (MMSE and DRS scores) were introduced because of the stop-signal inhibition task, which has fixed parameters regarding reaction times. Indeed, a pretest had revealed that the performance of the stop-signal task was problematic for individuals scoring less than the given MMSE and DRS limits.

Participants were recruited via contacts of the experimenter and their friends, relatives, or neighbors or were former participants of a memory group. In order to include participants with a larger range of cognitive scores, we also recruited individuals who consulted in a memory clinic. A complete neuropsychological, neurological, and psychiatric evaluation showed that no participant of the memory clinic fulfilled the criteria for dementia. Two participants had to be excluded because of data collection problems during the stop-signal inhibition task. The final sample comprised 85 participants, 67 from the community and 18 from the memory clinic. All participants gave their written consent to participate in the study, and the study was approved by the local ethics committee.

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DESIGN

Participants were randomly allocated to one of two groups: stop-signal implementation intentions or prospective memory implementation intentions. The participants of the *stop-signal implementation intentions group* were guided in the formation of an implementation intention for the stop-signal inhibition task but received standard (control) instructions for the prospective memory task. In contrast, the participants of the *prospective memory implementation intentions group* were guided in the formation of an implementation intention for the prospective memory task but received standard instructions for the stop-signal task. Thus, each participant formed part of the experimental group for one task and part of the control group for the other task.

MEASURES

Prospective memory task

The first experimental task aimed to assess event-based prospective memory and was an adaptation of the *day-of- the-week task* from Chasteen et al. (2001). Each participant was asked to write the day of the week on the top right corner of each sheet of paper that he or she received. Because writing the day of the week was not a focal part of the experiment (i.e., the cue of the prospective memory task does not have to be processed for the ongoing tasks, Chasteen et al., 2001; McDaniel, Einstein, et al., 2008), controlled processes are required for the performance of this prospective memory task (McDaniel & Einstein, 2000). The standard instruction was formulated as follows: 'From now on, I would like you to write the day of the week on each sheet of paper you receive during this session. So, on each sheet I give you, whether it is a questionnaire, a test, etc., you will write the day of the week, namely *[the experimenter completes with the correct day],* on the top right corner. I ask you to remember this task; I will not remind you to do it. Do you have any questions?' In total, seven occasions on which to write the day of the week were presented during the testing session (see the procedure on the succeeding texts for the specific items).

After giving the prospective memory task instructions, a word span task (Majerus, 2012) was presented to the participants. Before the first item of the prospective memory task, participants had to complete 5 min of this filler task, which consisted of repeating sequences of monosyllabic or three-syllabic words. The length of the sequences increased as long as at least two of four answers were correct.

At the end of the prospective memory task, all participants were invited to complete a short postprospective memory questionnaire, assessing the task difficulty, effort, and motivation to do their best before and during the task on a 7-point Likert scale. In addition, participants of the control group were asked whether they spontaneously used a (visual or verbal) strategy.

Experimental manipulation

Implementation intentions group were read the following text after the standard instructions: 'I would like you to close your eyes and to imagine, to visualize that I hold out a sheet of paper to you. Can you imagine this? Try now to imagine yourself writing *[correct day]* on the sheet of paper, okay? Try even to imagine the sheet of paper with *[correct day]* written on it on the top right corner, with your own handwriting. You can now open your eyes and read this sentence aloud'. The experimenter held out a card to the participant, with the sentence, 'if I receive a sheet of paper, then I write

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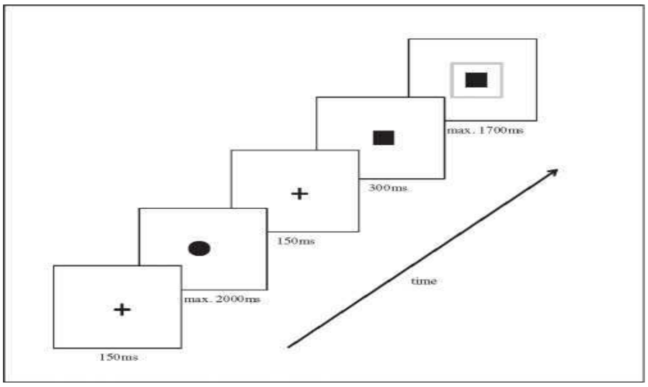
"[correct day]" on the top right corner'.

Inhibition task

The second experimental task was a computerized inhibition task based on a *stop-signal* paradigm. In the first part of the task, participants learned to categorize geometric forms (a square and a circle) that appeared sequentially in the middle of the computer screen by pressing two keys of an answer device (SR-Box) with both index fingers. This automation phase constituted 60 trials. The stop-signal phase then started. Participants had to categorize the stimuli in the same way (go trials) but were told to withhold their response if a red frame appeared around the geometric form (stop trials). After 16 familiarization trials, the test phase started, consisting of two blocks of 96 trials, with 25% stop signals.

Every block had the same proportion of squares and circles. During the entire task, each stimulus was preceded by a fixation cross in the middle of the screen for 150 ms. The geometric form then appeared until a response was given, for a maximum of 2000 ms. The stop signal appeared 200, 250, 300, or 350 ms after the stimulus (refer to Figure 1 for an example). Standard instructions appeared on a white screen at the beginning of each phase. They were read aloud by the experimenter, and the comprehension of the participant was verified.

Figure 1*. Example of two stop-signal trials: one go trial and one stop trial with a stop-signal delay of 300 ms. The gray frame around the square in the last screen of the figure appears red in the task*



To avoid any unwanted sequence effects, we created two tasks with stimuli presented in a different order. To ensure the absence of lateralization effects, we counterbalanced the answer keys between participants. This task allowed us to compute a measure of the latency of the stop process, the stop-signal reaction time (SSRT), an index that integrates go reaction times and inhibition errors (Logan & Cowan, 1984). The idea of this index is that the latency of the stop process can be estimated from the start and the end of the stop process. The stop process starts at the occurrence of the stop signal (which is experimentally controlled and therefore easily identified). Its end has to be inferred from the reaction time distribution in the observed go trials. If responses are not stopped in *n*% of the stop trials, the end of the stop process is on average equal to the *n*th percentile of the reaction time distribution in go trials. The stop-signal interval is subtracted from the *n*th reaction time to estimate the SSRT. SSRTs are calculated for each interval and then averaged. A longer SSRT represents lower inhibition performances (Logan, 1994).

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As for the prospective memory task, at the end of the inhibition task, all participants completed a short poststop-signal questionnaire, assessing the task difficulty, effort, and motivation to do their best before and during the task on a 7-point Likert scale. The participants of the control group were asked whether they spontaneously used a (visual or verbal) strategy.

Experimental manipulation

The participants of the stop-signal implementation intentions group were guided in the formation of visual and verbal implementation intentions before the beginning of each test block. They were read the following instructions: 'Before you start, I would like you to close your eyes. Try to imagine, to visualize yourself doing the task, categorizing squares and circles. Can you imagine this situation? Imagine now that, as before, you see one of the two forms appearing on the screen, followed by the red frame, okay? Try now to imagine that you withhold your response. Can you imagine it? You can now open your eyes and read this sentence aloud'. The experimenter then held out a card to the participant, with the sentence, 'if the red frame appears, then I withhold my response'.

The verbalization and imagery habits questionnaire

In order to assess the verbalization and visualization habits in everyday life, participants completed the verbalization and imagery habits (VerIm) questionnaire. This questionnaire was inspired by Paivio's questionnaire on imagery and verbal habits and skills (Paivio & Harshman, 1983), which was not used, because it allows only bimodal answers (true/false) and because of its length (>80 items, including verbal and visual habits, and difficulties in learning languages, vividness of dreams, etc.). The VerIm questionnaire is composed of eight items, with four items related to verbal strategies and four to visual strategies (Appendix).

The UPPS-P Impulsivity Scale

To assess impulsivity, we used the short UPPS-P Impulsive Behavior Scale (Billieux et al., 2012). This questionnaire measures five impulsivity components: negative and positive urgency (i.e., the tendency to react impulsively in contexts of negative, respectively, positive, emotions), lack of perseverance, lack of premeditation, and sensation seeking in 20 items on a 4-point Likert scale.

Letter-number sequencing

The letter-number sequencing (LNS, Wechsler Adult Intelligence Scale-III, Wechsler, 2000) task was used to assess working memory. The task consists of reorganizing progressively increasing sequences of numbers and letters read by the experimenter by enumerating first the numbers in increasing order and then the letters in alphabetical order. This task was shown to be a good predictor of fluid intelligence (Shelton, Elliott, Hill, Calamia, & Gouvier, 2009).

Control measures

We administered, as measures of general cognitive functioning, two commonly used scales in older adults, the MMSE (Folstein et al., 1975) and the DRS (Mattis, 1973). We also collected general demographic information about the participants (date of birth, gender, education, and medical history).

As several sheets of paper had to be distributed to write the day on them (prospective memory task), two further questionnaires were administered as items for the prospective memory task. The

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administration of these questionnaires assessing apathy and goal-directed behaviors in everyday life allowed collecting validation data the results of which will be described in another study.

PROCEDURE

Participants were tested individually and were told that they would perform a computerized task, complete some cognitive tests, and answer several questionnaires. For all participants, the tasks were given in the same order (Figure 2), counterbalancing the instruction order (half of the participants did the first experimental task with standard instructions whereas the other half did it with implementation intentions). In order to check that the participants did not spontaneously transfer the use of implementation intentions from the prospective memory task to the stop-signal task, a question addressed this issue in the poststop-signal questionnaire.

Figure 2. *Order of tasks. The items of the prospective memory task are marked with an asterisk (*). MMSE, mini mental state examination*

- Informed consent
- Letter-Number Sequencing
- VerIm Questionnaire
- *Prospective memory task instructions*
- Word span
- UPPS-P scale*
- Sentence writing (item from MMSE)*
- *Stop signal task* + post-stop signal questionnaire*
- Two questionnaires**
- Copy of two pentagons (item from MMSE)*
- Demographic questionnaire*
- (End of prospective memory task)
- Post-prospective memory questionnaire
- Mini Mental State Examination
- Dementia Rating Scale

STATISTICAL ANALYSES

For all statistical analyses, α was set at .05. After establishing the equivalency of both groups (stop-signal implementation intentions *vs*. prospective memory implementation intentions), we performed multiple regression analyses on the two dependent variables: inhibition performance (SSRT) and prospective memory performance. The regression analyses allowed controlling for age while introducing the main and interaction effects in which we were interested. We controlled for

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age because it correlated significantly with prospective memory (p = -.29, p =.007) and with SSRT (p = .40, p < .001). The condition was coded as a dummy variable (0 = control/standard instructions group, 1 = experimental/implementation intentions group). All continuous independent variables entered in the regressions were previously centered. Interaction terms were calculated with the centered variables to reduce potential multicollinearity (J. Cohen, Cohen, West, & Aiken, 2003).

RESULTS

PRELIMINARY ANALYSES: VERBALIZATION AND IMAGERY HABITS QUESTIONNAIRE FACTORIAL STRUCTURE

Because the VerIm questionnaire was created for the purpose of this study, we verified its internal structure and consistency. The factor analysis with varimax rotation confirms the expected bifactorial solution and explains 44% of the variance. The maximum loading of each item was found on the predicted factor, and the maximum loading of each item was >0.48 for verbalization and >0.66 for visualization. Cronbach's α for visualization was .83 and for verbalization was .63. Verbal and visual strategies did not correlate with one another (r=.14, p = .18).

SAMPLE CHARACTERISTICS

Table 1 shows the correlations between the variables and the reliability of the measures. As can be seen in Table 2, recruiting participants in the community and in a memory clinic allowed us to obtain a sample with more important variability in performances. Table 3 presents characteristics of both experimental groups. We conducted *t*-tests to identify any differences between the stop-signal implementation intentions group and the prospective memory implementation intentions group. The analyses revealed no significant differences between groups for age, years of education, cognitive functioning (MMSE, DRS, and LNS), impulsivity (UPPS-P), and verbalization and visualization habits in everyday life (VerIm).

EFFICACY OF IMPLEMENTATION INTENTIONS IN THE DAY-OF-THE-WEEK PROSPECTIVE MEMORY TASK

Because the responses on the prospective memory task followed a bimodal distribution, the dependent variable was dummy coded. If the day of the week was written on each page, the performance was scored 1; if this was not the case, the performance was scored 0. No participant of the prospective memory control group reported using a strategy close to implementation intentions to perform the task, nor did a participant of the prospective memory experimental group report difficulties in forming the implementation intention. Only 13% of the control group succeeded in the prospective memory task, whereas in the experimental group, 43% did so.

To control for age and to be able to introduce different interaction terms, we conducted a logistic regression on prospective memory performance. We examined the specific contribution of the condition (experimental vs. control), working memory, urgency, and verbalization and visualization habits (and their interactions with condition), while controlling for age. A significant model emerged ($\chi^2(1)$ = 34.975, p< .001, Hosmer & Lemeshow R^2=.35, Cox & Snell R^2 = .34, Nagelkerke R^2 = .49), with main effects for condition and age, and a significant interaction between condition and visualization habits (Table 4). No other main or interaction effect was significant. Figure 3 (on the basis of a

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procedure from Aiken & West, 1991; illustration based on Dawson, 2011) depicts the interaction effect between conditions and visualization habits. Whereas the performance of participants with low visualization habits did not differ between the experimental condition and control condition, implementation intentions were more effective than standard instructions in participants with high visual habits.

Interestingly, the examination of the distributions of correct prospective memory responses in the control and the experimental groups suggested that the efficacy of implementation intentions consisted essentially of the transition from six to seven correct responses. More precisely, whereas in the control group, many participants completed the task six times (and very few seven times), in the experimental group, the opposite pattern was observed (very few participants had six correct responses but many had seven correct responses).[1]

EFFICACY OF IMPLEMENTATION INTENTIONS IN THE STOP-SIGNAL PERFORMANCE

Table 5 presents the descriptive statistics of performance in the stop-signal task by condition. The *t*-tests revealed no significant difference between groups in reaction times during the automation phase ($t = 0.00$, $p > .99$) or during the task ($t = —1.62$, $p = .11$). In addition, the percentage of correct categorization responses was high (98%), whereas nonresponses to go trials were rare (0.2%).

We used the same procedure as for the analysis of the prospective memory performance, except that a linear regression was performed. In order to control for general processing speed and age and to introduce different interaction components, we conducted a multiple regression analysis to assess the efficacy of implementation intentions for inhibition performance. The dependent variable was the SSRT (a lower score indicating better inhibition performance). We examined the effect of condition, working memory, urgency, verbalization and visualization habits, and their interactions with condition while controlling for response speed (Go RT) and age.

A significant model emerged: $F(13, 71) = 3.545$, $p < .01$, $R^2 = .394$, adjusted $R^2 = .283$. Table 6 provides information about unstandardized and standardized regression coefficients. Main effects for Go RT and condition were significant, as was the interaction effect visualization x condition. Age, verbalization, visualization, (positive or negative) urgency, and the other interaction effects were not significant. Analysis of the residuals suggested that they were normally distributed. No sign of multicollinearity was evident.

Figure 4 (realized with the material of Dawson, 2011) illustrates the interaction effect between visualization and condition on the SSRT (the lines are those calculated by the regression analysis and are plotted between —1 and +1 *SD* of the visualization scores). As for prospective memory, the stop-signal performance of participants with low visualization habits did not differ between the experimental condition and the control condition. Nonetheless, implementation intentions were more effective than standard instructions in participants with high imagery habits.[2] As the poststop-

[1] *A logistic regression, testing whether the effect of implementation intentions depended on age (we entered age, condition, and their interaction as predictors), revealed no significant interaction effect (p > .10).*

[2] *A linear regression with age, condition, and age x condition as predictors showed no significant interaction effect.*

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signal questionnaire revealed that one participant of the stop-signal control group had visualized himself executing the task (visual implementation intention) and one participant of the stop-signal implementation intention group said that he was not able to visualize the implementation intention, we reran the analysis without these two participants. The same significant main and interaction effects emerged.

***Table 1**. Pearson's correlations and reliability measures*

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	Reliability
1. Age	1											—
2. MMSE	−.383***	1										—
3. DRS	−.501***	.575***	1									—
4. Letter-number sequences	−.364**	.467***	.462***	1								.62[a]
5. Verbalization	−.122	.218*	.155	.192	1							.63[b]
6. Visualization	−.347**	.225*	.424***	.194	.194	1						.83[b]
7. Negative urgency	−.087	.195	.056	.145	.024	−.021	1					.75[b]
8. Positive urgency	−.187	.244*	.126	.079	.197	.023	.500***	1				.78[b]
9. Lack of premeditation	−.017	.094	.000	.014	−.030	.006	.504***	.430***	1			.77[b]
10. Lack of perseverance	.105	.210	.069	.114	.099	−.087	.248*	.182	.394***	1		.80[b]
11. Sensation seeking	−.111	.258*	−.080	.039	.107	.035	.345**	.568***	.384***	.141	1	.82[b]
12. Stop-signal reaction time												
Control group	.396*	−.133	−.110	−.134	.148	−.104	−.200	.020	−.028	.192	−.021	.34[a]
Experimental group	.380*	−.349*	−.282	−.364*	−.220	−.376*	.026	.061	−.005	−.087	−.008	
13. Prospective memory score												.93[bc]
Control group	−.061	.167	.147	.113	.130	−.011	−.159	−.270	−.114	.063	−.213	
Experimental group	−.501**	.329*	.293	.029	.209	.339*	.234	.219	.025	.040	.173	

Note: The table presents Pearson's correlations among the variables.
MMSE, mini mental state examination; DRS, Dementia Rating Scale.
[a]Split-half (odd-even) correlation and Spearman-Brown prophecy formula.
[b]Cronbach's alpha.
[c]Calculated on total correct items [0;7].
* $p < .05$; **$p < .01$; ***$p < .001$.

***Table 2**. Characteristics of community and memory clinic participants*

	Community	Memory clinic	*t*-test
Age	69.9 (7.4)	73.6 (6.5)	-1.96
Education	13.5 (3.7)	13.3 (3.5)	0.21
MMSE	28.0 (1.5)	25.8 (2.4)	3.61[a]**
DRS	137.9 (4.7)	132.8 (5.4)	3.93***
Letter-number sequences	9.8 (1.9)	8.3 (1.9)	2.97**
Verbalization	10.4 (2.5)	8.9 (2.2)	2.23*
Visualization	11.1 (3.3)	9.1 (2.6)	2.45*
Negative urgency	9.2 (2.5)	9.2 (3.2)	-0.04
Positive urgency	10.8 (2.7)	10.1 (3.3)	0.95
Lack of premeditation	7.8 (2.4)	7.9 (2.4)	-0.22
Lack of perseverance	6.5 (2.2)	6.6 (2.2)	-0.19
Sensation seeking	9.4 (2.6)	8.4 (3.1)	1.44

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Stop-signal task			
SSRT	229.1 (40.0)	229.8 (55.6)	-0.06
Go RT	568.9 (87.7)	604.8 (103.4)	-1.48
Inhibition errors	18.3 (8.7)	15.4 (7.9)	1.29
Prospective memory task			
PM total [0;7]	4.4 (2.7)	3.4 (3.2)	1.17[a]
PM score	0.28 (0.5)	0.24 (0.4)	0.36

Note; The table displays means and standard deviations in parentheses. MMSE, mini mental state examination; DRS, Dementia Rating Scale.
[a]Taking into account the inequality of variances.
*$p < .05$;
**$p < .01$;
***$p < .001$.

DISCUSSION

Our objective in the current study was to assess the efficacy of implementation intentions in older adults in two important cognitive functions in the performance of goal-directed behavior, prospective memory, and inhibition.

Table 4. Logistic regression analysis on the day-of-the-week prospective memory task

		95% CI for odds ratio		
Variables entered	B *(SE)*	Lower	OR	Upper
Constant	-2.48 (0.62)**		0.08	
Age	-0.15 (0.06)**	0.77	0.86	0.96
LNS	0.04 (0.27)	0.61	1.04	1.76
Condition	2.26 (0.75)**	2.22	9.57	41.33
Verbalization	0.22 (0.26)	0.75	1.25	2.08
Visualization	-0.16 (0.18)	0.60	0.86	1.22
Negative urgency	0.04 (0.22)	0.67	1.04	1.61
Positive urgency	-0.46 (0.25)	0.39	0.64	1.04
Condition x verbalization	0.01 (0.31)	0.55	1.01	1.87
Condition x visualization	0.52 (0.25)*	1.02	1.68	2.74
Condition x LNS	-0.57 (0.37)	0.27	0.57	1.18
Condition x negative urgency	0.28 (0.32)	0.72	1.33	2.46
Condition x positive urgency	0.50 (0.30)	0.91	1.65	2.98

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Note; CI, confidence interval; LNS, letter-number sequencing; OR, odds ratio.
**p < .05;*
***p < .01.*

Our study emphasized a positive effect of implementation intentions in a prospective memory task and in an inhibition task in older participants. In addition, the results indicate a moderating effect of visualization habits on the efficacy of implementation intentions. Verbalization habits, urgency, and working memory did not influence performance on either task.

***Table 3**. Characteristics of the experimental groups*

Demographical and psychological characteristics	Stop-signal experimental group	Prospective memory experimental group	t (84)/ $\chi^2(1)$	p
Number of participants	45	40	—	
Participants from memory clinic	18%	23%	0.77	
Gender (percentage of men)	22%	25%	0.25	
Age	70.0 (6.2)	71.4 (8.5)	-0.92	.36
Years of education	12.9 (3.3)	14.1 (4.0)	-1.50	.14
MMSE	27.8 (1.8)	27.2 (2.1)	1.32	.19
DRS	137.4 (4.4)	136.3 (6.1)	0.97	.32
LNS	9.6 (1.9)	9.4 (2.1)	0.51	.61
UPPS-P Impulsivity scale				
Urgency	9.7 (2.5)	8.7 (2.7)	1.75	.08
Positive urgency	11.0 (2.5)	10.2 (3.2)	1.45	.15
Lack of premeditation	7.6 (2.2)	7.9 (2.6)	-0.53	.60
Lack of perseverance	6.7 (2.1)	6.3 (2.2)	0.89	.38
Sensation seeking	9.2 (2.5)	9.3 (3.1)	-0.20	.84
VerIm Questionnaire				
Verbalization	10.2 (2.3)	9.9 (2.8)	0.58	.56
Visualization	10.4 (3.1)	11.1 (3.3)	-0.90	.37

Note; All p > .08. The table displays the mean values; the standard deviations are reported in parentheses.

MMSE, mini mental state examination; DRS, Dementia Rating Scale; LNS. letter-number sequencing; VerIm, verbalization and imagery habits.

One of the main results of the current study was that the visualization habits in everyday life moderated the efficacy of implementation intentions in the day-of-the-week prospective memory task and the stop-signal inhibition paradigm. In both tasks, participants needed to have strong visualization habits to benefit from implementation intentions.

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How do visualization habits improve the efficacy of implementation intentions? According to Marks (1999), mental imagery has an important adaptive function in the preparation of action, intervening in selection, planning, and rehearsal. The encoding of intentions relies upon different processes, including episodic memory, planning, and coordination; it implies to form associations between the context in which the action has to be performed, the cue leading to action initiation, and the to-be-performed action. Thus, it has been shown that imagery facilitates the creation of associations in memory (Bower, 1970) and that individuals with better imagery abilities permitted better performances in retrospective memory (Marks, 1973).

***Table 4**. Logistic regression analysis on the day-of-the-week prospective memory task*

Variables entered	B (*SE*)	95% CI for odds ratio Lower	OR	Upper
Constant	−2.48 (0.62)**		0.08	
Age	−0.15 (0.06)**	0.77	0.86	0.96
LNS	0.04 (0.27)	0.61	1.04	1.76
Condition	2.26 (0.75)**	2.22	9.57	41.33
Verbalization	0.22 (0.26)	0.75	1.25	2.08
Visualization	−0.16 (0.18)	0.60	0.86	1.22
Negative urgency	0.04 (0.22)	0.67	1.04	1.61
Positive urgency	−0.46 (0.25)	0.39	0.64	1.04
Condition × verbalization	0.01 (0.31)	0.55	1.01	1.87
Condition × visualization	0.52 (0.25)*	1.02	1.68	2.74
Condition × LNS	−0.57 (0.37)	0.27	0.57	1.18
Condition × negative urgency	0.28 (0.32)	0.72	1.33	2.46
Condition × positive urgency	0.50 (0.30)	0.91	1.65	2.98

Note; CI, confidence interval; LNS, letter-number sequencing; OR, odds ratio.
**p<.05;*
***p<.01.*

***Figure 3**. Probability of prospective memory (PM) success as a function of visualization and condition*

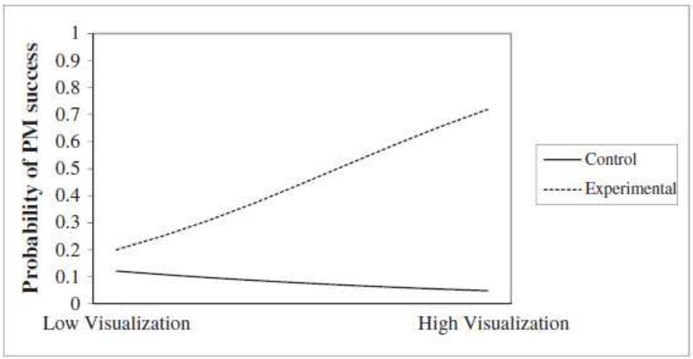

Figure 4. *Interaction effect between visualization and condition on stop-signal reaction time (SSRT)*

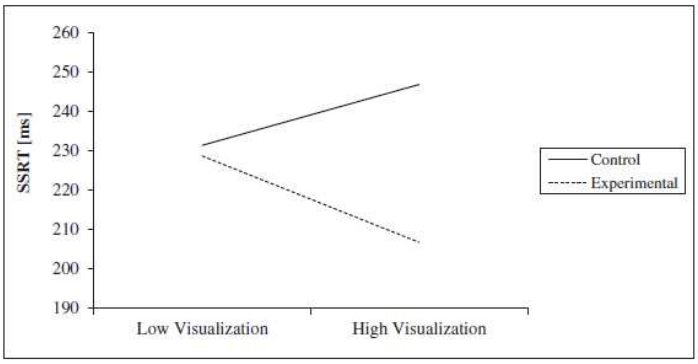

Table 5. *Stop-signal data for experimental and control groups*

Stop-signal data	Experimental group *M (SD)*	Control group *M* (*SD*)
Automation RT (ms)	558 (92)	558 (114)
Go RT (ms)	592 (79)	560 (103)
Inhibition errors	15.07 (6.8)	20.73 (9.3)
SSRT (ms)	222 (39)	237 (47)

Note; Automation RT, reaction time during the automation phase; Go RT, reaction time on go trials; SSRT, stop-signal reaction time.

Table 6. *Multiple regression analysis on stop-signal reaction task*

Variables entered	B	*SE* B	β	Semi-partial correlations
(Constant)	239.1	6.1		
Go RT	0.2	0.1	.46**	.35
Age	1.2	0.7	.20	.17
Condition	-21.4	8.7	-.25*	-.23
Verbalization	1.7	2.3	.10	.07
Visualization	2.4	2.0	.18	.11
LNS	2.8	3.2	.13	.08
Negative urgency	-3.6	2.8	-.22	-.12

Positive urgency	3.2	2.5	.21	.12
Condition x verbalization	0.4	3.7	.02	.01
Condition x visualization	-5.8	2.9	-.30*	-.19
Condition x LNS	-5.6	4.3	-.18	-.12
Condition x negative urgency	4.7	3.8	.20	.12
Condition x positive urgency	-1.2	3.5	-.05	-.03

Note; Go RT, reaction time on go trials; LNS, letter-number sequencing; SSRT, stop-signal reaction time.
*$p < .05$;
**$p < .01$.

Such processes could therefore also occur for future intentions. Brewer et al. (2011) demonstrated that the use of imagery in encoding event-based intentions (i.e., forming what we referred to as visual implementation intentions) facilitates prospective memory performance by strengthening the cue-to-context association. One hypothesis would therefore be that the combined verbal and visual implementation intentions that we used strengthened the cue-to-context association. Nevertheless, it is also possible that visualization facilitates cue detection by increasing the activation of the cue in memory or even by increasing the commitment to the intention. Regarding the question of why visual habits are necessary for implementation intentions to be effective, a study by Plaie and Isingrini (2003) showed that compared with younger adults, older adults require more time to form mental images and form less precise images, especially if they have to form mental images on the basis of verbal entries—exactly what the present implementation intentions instructions required. Given these difficulties, an increased habit of using visual techniques could help older adults to form visual images better (faster or with fewer costs) or to pass more easily from verbal instructions to their visual counterpart. Another possibility is that the images they form would be more precise, more complete, or contain more significant elements.

These results could have important implications for implementation intention use in general or in clinical populations. If the visualization habits moderate only the efficacy of visual (or combined verbal and visual) implementation intentions, two possibilities must be considered when using implementation intentions with individuals with low visualization habits. Individuals who seldom use visual strategies could be taught only the use of the verbal implementation intentions or—if visual or combined implementation intentions are more effective—be trained in visual strategies before the intervention. Further studies should therefore compare verbal, visual, and combined verbal and visual implementation intentions and should assess visual and verbal habits in parallel. This type of design would allow direct comparison of the efficacy of the different forms of implementation intention, taking into account the role of daily use of verbal and visual strategies for each.

One question that arises is why the combined implementation intentions we used were not efficient in participants with low visualization habits. As these implementation intentions also contained a verbal component, they should have been effective despite low visualization habits or should at least have been effective in the participants with high verbal habits. Perhaps the instruction for the verbal implementation intention, which required reading of the implementation intention once, was not strong enough to create the cue- to-context link on a verbal level in the older participants. In fact, in the studies that used a pure verbal implementation intention (without a visual component) in aging, the instructions required the participants to silently read the implementation intention, to write it on a sheet of paper, *and* to repeat it aloud to the experimenter (McFarland & Glisky, 2011b), or to read it aloud *three* times (Zimmermann & Meier, 2009). Such an intensive verbal encoding instruction may have been necessary, whereas the simple reading of the implementation intention we requested was not sufficient to create the implementation intention effect. Besides the length difference, another difference between the verbal and the visual component in the current study was the extent to which the instructions were elaborated: Indeed, the visual component was more detailed than the verbal component, providing more contextual information. Further studies should therefore extend the verbal implementation intention instructions to match the visual instruction more closely. Finally, another possible explanation for the absence of the moderation of the verbalization habits is that the reliability of the verbalization scale was not optimal. Further studies should therefore try to slightly modify the verbalization items in order to improve their homogeneity.

Neither in the prospective memory task nor in the inhibition task did working memory moderate significantly the effect of the strategy. In other words, implementation intentions seem to be effective independently of working memory capacities. This result supports and extends the results of McFarland and Glisky (2011b), which showed no moderating effect of executive abilities (as evaluated by a composite executive score). Age—which has been shown to be associated with lower controlled resources—did not moderate the efficacy of the technique either. Consequently, the current study is compatible with the idea of automaticity of implementation intentions, with the argument that good working memory abilities are not a prerequisite for using implementation intentions. If implementation intentions are based on automatic processes, the strategy should be effective in populations with reduced controlled processes, such as older adults. Indeed, the age-related differences mentioned earlier appear principally when controlled processes are required, whereas automatic inhibition (Andrés, Guerrini, Phillips, & Perfect, 2008; Collette, Germain, Hogge, & Van der Linden, 2009) and automatic prospective memory processes (Logie, Maylor, Della Sala, & Smith, 2004) are globally preserved. Thus, the use of implementation intentions could be taught to older adults to improve their completion of goal-directed behaviors in everyday life. However, a study conducted in older adults with subjective or objective cognitive difficulties (patients of a memory clinic who had received no diagnosis, a diagnosis of mild cognitive impairment, or a diagnosis of dementia) has shown that when working memory (as assessed by forward and backward digit span) was very low, implementation intentions were no longer efficient (Burkard et al., 2014).

The lack of correlation between the prospective memory task and the working memory task could suggest, nevertheless, that the working memory task we used did not tap the executive processes that correlate with higher order cognition. Indeed, working memory tasks that imply the active maintenance of information in the face of concurrent processing and attention shifts (such as complex span tasks, consisting, for example, of reading sentences aloud and maintaining in memory the last word of each sentence) have been shown to well predict higher order reasoning tasks. In contrast, short-term memory tasks, which require one to simply maintain information without manipulation, did not predict these higher order tasks (Conway, Cowan, Bunting, Therriault, &

Minkoff, 2002). Although the task we used required manipulation and was not simply a short-term memory task, it might require less switching than complex span tasks, given the fact that there was no interfering task. Another explanation for the absence of correlation between prospective memory and working memory in our study is related to the prospective memory task. Indeed, it seems likely that the participants did not continuously monitor for the occurrence of a cue (as is the case in classical laboratory paradigms) and that they monitored only between finishing one task and starting the next one (see Scullin, McDaniel, & Shelton, 2013 for a framework including the possibility of prospective memory tasks that do not require continuous monitoring). In this case, the task might have required some, but not an important amount of, controlled resources. Thus, the choices of the tasks (prospective memory and/or working memory) might explain the lack of correlation between working memory and prospective memory in the current study.

Although Churchill and Jessop's studies (2010; 2011) showed a consistent moderating effect of urgency on implementation intention efficacy, our data did not suggest any significant interaction with urgency, either in positive or in negative affect conditions. One possible explanation would be that participants in the current study, confronted with laboratory tasks, did feel less emotionally aroused than participants in Churchill and Jessop's studies, confronted with dieting goals. As mentioned earlier, in a sample of young adults, implementation intentions improved inhibition performances in individuals with high urgency, as long as they were not emotionally aroused (Burkard et al., 2013).

Limitations

Our study had several limitations. One is that the order of the experimental tasks was not counterbalanced. Indeed, the prospective memory task instructions were always given before the stop-signal task instructions. One could thus argue that the participants of the prospective memory implementation intention condition could have transferred the use of implementation intentions to the stop-signal task. Nevertheless, on the one hand, this seems unlikely because implementation intentions were not described as a strategy and because the experimental tasks have very different natures. On the other hand, to ensure that the strategy was not spontaneously adopted by the control group, we used postexperimental task questions for both tasks. More specifically, these questions assessed whether the participants had used a strategy to perform the task, whether they repeated the instructions to themselves, and whether they imagined themselves performing the task. This happened in only one participant for the stop-signal task. Excluding this subject from the analyses did not change the results. We are thus confident that the fixed order of the experimental tasks did not constitute a threat to the validity of the findings. Importantly, it should be noted that even if some participants of the prospective memory implementation intentions group spontaneously used implementation intentions on the stop-signal task, this would have minimized the here observed effect.

Another limitation is related to the fact that our prospective memory task could not be scored on a continuous scale, as the distribution of the responses was bimodal. The dummy coding that we adopted in consequence had the disadvantage of loss of variability in the performance.

A general limitation, true of most studies assessing the efficacy of implementation intentions, is that the control group was allowed less time to encode the intention. In consequence, it is difficult to determine whether the effect is due to the implementation intention specifically or to the longer encoding time. It would therefore be interesting for future studies to include a control group with encoding time that was equal to that of the implementation intentions group. The control condition should nevertheless be chosen carefully, taking into account that the instruction should be as follows: (i) last as long as the implementation intention instruction and therefore not depend on participants' speed; (ii) not lead to establishing a cue-to-context link; and (iii) not include a motivational component or a component increasing the commitment to the task.

Two limitations were related to our sample. We chose to include in our study participants with a wide range of cognitive scores. We included not only well-functioning older adults but also subjective memory complainers. One limitation of this choice is that the variability of performances we observed may depend on a multitude of factors (e.g., negative mood, motivation, apathy, or sleep disorders) that we did not assess. Further studies should therefore investigate the possible moderating effect of these variables on the efficacy of implementation intentions in aging. Another limitation was that our sample included more women than men. Although in our sample there was no significant gender difference in verbalization or visualization habits, $F(2,82) = 1.93$, $p = .15$, this imbalance could nonetheless constitute a further limitation.

In conclusion, simple flexible interventions such as implementation intentions seem to be a promising tool in improving cognitive functioning in older adults. Interventions designed to enhance prospective memory and inhibition are still at their beginnings, and strategies that rely principally on automatic processes are therefore of great interest for populations with reduced cognitive resources, as is the case for older adults. Further studies should include participants with more serious cognitive difficulties and use ecological tasks to complement laboratory tasks. Indeed, whereas in prospective memory, two studies have shown a beneficial effect of implementation intentions in ecological tasks in older adults, studies about their efficacy in real-world inhibition tasks in aging are still needed.

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APPENDIX

VerIm questionnaire (English version)

		Rarely	Sometimes	Often	Very often
1.	When I remember an event I've experienced, I imagine it in the form of pictures.	□	□	□	□
2.	When I'm trying to learn or memorize something, I try to repeat it verbally (aloud or silently).	□	□	□	□
3.	When I'm thinking, I imagine things in the form of pictures.	□	□	□	□
4.	I use mental images when I have something to remember.	□	□	□	□
5.	When I'm thinking, I talk to myself inwardly.	□	□	□	□
6.	When I remember an event I've experienced, I 'retell' the event to myself in words.	□	□	□	□
7.	When someone tells me about things that happened to them or when I read, a picture of the events in question comes into my mind.	□	□	□	□
8.	I put what I experience and feel into words.	□	□	□	□

Items 2, 5, 6, and 8 form the verbalization factor, and items 1, 3, 4, and 7 form the imagery factor.