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ORIGINAL INVESTIGATION

Fluid mechanics moderate the effect of implementation intentions on a health prospective memory task in older adults

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Abstract The aim of the present study was to test if a cognitive strategy improves older adults' prospective memory performance in a naturalistic health task. Moreover, it was tested if a possible strategy effect is moderated by individual differences. Therefore, a group of older adults was asked to perform a task taken from the medication adherence literature (i.e., blood pressure monitoring). Half of them were asked to form implementation intentions. Additionally, crystallized pragmatics and fluid mechanics, conscientiousness, self-efficacy, and lifestyle factors were assessed as possible moderators. Results showed a strong positive strategy effect on prospective memory. Moreover, the effect was qualified by a significant interaction and only emerged for participants with low levels in fluid mechanics. No other moderator showed an effect. In conclusion, an enhancing effect of implementation intentions on prospective memory seems to be dependent on individual differences in cognitive capacity and less related to key motivational or personality variables.

Keywords Prospective memory · Implementation intentions · Fluid mechanics · Aging

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Prospective memory: an overview

Cognitive functions associated with remembering to perform delayed intentions without an explicit reminder are summarized as *prospective memory* (Ellis 1996; Ellis and Kvavilashvili 2000). Typical everyday prospective memory tasks are remembering to stop at a store to buy bread, to congratulate someone for their birthday, to turn off the stove after cooking, or to take medication on time. Prospective memory has been receiving increased attention from applied memory research as prospective memory errors may cause more than half of everyday memory problems (Crovitz and Daniel 1984; Terry 1988). Thus, prospective memory has been identified as one of the most crucial applied memory challenges, especially in older adults (Maylor 1990).

However, so far, most studies have used lab-based prospective memory paradigms to explore cognitive processes, task characteristics, and individual difference variables associated with successful prospective remembering. Here, typical tasks involve remembering to press a predetermined response key on the computer keyboard at a specific time or when a specific event occurs (e.g., Einstein and McDaniel 1990; Kliegel et al. 2001; Marsh and Hicks 1998; West and Craik 1999). While these studies have yielded much insight in the microstructure of cognitive processes underlying prospective memory, Phillips et al. (2008) have recently argued that typical lab-based prospective memory tasks show relatively low ecological validity and may not reflect the demands of everyday life sufficiently in order to allow transfer of results into predicting everyday memory functioning. Thus, results from studies using these paradigms have to be interpreted carefully in regard to determinants of real-life prospective memory performance.

Prospective memory in an applied context

Considering this potential issue for applied contexts, researchers have also embedded prospective memory tasks in participants' everyday life. Here, participants are asked to carry out specific assignments during everyday routines, for example, logging times in a personal organizer (e.g., Bailey et al. 2010; Rendell and Thomson 1999) and call or text the researcher at specific times (e.g., Maylor 1990; Schnitzspahn et al. 2011). According to Phillips et al. (2008), these tasks have considerably higher ecological validity. Yet, even those tasks may still not reflect real life prospective memory as they are still imposed by the experimenter and not necessarily meaningful for the participants (e.g., sending text messages with one letter or logging time into PDAs). Thus, even findings from those studies do not automatically generalize to real-life prospective memory performance.

Thus, the first aim of the current study was to further explore prospective memory performance in real life, using a task of high ecological validity and of high meaning for the participants. As suggested by Phillips et al. (2008) and successfully used in a former study (Liu and Park 2004), we used medical adherence behavior as the critical prospective memory task. Moreover, we selected older adults as the target sample for which medical adherence behavior should be especially relevant. This is because older people have a rising number of health-related conditions, and health-related behavior often heavily relying on prospective memory (for example, taking medication on time, keeping doctor's appointments, and monitoring blood glucose or blood pressure levels) increases in importance with advancing age (Park et al. 1994; Steinhagen-Thiessen and Borchelt 1999). Yet, older adults tend to report more everyday memory failures and greater concern about them than young adults (e.g., Cavanaugh et al. 1983).

Prospective memory and implementation intentions

The second goal of the present study concerned the thorough examination of a strategy to possibly enhance prospective memory performance in this medication adherence task. Because errors in such a task resulting in omissions of medical treatments may even cause life-threatening conditions, identifying a possibility to enhance performance is especially vital and may help foster and maintain independence in old age (McDaniel et al. 2008; Rendell and Craik 2000). However, besides its applied importance, this research question has a critical conceptual angle: Current health psychology models argue that efficiently bridging the gap between the formation of an intention to show a specific health behavior and actually showing this behavior requires specific plans of how, when, and where one aims to implement the intended behavior (Schwarzer 1992). One way the experimental literature has adopted to examine those planning processes is implementation intentions (Gollwitzer 1993, 1999). Implementation intentions have shown to improve prospective memory performance by the formation of if (situation)—then (behavior) plans ("If situation x arises, then I will initiate behavior z"). By forming a specific plan in the intention formation phase defining where, when, and how the person is thought to initiate the desired response in a certain situation, the intended goal-directed behavior is directly linked to specific situational cues. This strong behavior-cue link is assumed to automatically lead to the performance of the desired behavior when encountering the situational cues. Because implementation intentions are said to rely on automatic memory processes (Gollwitzer 1999, 2006), which are less age-dependent than controlled components of memory (Jacoby et al. 1996; Park et al. 2002), older adults should especially benefit from the formation of implementation intentions (Gollwitzer 1999; Wilson and Park 2008). Surprisingly, so far only very few studies have experimentally tested the effect of implementation intentions on prospective memory performance in old age.

Chasteen et al. (2001) were the first to demonstrate improvement in prospective memory performance in old age through the formation of implementation intentions. Participants were asked to write the day of the week at the top right corner of each response sheet presented at a testing session. Participants who formed implementation intentions wrote the day of the week twice as often on the response sheets than participants who used alternative memory strategies. Schnitzspahn and Kliegel (2009) confirmed and extended this finding by showing positive implementation intention effects on different types of lab-based prospective memory tasks in (young-) old adults. Zimmermann and Meier (2010) could show that the prospective memory performance benefit after forming implementation intentions in older adults was mainly due to a better performance in the prospective component and did not lead to impaired ongoing task performance.

So far, only one study used implementation intentions to improve prospective memory performance in older adults in a naturalistic task. In this study by Liu and Park (2004), 31 nondiabetic participants were instructed to check their blood glucose level four times daily over a period of 3 weeks. Before task performance, one group (rehearsal group) was additionally asked to rehearse the prospective memory task instruction, while another group (deliberation group) was asked to list pros and cons about the task on a worksheet. The third group formed implementation intentions to remember performing blood glucose monitoring

according to the instructions. Participants in the implementation intentions condition remembered to test their blood glucose level nearly 50 % more often than participants in the rehearsal and deliberation group; yet, there were still considerable individual differences. The results therefore strongly suggest that implementation intentions are in general a useful strategy to improve prospective memory performance in and outside of the laboratory. The latter finding is of particular importance for the current study and following up on it, we investigated whether this result generalizes to a different health-related prospective memory task in older adults' everyday lives, such as blood pressure monitoring. A replication of the strong implementation intention effect found by Liu and Park (2004) is especially important, because Liu and Park only tested 10 participants in the implementation intentions condition.

Prospective memory and implementation intentions: possible moderators

The final aim of the present study was to identify possible moderator variables affecting the effectiveness of implementation intentions on prospective memory performance. This research goal is especially important from a conceptual perspective as it specifies processes underlying the strategy effects. The present study thereby considers individual differences in implementation intentions and follows up on the first studies suggesting that not everybody profits (equally) from the formation of implementation intentions (although the majority of the literature on implementation intentions argues this to be a general effect, see Gollwitzer 1999). For example, in one of our own studies, Schnitzspahn and Kliegel (2009) found that the formation of implementation intentions in fact enhanced prospective memory only for the young–old adults, but not for the old–old adults. On the contrary, their performance was even impaired in a less resource-demanding prospective memory task. Thus, this study suggests an interaction of individual differences and the effectiveness of implementation intentions. Further, the level of cognitive resources was suggested as a possible mechanism, but the study did not have the means to actually test this hypothesis. In a similar vein, Zimmermann and Meier (2010) suggested that (given a sufficient minimal level of cognitive resources which may have been lacking for the old–old adults in Schnitzspahn and Kliegel's sample) individuals with reduced processing resources should benefit most from the formation of implementation intentions, as their results showed that implementation intentions especially enhanced prospective memory performance in older adults compared to young adults and adolescents. This idea was recently taken up by McFarland and Glisky (2011), who investigated the relation between frontal lobe function, as characterized by performance in neuropsychological tests, and implementation intentions in a group of older adults, in a lab-based prospective memory task. With regard to the effect of implementation intentions on prospective memory performance, it was hypothesized that the magnitude of improved performance from standard to implementation intention instructions may be greater for the low-frontal lobe group, as they are less likely to generate a link between cue and intention under standard instruction than is the high-frontal lobe group. However, high-frontal lobe participants also benefitted from implementation intentions and no significant group x instruction interaction was found. Taken together, it is currently an open question as to whether implementation intentions exert a general effect on prospective memory performance in older adults or if it is moderated by general cognitive resources. Thus, the current study explicitly tested this possibility in a group of healthy older adults.

Besides cognitive resources, the current study for the first time also set out to initially explore additional possible moderators of implementation intention effects on prospective memory in older adults. Specifically, personality and environmental factors were explored as everyday prospective memory performance seems to be especially affected by contextual factors (and possibly even more so than by cognitive variables as suggested by Wilson and Park 2008). In particular we explored the following additional moderators:

At first, conscientiousness was examined. Conscientiousness as a relatively stable personality trait is defined by terms like ambitious, hardworking, and self-disciplined (McCrae and Costa 1987). People with such a tendency are generally more likely to perform regular health-related behavior (Conner and Abraham 2001, Study 2; O'Cleirigh et al. 2007). Therefore, participants with low conscientiousness can be expected to profit especially from the formation of implementation intentions, while participants with higher conscientiousness may already perform close to a perfect level. Accordingly, an interaction between instruction condition and conscientiousness indicating that only participants with low conscientiousness profited from implementation intentions was expected.

Second, self-efficacy was included. Self-efficacy is defined as "the belief in one's capabilities to organize and execute the courses of action required to produce given attainments" (Bandura 1997, p. 3). Assuming self-efficacy influences the effect of implementation intentions in older adults, the rational of this analysis rests on the prediction that low self-efficacy may limit the effectiveness of this cognitive strategy (Wieber et al. 2010). Therefore, older adults with high self-efficacy can be expected to profit especially from the formation of

implementation intentions, and an interaction between instruction group and self-efficacy was expected.

Finally, contextual factors such as everyday stress or busyness/stability of lifestyle have been shown to influence prospective memory performance in everyday life (Schnitzspahn et al. 2011) as well as medical adherence (Wilson and Park 2008). In addition, a lifestyle which is marked by unstable contextual cues might prevent implementation intention effects as the necessary detection of situational cues that are thought to trigger behavior may be especially difficult. Therefore, a high stability of lifestyle may facilitate the effect of implementation intentions on blood pressure monitoring in older adults and lead to an interaction between instruction group and stability of lifestyle. To sum up, by experimentally manipulating implementation intentions and assessing general cognitive resources, conscientiousness, self-efficacy, and stability of lifestyle as possible moderators, the present study explored which individual difference measures may influence the effectiveness of implementation intentions on prospective memory performance in older adults in a naturalistic health-related task.

Method

Participants and design

The sample comprised 40 community-dwelling older adults (22 females), from Dresden and the surrounding areas, aged 61 to 79 years. No participant reported neurological or psychological diseases. To control for pre-experience differences in the naturalistic prospective memory task, any experience with using a blood pressure monitor regularly was an exclusion criterion. Thus, one male participant was excluded from the analyses due to the fact that he already performed regular blood pressure checks, resulting in a sample of 39 participants (mean age = 68.6 years, $SD = 4.99$). Everyone who participated in this study took part in a lottery for three book vouchers worth 15 Euro each.

The study followed a between-subjects design (implementation intentions versus control group). Participants were randomly allocated to the two different instruction groups. The implementation intentions group (7 males, 12 females) and the control group (10 males, 10 females) did not differ significantly concerning age, gender, self-efficacy, lifestyle stability, or intelligence (see Table 1). However, participants in the control group reported more cardiovascular diseases and showed higher levels of education.

Table 1 Participants' mean scores and standard deviations on demographic and individual variables as a function of instruction group (control vs. implementation intentions)

	Instruction group		t-/χ^2-value
	Control ($N = 20$)	Implementation intentions ($N = 19$)	
Age (years)	68.64 (4.69)	68.53 (5.41)	−0.08
Education (years)	12.50 (0.51)	11.44 (1.62)	7.92*
Self-reported health	1.30 (1.26)	1.21 (0.92)	−0.25
Cardiovascular disease	0.50 (0.51)	0.11 (0.32)	7.13**
Cognitive variables			
Fluid mechanics	10.90 (2.25)	10.84 (1.80)	−0.09
Crystallized pragmatics	114.65 (8.74)	112.05 (9.45)	−0.89
Individual variables			
Conscientiousness	2.90 (0.54)	3.02 (0.44)	0.75
Self-efficacy	31.15 (3.8)	31.11 (3.13)	−0.04
Stability of lifestyle	8.65 (1.93)	9.21 (1.87)	0.92

* $p < 0.05$, ** $p < 0.01$

Materials and tasks

To assess general *cognitive abilities*, a German vocabulary test (Lehrl 1995) was used as an indicator for *crystallized pragmatics* and the digit symbol subtask of the Wechsler Adult Intelligence Scale (Wechsler 2006) as an indicator for *fluid mechanics* (Baltes et al. 1999).

In addition, participants were given the *conscientiousness* scale (12 items) of the NEO-Five-Factor Inventory (Borkenau and Ostendorf 1993) and the General *Self-efficacy* Scale (10 items) from Schwarzer and Jerusalem (1999). S*tability of lifestyle* was assessed through "The Martin and Park Environmental Demands Questionnaire" (Martin and Park 2003; 4 items).

Everyday *prospective memory* performance was measured by asking participants to check their blood pressure three times per day for a period of five consecutive days (Monday to Friday) with the help of a blood pressure monitor, which stored the exact timing of each activity. Each participant could freely choose individual times for executing the blood pressure tests at the baseline session (see below). Following Liu and Park (2004), prospective memory performance was scored as correct, if the blood pressure task was completed within a 10-min window around the individual goal time.

Procedure

In a baseline session at the university, participants filled in the above-mentioned questionnaires to measure individual differences and performed the tasks measuring general cognitive abilities. Afterward, participants learned how to use the blood pressure monitor for the lower arm ("Sanitas

SBM 03"). Following a demonstration of the monitors' usage and application, participants practiced by themselves until they successfully executed the blood pressure test on their own and felt save to do so. After that, the prospective procedure was explained, which required participants to perform the blood pressure tests in their everyday life during the following week. Participants were informed that it was the aim of the following week to try to not forget performing any blood pressure test on time and that the blood pressure monitor would store the exact times and dates of its application electronically. Moreover, participants were explicitly told that they must not use outside assistance to remember the measurements, for example, setting timers or asking friends to remind them. Participants in the implementation intentions condition were instructed to specify and visualize when, where, and how they wanted to perform the blood pressure tests. In the first step, they were asked to write down specific information concerning time, place, and manner for the three planned blood pressure measurements per day (e.g., "Please consider which times would be most suitable for you to perform the blood pressure measurement. Note the specific times below."). In the second step, all information was combined to form the if—then implementation intention statement (e.g., "If I am in the living room next week from Monday to Friday at 8 am, 12 pm and 6 pm, I will check my blood pressure with the handed over blood pressure monitor."), which was written down on the worksheet too. Afterward, with eyes closed, participants should mentally imagine and visualize the exact moment and place of the measurement and how they would carry out the blood pressure test (see Liu and Park 2004; Schnitzspahn and Kliegel 2009, for similar procedures).

Participants in the control condition were asked to write down the specific times they wanted to perform the blood pressure tests on a worksheet. In addition, to assure equal times for both groups when exposing themselves to the topic of blood pressure monitoring, participants in the control group read an article about blood pressure-related issues.

The whole session lasted 1 h for participants in both conditions. At the end of the following week, participants returned their blood pressure monitor and had the opportunity to talk about their experiences and ask questions concerning the study aim.

Results

First, the rates of overall forgotten blood pressure tests were analyzed. Participants forgot to test their blood pressure as intended on average 2.41 ($SD = 3.15$) times out of 15 (16 %).

Exploring differences in prospective memory performance as a function of instruction

In the second analytical step, prospective memory performance was examined as a function of instruction group. Specifically, to test whether participants of the two instruction groups differed in regard to their everyday prospective memory performance, a one-way ANOVA with instruction as the between-group factor was calculated. The number of forgotten blood pressure tests served as the dependent variable. Results showed a large-sized effect of instruction on the number of forgotten blood pressure tests, $F(1, 37) = 16.66$, $p < 0.001$, $\eta_p^2 = 0.31$. Participants in the implementation intentions group approached the intended perfect performance level ($M = 0.63$, $SD = 1.21$) and forgot significantly fewer times to test their blood pressure than participants in the control group ($M = 4.10$, $SD = 3.51$). On average, participants in the control group forgot five times more often to execute their blood pressure testing (see Fig 1).

Exploring the moderating role of individual differences on implementation intention effects in prospective memory

To determine whether individual differences influence the aforementioned effect of implementation intentions on participants' ability to perform blood pressure monitoring, a median split approach was used.[1] Following the procedure recommended by Baron and Kenny (1986), two-way independent ANOVAs were applied with instruction as one factor and one individual difference measure as the second factor. Post hoc tests were calculated for significant interaction effects only. Note that in all of the following analyses, the instruction condition remained a significant main effect.

Cognitive variables

A two-way independent ANOVA with instruction and *fluid mechanics* as factors revealed a large-sized main effect of fluid mechanics, $F(1, 35) = 6.81$, $p < 0.05$, $\eta_p^2 = 0.16$. Participants with a high score in the digit symbol subtask forgot significantly fewer times to measure their

[1] Moderator analyses with continuous moderator variables confirm the results of the median split approach. Specifically, only in the control group, a significant relation between fluid mechanics and prospective memory performance occurred ($r = -0.42$, $p < 0.05$). In contrast, for those adults who were given implementation intention instructions, no relation between fluid mechanics and prospective memory performance was found ($r = 0.01$). No other possible moderator showed a relation with prospective memory performance in one of the two experimental groups.

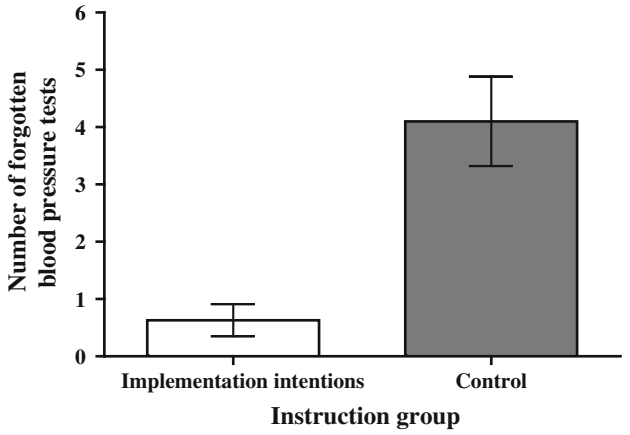

Fig. 1 Average number of forgotten blood pressure tests as a function of instruction group. *Error bars* represent the standard error (*SE*)

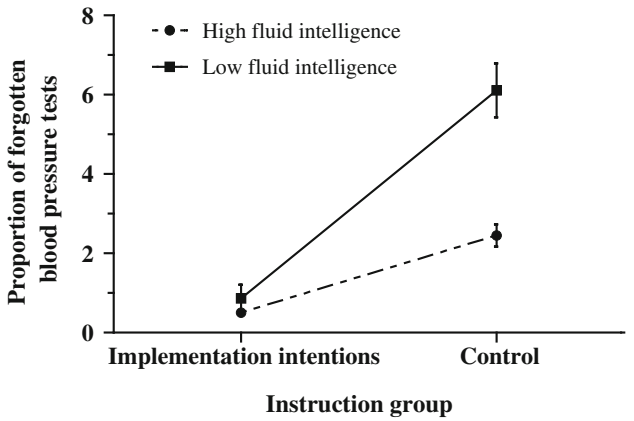

Fig. 2 Average number of forgotten blood pressure tests as a function of instruction group displayed separately for participants with high and low fluid mechanics. *Error bars* represent the standard error (*SE*)

blood pressure on time than participants with low scores ($M = 1.43, SD = 1.67$ vs. $M = 3.81, SD = 4.18$). Moreover, this factor interacted significantly with instruction condition ($F(1, 35) = 4.60, p < 0.05, \eta_p^2 = 0.12$) (see Fig. 2).

T-tests were used for post hoc analyses to examine the interaction effect. Comparing participants with low and high fluid mechanics in the control group revealed a significant large-sized effect of fluid mechanics, $t(18) = 2.67$, $p < 0.05$, $d = 1.15$. Cohen (1988) defines effect sizes of 0.2 as small, 0.5 as medium, and 0.8 as large. As shown in Fig. 2, here, participants with high fluid mechanics forgot significantly fewer times to check their blood pressure than participants with low fluid mechanics. In contrast, no significant difference was found between participants with high versus low levels of fluid mechanics in the implementation intentions group, $t(17) = 0.61$, $p = 0.55$, $d = 0.26$.[2]

Results for *crystallized pragmatics* as possible moderator revealed neither a significant main effect ($F(1, 35) = 0.39$, $p = 0.54$, $\eta_p^2 = 0.01$) nor an interaction effect ($F(1, 35) = 0.37$, $p = 0.55$, $\eta_p^2 = 0.01$).

Conscientiousness

No significant main effect was revealed for conscientiousness, $F(1, 35) = 0.17$, $p = 0.69$, $\eta_p^2 = 0.01$. Participants with high and low conscientiousness scores forgot to test their blood pressure to a similar extent. Furthermore, conscientiousness did not interact with instruction, $F(1, 35) = 0.82$, $p = 0.37$, $\eta_p^2 = 0.02$.

Self-efficiency

A two-way univariate ANOVA with self-efficiency and instruction as factors displayed neither a significant main effect ($F(1, 35) = 0.18$, $p = 0.68$, $\eta_p^2 = 0.01$) nor an interaction ($F(1, 35) = 0.03$, $p = 0.86$, $\eta_p^2 = 0.001$).

Stability of lifestyle

No significant difference between participants with high and low stability of lifestyle was found concerning their prospective memory performance, $F(1, 35) = 0.67$, $p = 0.76$, $\eta_p^2 = 0.003$. Results also showed no interaction effect between stability of lifestyle as possible moderator and instruction group as the second factor, $F(1, 35) = 0.56$, $p = 0.46$, $\eta_p^2 = 0.02$.

Discussion

The first aim of the current study was to examine everyday prospective memory performance in older adults in a health-related task. The second aim was to test if performance in this task can be enhanced by implementation intentions. Finally, it was explored if implementation intentions improve performance equally in all participants or if some participants profit especially from implementation intentions. Firstly, discussing general performance levels in this everyday task, our results show a good overall performance in the health-related task of measuring one's

[2] Non-parametric test results confirm the interaction. While individuals with low and high levels of fluid mechanics differed significantly in their prospective memory performance in the control condition ($U = 21.50$, $p < 0.05$, $r = -0.48$), no significant performance difference was found between participants with high versus low levels of fluid mechanics in the implementation intentions group, $U = 38.50$, $p = 0.89$, $r = -0.08$.

blood pressure regularly on a daily basis. This finding is in line with studies exploring prospective memory performance in older adults with the help of more artificial tasks, which have even shown an age benefit in the elderly (for meta-analyses, see Henry et al. 2004). However, still, even in this health task of high importance, a substantial level of forgotten intentions (16 %) could be detected. Especially, results in the control group (27.33 % forgotten blood pressure tests) can be compared to results from medical adherence studies assessing performance without implementing strategies. A quantitative meta-analytic review by DiMatteo (2004) on medical adherence found an average non-adherence rate of 24.8 % ($k = 569$). Thus, our results are in line with the literature and display the fact that even though research suggests a better medical adherence rate for older adults than their younger counterparts, a relative high rate of not performed prospective memory tasks occurs in older age too.

Obviously, prospective memory errors in tasks related to one's health can have severe consequences. Thus, from an applied perspective, it is extremely important to find means to reduce the rate of failures in implementing health intentions in the elderly to close to zero. In this context, one promising approach seems to be implementation intentions. As revealed by the current study, with this strategy, older adults' performance could be increased dramatically. As predicted, we found better prospective memory performance for participants in the implementation intentions condition: Participants in the control group forgot five times more often to execute their blood pressure testing. Moreover, participants using the implementation intentions strategy succeeded in implementing their intentions with a non-adherence rate close to zero over a 5-day period exactly as instructed. While the overall small amount of errors in the implementation intentions group could be regarded as a possible study limitation from a psychometric point of view, from an applied perspective, this result is exactly what we were aiming for as the goal was to find a method that enhances performance at the maximum. This is only the second study to demonstrate this effect and therefore corroborates Liu and Park's (2004) findings using a different task critically allowing a more generalized conclusion. This effect is even more impressive given the fact that participants in the control condition showed higher levels of education, which was related to better medication adherence behavior in former studies (Rose et al. 1996; Velicer et al. 2007) and reported higher prevalence of cardiovascular diseases, which should lead to a higher level of personal task importance. Thus, our result indicates that a high level of education and personal concernment is not enough to perform health-related behavior as prescribed and underlines the power of the implementation intentions strategy.

While implementation intentions seem to be an effective strategy to improve everyday prospective memory performance, an issue of considerable importance both from an applied and a conceptual perspective is whether this applies for all older adults or whether implementation intention effects are moderated by other variables. The conceptual debate has been initiated by several authors (e.g., Gollwitzer 2006; Liu and Park 2004; Park et al. 2007); yet, so far, there has not been much research to identify those variables in general and especially in older participants. Thus, the interaction effect revealed (and the ones not revealed) in the present study adds to this debate and it is perhaps the most important finding that only older adults with low fluid mechanics profited from the formation of implementation intentions. Post hoc tests only revealed a small and non-significant difference in the implementation intentions condition between participants with high and low fluid mechanics (odds ratio = 1), whereas in the control condition, participants with low fluid mechanics show a significantly greater non-adherence rate than participants with high fluid mechanics. Based on the odds ratio, these participants were 2.04 times more likely to forget the PM task. Hence, the present study strongly suggests a moderating influence of fluid mechanics on the efficacy of the implementation intentions strategy. Conceptually, this finding dovetails with assumptions about the mechanisms of implementation intentions as according to Gollwitzer (1999), the formation of implementation intentions creates a strong mental behavior-cue link, which leads encountering the specific situational cues automatically to the performance of the desired behavior. Thus, relying on rather automatic processes, the strategy of implementation intentions seems to compensate losses in fluid mechanics, leading participants with low fluid mechanics resources to perform as well as participants with high fluid mechanics resources. Positive effects of implementation intentions have also been found for different clinical populations with restricted cognitive resources, e.g., frontal lobe patients (Langfelder and Gollwitzer 2001) or schizophrenics (Brandstätter et al. 2001; Gollwitzer and Sheeran 2006), but to our knowledge, the current study is the first to find a moderation effect of fluid mechanics on implementation intentions in a non-clinical sample. Moreover, this result qualifies the finding from McFarland and Glisky (2011) and is in line with their initial conceptual expectations. They assumed, based on former research, that cognitively high functioning participants in the control condition would have spontaneously developed more specific plans (McFarland and Glisky 2009) and created a stronger link between cue and intention (Glisky et al. 1995, 2001; Glisky and Kong 2008) than did cognitively low functioning participants in the control condition. Given the different prospective memory tasks used in the study from McFarland and Glisky (2011) and in the current one, it is

plausible to assume that it was easier to spontaneously develop specific plans and strong cue-action associations for high functioning participants in the control condition in the present study as participants exactly knew the environment and the general circumstances from the situation where they were going to execute the intended action. In addition, it could be that participants in the current study were higher motivated to successfully complete the given task and therefore activated all their resources as former research has shown that older adults are more motivated to fulfill naturalistic than lab-based prospective memory tasks (Schnitzspahn et al. 2011).

Contrary not only to our exploratory assumptions but also to some prior research on young adults (O'Cleirigh et al. 2007; Webb et al. 2007), conscientiousness did not influence implementation intention effects. However, with 37 out of 39 participants showing conscientiousness ratings above 3.5 and 30 participants with values between 3.5 and 4.5 on a 5-point likert scale, participants showed homogeneously above-average conscientiousness, making the discovery of in-group differences possibly too difficult. Importantly, this result is in line with studies showing generally increased conscientiousness in older adults (Cuttler and Graf 2005), which was already suggested as one possible explanation for the general age benefit found in naturalistic prospective memory tasks (Phillips et al. 2008) and may also point to critical age differences in the effects of conscientiousness. In addition, former studies suggesting interaction effects between conscientiousness and implementation intentions investigated the influence of personal traits on behavior changes through implementation intentions over a longer period of time. Webb and colleagues (2007), for example, found a moderation effect for conscientiousness on implementation intentions in a sample of students for class attendance over a whole semester (8 weeks). Even though task importance may be similar to both samples (class grade vs. health), the quantity of the required behavior and the examined period are different, suggesting that personal traits such as conscientiousness might become more important in the long run, when obstacles get in the way and hinder the initiation of the intention. Thus, further research should aim to examine the influence of conscientiousness on the effect of implementation intentions in long-term health-related behavior, especially in old age.

Results concerning self-efficacy effects on health behavior showed a similar pattern. With all participants showing a medium to high score in the General Self-efficacy Scale (Schwarzer and Jerusalem 1999), the homogeneity of the group might again be the reason for this result. Bandura (1997) points out that self-efficacy increases with experience, which often goes along with advancing age, making it more likely for people in old age to show a general high self-efficacy, which is what we found and may distinguish our participants from younger adults tested in former studies (Schwarzer and Renner 2000; Schwarzer et al. 2008). Only two studies so far investigated the effect of self-efficacy on the strategy of implementation intentions in younger populations (Koestner et al. 2006; Wieber et al. 2010). Contrary to these two studies, we assessed self-efficacy as a personality trait rather than manipulating it, which might be related to differences in results. Further research should focus on between-group comparisons deliberately using participants with high and low self-efficacy or experimental manipulations and directly compare young and older adults to clarify if high self-efficacy influences the implementation intention effect.

The result of the current study concerning the influence of individual differences in the stability of lifestyle on everyday health-behavior performance contradicts the previous finding of Park and colleagues (1999) which showed that most non-adherent adults were those who led a hectic, non-routine lifestyle. One possible explanation for the present finding lies in the (not unrealistic) participants' possibility to choose their times individually, which may have offered participants with a rather unstable lifestyle the opportunity to choose times in which stable context cues were available (e.g., before going to bed or after getting up). Moreover, through the fact that all participants were retired, their busyness of lifestyle might be limited as they can influence and control their daily schedule by themselves. Hence, the current study seems to suggest that if participants can choose their own medical regiment, stability of lifestyle seems not to play an important role in medical adherence behavior and on the effectiveness of implementation intentions.

Possible limitations of the present study comprise the sample size. However, even with this rather small experimental study (which notably, however, included a sample size of similar or higher magnitude as McFarland and Glisky 2011 or Liu and Park 2004), the interesting interaction between instruction and fluid mechanics reached significance. Of course, due to sample size, the present results do not rule out the theoretical possibility that the other moderators tested may exert a small influence on implementation intention effects. However, their influence seems to be relatively minimal, given the small effect sizes revealed.

One could further argue that the inclusion criteria of no former blood pressure monitoring experience limit the ecological validity of the used task as none of the participants really needed to monitor their blood pressure. However, as we aimed to test the general usefulness of an implementation intention strategy, it was important to control for former experience in the given task which might have blurred our results. This approach is also in line with former research (Liu and Park 2004). Nevertheless, future studies should examine if the present results are also true

for patient populations and over a longer testing period. As blood pressure monitoring is usually a permanent requirement for older adults having problems with high blood pressure, it would be also interesting to test if an implementation intention strategy can provide long-term effects. Furthermore, future studies should include a baseline measurement of prospective memory performance, as the instruction effect would be even more convincing in a design allowing for within-participant comparisons and controlling for possible baseline differences.

Another possible limitation is the fact that we cannot completely rule out that participants used strategies to enhance their task performance given the naturalistic setting of the used prospective memory task. However, this seems most unlikely due to the following two reasons. Firstly, participants were explicitly asked not to use reminders or strategies during the task instructions. Secondly, the experiment was followed by an informal assessment in which we asked if the participants used strategies or did something to enhance their task performance. Most of the participants did not mention anything in this interview, while some only referred to actions to prepare carrying out the task.

As mentioned above, the overall small amount of errors in the implementation intentions group could be regarded as a possible study limitation from a psychometric point of view. Accordingly, the interaction between fluid mechanics and instruction has to be interpreted with caution. While the applied goal of the present study was to find a method that enhances performance at the maximum, further studies on the effectiveness of implementation intentions and possible moderators should verify the result by using a procedure that provokes more variance in performance.

All in all, the present study showed that an everyday prospective memory health task is performed far away from perfection in older adults, but that performance can be clearly enhanced (almost up to perfection) by using implementation intentions. Thus, this rather simple strategy may be recommended for intervention programs targeting health prospective memory tasks in the elderly. However, the present results also suggest some additional constraints as this seems to be especially (or only) true for those showing cognitive decline and therefore needing the most help to maintain a good performance level, as the current study could show that participants with low cognitive resources profited most from the formation of implementation intentions.

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