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REGISTERED REPORT

Adult age differences in remembering gain- and loss-related intentions

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ABSTRACT

Motivational and emotional changes across adulthood have a profound impact on cognition. In this registered report, we conducted an experimental investigation of motivational influence on remembering intentions after a delay (prospective memory; PM) in younger, middle-aged, and older adults, using gain- and loss-framing manipulations. The present study examined for the first time whether motivational framing in a PM task has different effects on younger and older adults' PM performance ($N = 180$; age range: 18–85 years) in a controlled laboratory setting. Based on lifespan theories of motivation, we assumed that the prevention of losses becomes more relevant with increasing age: We expected that older adults show relatively higher PM performance in a task with loss-related consequences following PM failure than in a task in which successful PM leads to gains. The opposite pattern of performance was expected for younger adults. The findings suggest that the relevance of reward and positive gain-related consequences for successful remembering appears to decrease with age. As hypothesised, a motivational framing × age interaction indicated that age differences in memory performance were smaller with loss-related than gain-related consequences, supporting a loss-prevention view on motivated cognition.

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A key proposition of lifespan psychology is that human development, at any point in life, involves both gains and losses in various domains, such as cognitive functioning, physical health, and social relationships (Baltes, 1987). However, the relative frequency of gain-related and loss-related events changes across adulthood: Younger adulthood is a period with a broad and growing range of developmental opportunities, in which gains predominate, whereas losses and resource limitations become increasingly pertinent in older adulthood (Baltes et al., 1998). Hence, the overall ratio of gains to losses becomes smaller and less favourable with increasing age. There is also agreement among adults of different ages in their expectations of prevailing gains in younger adulthood and increasing losses in later adulthood (Heckhausen et al., 1989; Mustafic & Freund, 2012). Correspondingly, people's goal orientation appears to shift from a predominant focus on achieving gains in younger adults towards an increased importance of maintenance in middle-aged adults and loss avoidance in older adults (Ebner et al., 2006; Freund, 2006; Heckhausen, 1999; Ogilvie et al., 2001; Staudinger et al., 1995).

In the proposed research, we investigated if and how gain- and loss-related consequences may affect memory for intended actions across adulthood. Based on a motivated-cognition perspective—which holds that motivational orientation guides perception, attention, and higher-order cognitive processes—we assumed that age differences in motivational orientation systematically impact memory. In what follows, we first discuss findings about the relative impact of positive and negative consequences on younger and older adults' memory. We then sketch research on adult age differences in memory for

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intended actions. Finally, we describe the experimental approach that we used to investigate memory for gain- and loss-related intentions in young, middle-aged, and older adults.

The relative impact of gains and losses on remembering

Positive–negative asymmetries in younger adulthood

A wealth of research on human cognition and emotion suggests that people experience gains or losses as positive or negative changes that have different impact on behaviour (e.g. Cacioppo & Berntson, 1994; Kahneman & Tversky, 1984; Rozin & Royzman, 2001). One important finding from this literature is that negative information often affects people more strongly than positive information (Baumeister et al., 2001; Peeters & Czapinski, 1990). However, a notable exception from this pattern seems to be memory functioning: Based on extensive reviews of the literature, Matlin and Stang (1978) concluded that positive information is remembered better than negative information due to selective rehearsal and compensatory processes in long-term memory. Moreover, negative associations tend to be weaker and less common than positive associations; as memories fade, they decrease less strongly for positive than negative experiences. For these reasons, people remember positive information more easily and quickly than negative information (Taylor, 1991). The majority of the studies on positive–negative asymmetries in memory have been conducted with younger adults (mostly undergraduate students in their early twenties). In the next section, we consider the literature on positive–negative asymmetries in older adulthood.

Positive–negative asymmetries in older adulthood

Age-related differences in many cognitive processes, including learning, recognition, and recall, suggest that younger and older adults evaluate positive and negative information differently (Mather et al., 2005; Spaniol et al., 2008; for overviews, see Murphy & Isaacowitz, 2008; Scheibe & Carstensen, 2010). Based on the literature, two different patterns regarding the relative impact of gain- and loss-related consequences could be expected: Following a *loss-prevention view*, older adults' motivational orientation towards the prevention of losses might result in higher sensitivity to negative than positive information when information has to be remembered. This appears to be the case particularly when a motivational component is involved in the task, as is the case when remembering has a decision- or action-relevant function and when there is an opportunity of actually avoiding negative or achieving positive consequences (Depping & Freund, 2013). Alternatively, *socioemotional selectivity theory* suggests that, as future time perspective decreases across adulthood, people become increasingly motivated to optimise their affective well-being. To the extent that goals associated with emotional meaning and well-being become more salient with increasing age, older adults might remember more positive or less negative information than younger adults (e.g. Mather & Carstensen, 2005). Both perspectives have received empirical support (for overviews, see Depping & Freund, 2013; Freund et al., 2012; Murphy & Isaacowitz, 2008; Scheibe & Carstensen, 2010) and suggest that changes in motivational orientation during adulthood impact cognition. Given the strong motivational component in prospective memory (see below), it is surprising that there are no studies of age-related differences in remembering intentions that either lead to positive consequences or prevent negative ones. The aim of the current study was to address this issue.

Cognitive aging and remembering intentions

In the present research, we focused on the influence of goal orientation on memory for intended actions (prospective memory; PM). PM always involves the retrieval of an intention as part of a goal-directed, declarative plan (e.g. Cohen & Hicks, 2017; Kliegel, McDaniel, et al., 2008; Smith, 2008). Therefore, motivational orientation likely plays a central role in PM tasks. Its inherent future orientation could make PM particularly sensitive to motivational influence and to information about looming losses or gains—perhaps more than other memory tasks. However, the role of motivational orientation in PM is unclear. Our central assumption was that changes in motivational orientation across adulthood may explain performance differences in memory for gain- and loss-related intentions. Specifically, the degree to which PM intentions are relevant for people of different ages should reflect their prior motivational orientation. Based on this thesis, we aimed to address the following research questions: With increasing age, are intentions associated with prevention of losses better remembered than intentions associated with the promotion of gains? Does goal orientation have similar impact on PM as it has in other tasks with different measures (e.g. self-report measures, Ebner et al., 2006; persistence, Freund, 2006)? How do cognitive processes involved in PM reflect these motivational changes?

The cognitive processes underlying age differences in PM have been extensively investigated (Einstein & McDaniel, 1990; Henry et al., 2004; Maylor et al., 2002; Smith & Bayen, 2006; Uttl, 2008; Zimmermann & Meier, 2006). The predominant finding from laboratory studies is that younger adults outperform older adults in time-based PM tasks (remembering to perform an intended action at a specific clock time; e.g. "attend a meeting at 2 pm") and event-based PM tasks (remembering to perform an action when a target event occurs; e.g. "buy bread when you pass the supermarket"). The magnitude of adult age differences in PM depends on task characteristics. Age differences are usually smaller in PM tasks in which salient cues support retrieval and reduce the strategic demands of monitoring the environment (Craik, 1986; Kliegel, Jäger, et al., 2008; Park et al., 1997).

However, there are also important "noncognitive" factors that may influence age-related differences in PM, such as emotional and motivational changes. So far, surprisingly little is known about the role of age-related changes in motivational orientation for PM: Why are specific intentions perceived as more relevant and remembered more accurately than others by younger and older adults? Intentions related to personal goals are likely perceived as important and may thus yield good PM performance through beneficial encoding strategies, high accessibility, or facilitated retrieval from memory (e.g. Penningroth & Scott, 2007). So far, several studies have manipulated the importance of PM tasks in younger adults through instructions and found that importance increases PM performance (Kliegel et al., 2001; Smith & Hunt, 2014); moreover, a few studies of PM included monetary or non-material incentives (Aberle et al., 2010; Brandimonte et al., 2010; Cook et al., 2015; McCauley et al., 2009; Meacham & Singer, 1977). In line with the assumption that the motivational intensity to reach a goal can be moderated by the magnitude of potential reward (Atkinson, 1957), these studies typically found that incentives increased PM performance (presumably through perceived importance) in younger adults (for an overview, see Walter & Meier, 2014). There is also initial evidence from this research that younger adults' PM performance increases in the presence of both reward and punishment, relative to non-incentivized control conditions (Cook et al., 2015). This work provides an important starting point for our proposed PM research on age differences in motivational orientation. As of yet, there are no attempts to link this line of research with lifespan theories of motivation and extend it to encompass the entire phase of adulthood.

The current study

In the current study, we addressed the motivation-cognition interplay in the domain of PM and conceptually brought together separated perspectives from cognitive, aging, and motivation research. The study focused on gain- and loss-related consequences of remembering and forgetting intended actions. We planned to test central hypotheses about the motivational impact of gains and losses from a theoretical lifespan perspective, suggesting that intentions related with the maintenance/avoidance of losses are relatively better remembered than gain- or growth-related intentions by older adults (whereas a reversed pattern was expected for younger adults).

Aging research about specific valence effects has yielded mixed findings (e.g. varying preferences for positively or negatively valenced stimuli, dependent on the decision context and type of task; e.g. Depping & Freund, 2013; Murphy & Isaacowitz, 2008; see also Grühn et al., 2005). Moreover, little is known about the role of adult age differences in motivational orientation in PM. We therefore conducted a preregistered study in a controlled laboratory setting to document our main predictions, our planned methods, and analyses in advance. We used the standard experimental paradigm of event-based PM (Einstein & McDaniel, 1990) to examine the impact of motivational framing manipulations on PM. In the PM paradigm, participants are engaged in an ongoing activity (e.g. a lexical decision task) while they have to additionally remember to perform an intended action (PM task; e.g. press an atypical key) when a specific event occurs (e.g. when the word *tiger* appears). The PM task is embedded in an ongoing activity because PM in everyday life rarely occurs in isolation and successful execution of an intended action typically requires the interruption of other ongoing activities. For example, one may be riding the bike and attending to the traffic, but then has to remember to stop at the supermarket to buy bread on the way home from work.

To investigate how age differences in motivational orientation affect PM, our planned laboratory study included two key predictor variables that are expected to influence PM: (a) participants' chronological age and (b) the type of consequence (gains following PM hits; or losses following PM misses). Participants between 18 and 85 years of age experienced gains and losses, contingent on their event-based PM performance. In a gain-frame condition, participants were informed that successful PM led to gains (accumulation of money or points); by contrast, participants in a loss-frame condition were instructed that PM failure led to losses (deduction of money or points). Thus, we framed the consequences of PM success or failure in terms of gains or losses, respectively. Similar framing manipulations in the laboratory have been applied in PM research only with younger adults so far (Cook et al., 2015).

Instructional framing has robust impact on people's decision making (Kahneman & Tversky, 1984; Kühberger, 1998) and research has shown that framing can have lasting effects on health-related and financial behaviour (McNeil et al., 1982; for an overview, see Rothman & Salovey, 1997). Moreover, for younger adults, messages framed to be congruent with their motivational orientation have been found to be more effective in inducing desired behaviours than messages incongruent with their motivational orientation: When given loss-framed messages, avoidance-oriented people showed higher compliance than approach-oriented people (and vice versa with gain-framed messages; Mann et al., 2004; cf. Idson et al., 2000). To the extent that motivational orientation changes across the lifespan from promotion of gains to prevention of losses, loss-framed manipulations may be more effective in older than younger adults, and vice versa with gain framed-manipulations.

Hypotheses

Based on the aforementioned considerations, we made the following predictions: Regarding PM performance as the main dependent variable (proportion of accurate responses on PM target events), we expected different effects of gain- and loss-framing on PM as a function of age: We thus hypothesised motivational framing × age interactions in PM performance (H_1). To the extent that older adults are more motivated to avoid losses than to achieve gains, they should be particularly sensitive to negative consequences and to show relatively better PM with loss-related than gain-related consequences. Alternatively, according to socioemotional selectivity theory and the related assumption of a positivity effect in older adulthood, older adults should show a stronger focus on positive than negative consequences, which would result in better PM with gain-related than loss-related consequences.

We further expected adult age differences in PM performance (H_2), based on previous cognitive aging research on PM (e.g. Kliegel, Jäger, et al., 2008; Smith & Bayen, 2006): Older adults in an event-based laboratory PM tasks were expected to show lower PM performance than younger adults; for middle-aged adults, we expected an intermediate pattern of PM performance, lying between younger and older adults. Notably, following a loss-prevention view, this also implies that age differences in PM are smaller for loss-related than gain-related intentions ($H_{3.1}$). Alternatively, following socioemotional selectivity theory and the related assumption of a positivity effect in old age, the age differences should show the reversed pattern, namely smaller age differences in PM for gain-related compared to loss-related intentions ($H_{3.2}$). These key predictions of motivational influence and cognitive aging on PM are schematically depicted in Figure 1 (panel a). Finally, we expected higher PM in groups with performance-contingent payoffs than in control groups, in which payoffs were not tied to performance, because motivational incentives typically enhance memory performance (H_4).

Regarding ongoing-task performance, we expected age-related slowing (H_5), which has been observed in many investigations of cognitive performance (Verhaeghen & Salthouse, 1997); this includes previous studies that focused on younger and older adults' ongoing-task response time and accuracy in the PM paradigm (e.g. Horn et al., 2013). That is, we expected older adults to respond slower in an ongoing task (lexical-decision task) than younger adults.

Method

Design

Our design included the between-subjects factor *motivational framing*, with three levels (gains; losses;

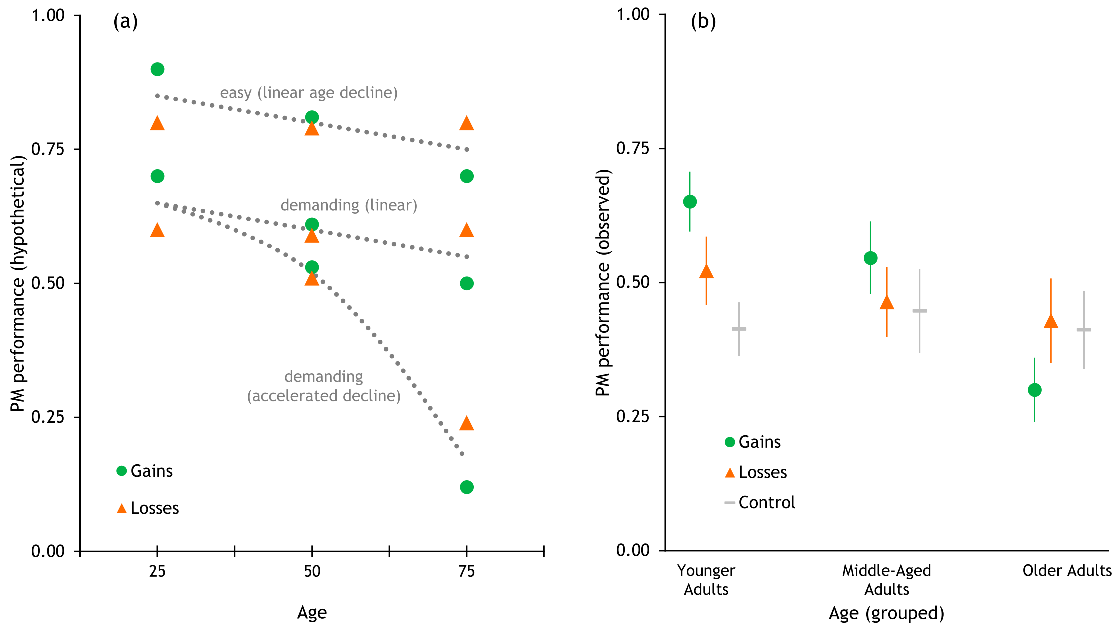

Figure 1. Panel a: Schematic illustration of PM performance as a function of chronological age for intentions with gain-related (green) and loss-related (orange) consequences from a loss-prevention view. Three hypothetical performance trajectories (grey dashed lines) are shown: Linear age-related decline in cognitively less demanding and more demanding PM tasks (e.g. event-based vs. time-based PM tasks). For tasks with accelerated age-related decline (that have been reported for complex PM tasks in particular), larger age differences in PM performance are conceivable. However, following the predictions of the loss prevention view, a relative advantage for loss-related over gain-related PM in older adulthood is expected. In all scenarios, motivational framing × age interactions are expected. Panel b: Observed PM performance in the study (means and standard errors) as a function of condition and age (grouped for younger, middle-age, and older adults).

control). Participants were randomly assigned to one of the three experimental groups with equal probability. Research on human memory in general and on PM in particular has often ignored the population of middle-aged adults. This is a missing pillar in much of the lifespan research on motivated cognition (Freund & Isaacowitz, 2013). Therefore, we included middle-aged adults in the proposed study. To achieve a sufficiently homogenous age distribution, we planned to sample an equally large number of younger adults (18–35 years of age), middle-aged adults (36–65 years), and older adults (66–85 years) within each experimental group. Participants' chronological age was then entered in regression analyses as continuous predictor variable (to avoid loss of information through categorising the age variable), but in case of significant interactions, additional follow-up tests within the three age groups were also possible.

Participants and sample size

Participants were native speakers of German with no cognitive impairments (e.g. dementia or stroke) and at least 18 years. We collected data from community-dwelling older, younger, and middle-age adults through a laboratory database and additional recruitment at locations such as gyms or community centres. Participants received credit points or a flat fee for participation (CHF 15 per hour) plus a performance-contingent bonus (for more detail see below). If a participant's data could not be used for analysis (see below for exclusion criteria), their data was replaced (before hypothesis testing) by collecting data from a further participant to achieve the planned sample size.

Previous meta-analyses indicate that the magnitude of age effects in PM depend on task characteristics (Henry et al., 2004; Kliegel, Jäger, et al., 2008; Uttl, 2008). There is converging agreement from this literature that age differences in demanding laboratory PM tasks (which we planned to implement in the current study) are medium-to-large, with reported effect sizes of $d = .72$ (Kliegel, Jäger, et al., 2008), *ds* = .77–1.13 (Uttl, 2008), and $d = 0.87$ (Henry et al., 2004). Notably, the authors in these meta-analyses also evaluated potential publication biases: Kliegel et al. (p. 206) concluded that there was "no evidence of a potential confound (…) due to publication bias" in the considered studies. Regarding motivational incentive manipulations, previous experiments with younger adults also yielded medium-to-large effect sizes of $d = .80$ (Cook et al., 2015).

Based on our central prediction for the primary criterion variable (i.e. a motivational framing × age interaction in PM performance) we calculated the required total sample size in a multiple regression model (with age, motivational framing, and their interaction, as predictors of PM performance) to detect interaction effects of size $r = .25$ (equivalent to an effect size of $d \approx 0.5$ or $f^2 \approx .06$) with a statistical power of .90, given an alpha level of .05. Given these settings, an a-priori power analysis with the software G*Power3 (Faul et al., 2007) indicated a required total sample size of $N = 178$ participants to evaluate single regression coefficients (weights) using two-tailed t tests; moreover, with this sample size, it was possible to detect differences of $d = .50$ in PM performance between both treatment groups and the control group (as reference category) with a power of .90. Aiming at an equal number of younger adults, middle-age adults, and older adults in each of the three experimental groups, we planned to collect data from 180 participants. Notably, our power analysis assumed effects sizes that were ca. 33% smaller than those reported in previous meta analyses (e.g. Kliegel, Jäger, et al., 2008). A visualisation of achieved power as a function of sample size and population effect sizes is in the Supplemental Materials.

Procedures and materials

Laboratory tasks

The basic procedure of the laboratory task was implemented as follows: Participants first worked on a short block of practice trials with feedback (30–50 trials) to familiarise themselves with an ongoing lexical-decision task. Overly slow or fast responding (i.e. below 0.2s or above 4s) was discouraged by providing initial feedback ("too fast" or "too slow" messages). Following this practice phase, participants performed a block of a lexical-decision ongoing task alone (*baseline phase*). Participants then received instructions for a PM task that differed depending on the experimental/motivational group. After a short filler delay (at least 2 min), participants then performed a block of an ongoing task in which PM target events occurred (*ongoing + PM phase*). Finally, participants completed cognitive tests and questionnaires and were asked which key they were instructed to press upon encountering a target event (action-recall check).

For the sake of reliability, we aimed at a sufficient number of target events and at avoiding floor or ceiling PM performance (Kelemen et al., 2006); that is, we aimed at avoiding mean PM performance in a condition below 10% or above 90% accuracy (cf. Uttl, 2008). In line with previous PM research, relevant target events occurred only on a small proportion of all ongoing-task trials (< 5%) to avoid a scenario similar to a vigilance test (e.g. Graf & Uttl, 2001). Hence, our ongoing tasks were of sufficient length to avoid overly repetitive target appearances: We aimed at a lower bound of 300 ongoing-task trials, equally interspersed between 12 PM target events. We used a non-focal PM task in which the PM target events were defined by specific initial letters. Participants were asked to press an atypical key whenever a presented string on the screen (word or nonword) began with one of these letters (see the Supporting Information for an illustration). The detection of PM target events in such tasks is relatively demanding because the stimulus features that are relevant for target detection and for successful ongoing-task decisions do not overlap. Therefore, ceiling effects in PM performance are unlikely (e.g. Scullin et al., 2010). Moreover, to make the ongoing task sufficiently engaging, a relatively difficult stimulus composition in the lexical-decision task was used: The task included low- and very-low frequency words; nonwords were created by randomly replacing only one vowel in a given word by another vowel. The proportion of correct lexical decisions in such tasks is typically below .90 (Horn & Bayen, 2015).

Motivational manipulation

The PM instructions differed between groups. Participants in a gain-frame group were informed that they could accumulate money (up to 6 CHF)—contingent on the proportion of PM target events that they responded to correctly (*PM hits*). Participants in a loss-frame condition were initially endowed with an amount of 6 CHF, from which losses could be deducted; participants in this condition were informed that they could maintain their full starting amount, but that they would lose up to 6 CHF, contingent on the proportion of PM target events they would miss (*PM misses*). Finally, in a no-frame control group, participants received standard PM

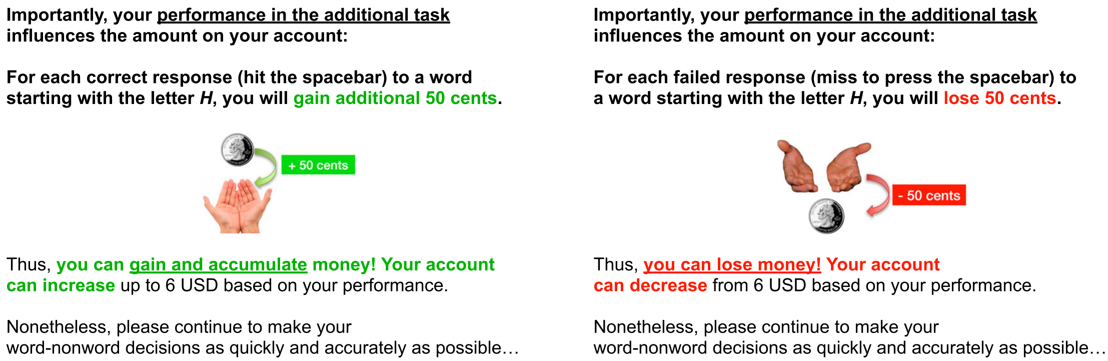

Figure 2. Example instructions for an event-based PM task inducing a gain frame (left) or a loss frame (right). The expected magnitude of performance-contingent payoffs was held identical, but the consequences and framing in terms of gaining or losing after remembering or forgetting to respond to target events, respectively, was manipulated.

instructions and an additional flat fee that was not contingent on PM performance (the typical situation in many previous PM experiments, in which only a fixed reimbursement was provided). This allowed us to evaluate baseline PM performance and to contrast people's intrinsic motivation to perform the PM task with conditions in which external consequences occur (cf. Brandimonte et al., 2010, for a study with young adults). Figure 2 shows an example of the basic instructions that we used to induce a motivational gain- or loss-framing. This basic procedure has been successfully tested in previous piloting work and a similar approach has also been taken in one study with younger adults (Cook et al., 2015).

Type of payoff

Younger adults may sometimes care more about money, whereas non-monetary consequences may matter more for older adults (e.g. Freund & Blanchard-Fields, 2014); therefore, providing the same type of consequences for all participants can have different effects across age groups. To better match the subjective value of the same amount of payoff across participants of different age, we therefore applied a previously tested procedure in which participants could initially choose which amount (percentage) of the subsequent payoffs they wished to keep for themselves or to donate to a humanitarian organisation (Doctors Without Borders; www.doctorswithoutborders.org) after the study. Allowing participants to choose their type of incentive may be viewed as what economists call a "revealed preference" (e.g. Samuelson, 1948). Instead of assuming that the same amount of money has the same value across participants, we let participants themselves set their preferred incentive combination in the experiment. Allowing optional choice between donations and direct monetary payments may thus account for the observation that some participants (particularly older adults) in past studies expressed that they do not want to be financially reimbursed (Freund & Blanchard-Fields, 2014). In order to use motivational incentives that are appealing to younger, middle-aged, and older adults, a flexible amount of earnings (i.e. between 0 and 100%) during the study could be optionally donated. Winning or losing a small amount of money (e.g. CHF 1) might not matter much to some study participants, but it may matter as a donation, given that CHF 1 can provide medical treatment of approximately six children suffering from malaria or two portions of additional nutrition for malnourished children. To stress the value of even small amounts gained or lost, participants were informed about these facts before the study and earnings were calculated and determined the actual donation later made to the charity. In an additional analysis, we statistically examined whether the type of payoff might have influenced people's performance (see section "additional data analyses").

Demographic variables and cognitive tests

We collected additional measures to characterise the sample of participants. This also allowed us to examine individual differences and potential covariation between motivational, economic, and cognitive variables in exploratory analyses.[1] The following information was collected from the participants: basic demographic information (including information about chronological age, gender, ethnicity, wealth and yearly income); short measures of fluid cognitive abilities (digit-symbol substitution) and crystallized abilities (spot-a-word vocabulary test); brief scales of loss aversion (Gächter et al., 2007) and social-value orientation (Murphy et al., 2011); personal goal orientation towards gains and losses (Ebner et al., 2006); baseline positive and negative mood (Watson et al., 1988); a prospective and retrospective memory questionnaire (Smith et al., 2000). Moreover, we included post-task memory questions about the required PM action and about the PM target items to check whether participants understood the instructions. As a manipulation check of the impact of framing instructions and of the perceived relevance of performance-contingent consequences, participants provided importance ratings regarding (a) the perceived importance to perform the PM task accurately, (b) the personal relevance of performance-contingent consequences (i.e. of gaining or losing points), and (c) the perceived importance to perform the ongoing tasks accurately. Further information about additional variables collected in the study and about cognitive tests is in the Supporting Information.

Ethics and open science policy

The study did not involve deception. All participants were reimbursed for their participation (flat fee) and monetary payoffs were provided after study completion. The data from the study, the materials, and analysis files are openly available through the Zenodo research data repository (doi.org/10.5281/zenodo.4923321) and the Open Science Framework (doi.org/10.17605/osf.io/9pwcd). Data are available in anonymized form in which participants' privacy is strictly maintained.

Planned analysis

Data exclusion

Data from participants who performed at chance level in the ongoing task were excluded from analyses (i.e. if ongoing-task accuracy, averaged across trials, was statistically indistinguishable from chance). Moreover, we excluded participants who never responded to any PM target event and additionally could not indicate in a post-task instructional check the PM key they were asked to press when encountering a target. These exclusion criteria are common in PM research to ensure that participants are adequately engaged in an ongoing activity and that PM failure is not attributable to forgetting the required action or PM instructions (e.g. Smith & Bayen, 2006). Moreover, single ongoing-task trials with extreme response times were discarded from data analysis (i.e. trials with response times more or less than 2.5 *SD*s from an individual's mean in a condition or fast guesses shorter than 0.2s).

Data quality and manipulation checks

First, the analysis of ongoing-task performance allowed us to check whether participants performed the tasks with sufficient accuracy (the power for this check was sufficiently large, > .90, in each group). Second, we tested whether PM performance was significantly above floor (>10% mean accuracy) and below ceiling level (<90% mean accuracy). We only tested our hypotheses and made further conclusions if this check was passed. Third, participants' importance ratings of the PM task, of the ongoing task, and of performance-contingent consequences (i.e. of gaining or losing points) were used to additionally evaluate the impact of the motivational manipulations. Finally, we included an additional control group in our design in which participants did not experience any external gain- or loss-related consequences (i.e. the standard situation in many previous cognitive PM experiments, in which only a fixed reimbursement was provided). This allowed us to evaluate baseline PM performance and to contrast people's intrinsic motivation to remember PM tasks across adulthood with conditions in which external monetary consequences occur.

Main data analyses and hypothesis testing

We statistically tested our hypotheses in the following way: Regarding PM performance as dependent criterion variable (proportion of correct PM responses on target events), we specified a linear multiple regression model with motivational framing (gain; loss; control) as effect-coded predictor and chronological age as mean-centered continuous predictor. The corresponding regression weights could then be evaluated with standard *t*-tests: First, to test hypothesis H_1, the weight of the framing × age interaction in the regression model was examined; in case of a significant framing × age interaction ($p < .05$), we conducted follow-up tests. These follow-up tests were implemented by examining, within the group of younger adults (18–35 years), middle-aged adults (36–65 years), and older adults (66–85 years), respectively, whether gain-framing led to a relative advantage in PM over loss-framing, or vice versa. Second, hypothesis H_2 was supported if the regression weight of age in the model was significant. Hypothesis H_3 could be tested by examining effects of age separately for gain and loss conditions. Finally, a planned contrast between both treatment groups and the control group (as reference category) served to test hypothesis H_4. Regarding ongoing-task performance, we specified a linear multiple regression model with participants' median response time (aggregated across trials of each person) as dependent criterion variable. Again, motivational framing (gain, loss, control) and age were entered as categorical and continuous predictors, respectively. If there was age-related slowing in ongoing-task performance (hypothesis H_5), then the effect of age in the regression model should be significant. A separate regression model (including the same predictors) served to evaluate participants' ongoing-task accuracy (mean proportion of correct lexical decisions) as criterion.

Additional data analyses

Two further analyses addressed the influence of potentially relevant covariates in the proposed study.[2] First, to examine whether people's survey-assessed motivational orientation (Ebner et al., 2006) also accounted for PM performance, we included the experimental framing condition, people's motivational orientation scores on three dimensions (orientation to gains, losses, maintenance), and the corresponding framing × orientation interactions as predictors in a multiple regression model. This made it possible to examine to what extent motivational-orientation scores accounted for memory performance, whether some of the three motivational dimensions accounted for relatively more performance-related variability than others, and to check the robustness of the main findings when other predictors were considered. Second, to examine whether the type of payoff moderated the relation between chronological age and PM performance (in the groups that receive performance-contingent payoffs), we ran an additional multiple regression in which the predictors age, framing, and type of payoff (amount kept for self vs. donation) and the interactions of age × framing and age × payoff-type were included.

Results

We collected data in a laboratory at the University of Zurich from 180 adults who met the prespecified inclusion criteria. Five participants performed the ongoing task at or below chance level and were thus replaced, following our preregistered exclusion criteria.[3] The alpha level for the statistical tests was set at .05. The data-quality checks indicated that mean PM performance in each experimental condition was significantly higher than .10 and lower than .90, respectively (all ts > 8.37; all ps < .001), and that each participant completed the ongoing-lexical decision task at above-chance-level accuracy, allowing us to analyze the data following our preregistered plan. In what follows, we first present the results of the confirmatory main analyses. We then report exploratory additional analyses, in which we examined statistical relations among further variables. Characteristics of the participants are presented in Table 1 (including demographic information, scores from cognitive, motivational, and further self-report scales).

Confirmatory analyses

Task-performance variables (as a function of experimental condition and age group) are shown in Table 2. PM performance is visualised in Figure 1 (panel b). The results from the planned multiple regression analyses are in Table 3.

Memory performance

The predictor variables included in the regression model accounted for significant variability in PM performance, $R^2 = .10$, $F(5, 174) = 3.86$, $p = .002$. We first tested the hypothesis (H_1) of an interaction in PM performance between motivational framing and age. The age × gains interaction (but not the age × losses interaction) was significant. The pattern in Table 2 (see also Figure 1b) indicates that, particularly in the gain-fame condition, PM performance was lower in older than younger adults. Follow-up analyses indicated that PM performance differed between experimental conditions in younger adults, $F(2, 57) = 4.54$, $p = .015$, with a relative advantage in younger adults' memory performance in the gain-frame condition, $B = .40$, $t(57) = 2.67$, $p = .010$. In contrast, there were no significant differences in PM performance between experimental conditions in middle-aged or older adults (Fs < 1).

We next tested whether there were overall age differences in PM performance (H_2). This was the case: The regression coefficient for age was significantly negative, indicating age-related decreases in event-based PM performance, which is relatively

Table 1. Sample Characteristics and Their Correlations With Age and With Memory Performance.

Variables	*M* or %	(*SD*)	r_{Age}	$r_{PM\ gain}$	$r_{PM\ loss}$	$r_{PM\ control}$
Demographics						
Age (years)	50.83	(21.08)	—	−.49**	−.10	−.10
Gender (% female)	59%		−.13	−.02	−.12	−.05
Ethnicity (% European)	91%		−.22**	.21	.12	.05
Education level	4.16	(1.59)	−.06	.11	.12	−.02
Income level	2.88	(2.00)	.07	−.02	.21	.13
Laboratory task						
PM performance	.47	(.31)	−.23**	—	—	—
OT accuracy	.96	(.03)	.11	.38**	.36**	.31*
OT response time (in s)	1.41	(0.45)	.39**	.06	.34**	.11
Monetary motivation	52.63	(38.60)	−.21**	.30*	.34**	−.06
Importance OT	83.69	(22.49)	−.24**	.01	.06	−.09
Importance PM	77.39	(25.40)	−.15*	.44**	.41**	.45**
% payoff retained	48.64	(43.01)	.11	−.06	−.33*	—
Cognitive scales						
Speed	32.54	(10.05)	−.68**	.49**	.37**	.28*
Vocabulary	31.99	(2.83)	.36**	.10	.22	.10
Motivation/emotion scales						
Gain orientation	6.46	(1.24)	−.18*	−.22	.08	−.04
Maintenance orientation	5.96	(1.59)	.53**	−.11	−.07	−.01
Loss-avoidance orientation	5.58	(1.96)	.57**	−.34**	.04	−.02
Positive affect	3.22	(0.69)	.17*	−.08	.31*	−.06
Negative affect	1.35	(0.48)	−.16*	−.05	−.13	−.05
Social-value orientation	28.90	(13.78)	.03	.01	.21	.06
Further self-report scales						
Health	5.59	(1.03)	.00	.21	.10	.00
Life satisfaction	5.62	(1.01)	.03	.02	.18	.05
Prospective failures	3.76	(0.57)	.23**	−.07	−.11	−.16
Retrospective failures	3.91	(0.51)	.13	.03	.08	−.04

Note. PM = prospective memory; OT = ongoing task; ethnicity: 1 (*European*) to 8 (*other*); education ranges from 1 (*obligatory schooling*) to 6 (*university education*); yearly income ranges from 1 (< 39,000 CHF) to 8 (> 160,000 CHF) in increments of 20,000 CHF; r_{Age} = correlations with chronological age in years; $r_{PM\ gain}$, $r_{PM\ loss}$, $r_{PM\ control}$ = correlations with PM performance in the gain, loss, control groups, respectively; *$p < .05$; **$p < .01$

common in lab-based studies (e.g. Henry et al., 2004; Horn et al., 2013; Kliegel, Jäger, et al., 2008).

To test hypotheses $H_{3.1}$ and $H_{3.2,}$ and to further probe the interaction between age and framing condition, we regressed PM performance on age separately in each experimental condition. In the gain-frame condition, the regression coefficient for age was significantly negative, $B = -0.51$, $t(59) = -4.30$, $p < .001$. In contrast, in the control condition ($B = -0.09$) and loss-frame condition ($B = -0.11$) the regression coefficients for age were not significant (*ts* < 1, *ps* > .429). Given the framing × age interaction reported above, this indicates that age differences in memory performance were smaller for loss-related than for gain-related intentions ($H_{3.1}$). In contrast, there was no statistical support for an alternative view ($H_{3.2}$) of age differences being smaller for positive gain-related than loss-related intentions. In fact, the performance pattern pointed in the opposite direction.

To test whether performance-contingent incentives enhanced memory performance (H_4), we conducted an additional analysis to contrast performance in the control condition to performance in the gain/loss conditions (with the same predictors as in Table 3; but using Helmert-contrast coding for the experimental conditions: "incentivized vs. control" and "gains vs. losses"). Analysis of regression coefficients indicated no main effect of performance-contingent incentives on PM, $B = -0.19$, $t(174) = -1.26$, $p = .208$, and no general advantage of gain-related over loss-related consequences, $B = 0.08$, $t < 1$, $p = .636$. Thus, contrary to our expectation, performance-contingent incentives did not improve memory performance across the board. The incentive × age interaction was not significant, $B = 0.22$, $t(174) = 1.44$, $p = .151$. However, the advantage of gain over loss incentives was qualified by age, as indicated by a significant interaction: $B = -0.41$, $t(174) = -2.27$, $p = .025$. Follow-up analyses showed that in younger adults, incentives improved memory performance (relative the control condition), $B = -0.57$, $t(57) = -2.50$, $p = .015$, but that was not the case in middle-aged or older adults (all *ts* < 1.28, *ps* > .205).

Table 2. Task Performance (Prospective Memory, Ongoing Task) and Importance Ratings.

	M			*SE*		
	Younger adults ($n = 60$)	Middle-aged adults ($n = 60$)	Older adults ($n = 60$)	Younger adults	Middle-aged adults	Older adults
Age (years)	27	51	75			
PM performance						
gains	.65	.55	.30	.06	.07	.06
losses	.52	.46	.43	.06	.07	.08
control	.41	.45	.41	.05	.08	.07
OT accuracy						
gains	.96	.95	.97	.01	.01	.00
losses	.95	.96	.96	.01	.01	.01
control	.95	.96	.96	.01	.01	.01
OT response time						
gains	1228	1409	1518	84	90	87
losses	1200	1504	1586	79	92	115
control	1205	1326	1725	90	74	121
% payoff retained						
gains	46	49	59	9	11	9
losses	46	42	51	11	9	10
Importance PM						
gains	84	82	69	5	4	8
losses	77	86	73	6	4	5
control	73	79	72	5	6	5
Importance OT						
gains	87	85	85	5	5	6
losses	88	86	62	3	3	8
control	89	92	81	2	2	5

Note. PM = prospective memory; OT = ongoing task; PM performance = proportion of accurate responses on prospective-memory target events; OT accuracy = proportion of correct word and nonword responses in the ongoing lexical-decision task; response time = median response time in the ongoing task (in ms); Importance = self-report ratings (0–100) of participant's perceived importance of the tasks; payoff retained = percentage of performance-based payoff that participants kept for themselves.

Ongoing-task performance

To test the hypothesis of age-related slowing (H_5), we regressed participants' median response times on nontarget ongoing-task trials on the predictors age, experimental condition, and their interactions (Table 3). The predictor variables included in the regression model accounted for significant variability in response times, $R^2 = .16$, $F(5, 174) = 6.50$, $p < .001$. The regression coefficient of age was significantly positive (higher age was associated with longer response times), indicating age-related slowing in the ongoing task. There were no further significant effects or interactions (all *t*s < 1, *p*s > .439), suggesting that the motivational manipulations did not affect how quickly people responded in the ongoing lexical-decision task. Regarding ongoing-task accuracy, the included predictor variables did not significantly account for variability, $F<1$.

Table 3. Regressions of Task-Performance Variables (Prospective Memory and Ongoing Task) on Age and Experimental Conditions.

	Criterion Variable											
	PM Performance				OT Response Time				OT Accuracy			
Effect	Estimate	*SE*	*t*	*p*	Estimate	*SE*	*t*	*p*	Estimate	*SE*	*t*	*p*
Intercept	−.01	.07	−.08	.934	.00	.07	−.02	.986	.00	.07	−.02	.984
Age [a]	−.23	.07	−3.26	.001	.39	.07	5.55	.000	.11	.08	1.42	.157
Gains [b]	.11	.10	1.05	.297	−.06	.10	−.57	.570	.04	.11	.40	.693
Losses [c]	.02	.10	.23	.822	.05	.10	.52	.604	−.01	.11	−.05	.960
Age × Gains	−.27	.10	−2.67	.008	−.08	.10	−.77	.440	−.10	.11	−.92	.361
Age × Losses	.13	.10	1.27	.204	.01	.10	.06	.955	.11	.11	1.05	.294

Note. Planned tests of regression coefficients ($df = 174$) for hypotheses described in the section "Confirmatory Analyses". PM = prospective memory; OT = ongoing task; [a] continuous predictor variables were *z*-transformed in all analyses. [b] categorical predictors were effect-coded: −1 = control, 0 = losses, +1 = gains. [c] −1 = control, 0 = gains, +1 = losses.

Additional exploratory analyses

Memory performance and motivational orientation

We additionally explored if and how people's motivational orientation on three dimensions (motivational-orientation scores regarding gains, maintenance, loss prevention in personal goals) correlated with memory performance or interacted with the experimental incentive manipulations. As shown in Table 1, people's gain-orientation scores correlated negatively with age, whereas maintenance orientation and loss-avoidance orientation were strongly positively correlated with age. This is in line with previous research (e.g. Ebner et al., 2006; Gong & Freund, 2020) suggesting that the motivation to achieve further gains decreases with age, whereas the motivation to maintain available resources and to prevent further losses increases with age.

We then examined whether the scores from these motivational scales could account for variability in PM performance above and beyond age and the experimental manipulations. A multiple-regression analysis with the same predictors as in the confirmatory analyses and the added motivational scores (and their interactions with experimental condition) did not indicate systematic or significant relations between motivational-orientation scores and PM and also did not alter the main conclusions from the main analyses reported above (the additional exploratory analyses are in Supplement 4).

Because the items we used to measure motivational orientation involved participants' individual goals (cf. Ebner et al., 2006), it is possible that these items captured motivational aspects that were relatively distant from the intentions relevant in the lab-based cognitive task. We therefore asked participants more specifically how important it was for them to earn further money in the memory task (verbatim instructions are in the Supplemental Materials). Like gain orientation, this index of monetary motivation correlated negatively with age (see Table 1); in addition, monetary motivation correlated positively with PM performance in the gains and loss conditions, in which performance-contingent incentives were provided. Therefore, to explore whether a more task-specific motivational index could account for variability in PM, we also examined a regression model including monetary motivation as predictor. The analyses showed that monetary motivation did not significantly interact with (or alter) the effects of the other predictor variables (age, experimental condition); however, monetary motivation correlated positively with PM performance above and beyond the other predictors (as specified in the confirmatory analyses above). Moreover, a correlational analysis showed that monetary motivation could partially account for age-related variability in memory performance (Supplement 5 includes further details).

Memory performance and type of payoff

We next explored whether the type of incentive (the amount of money that participants either donated or kept for themselves) had an influence on memory performance or moderated the relation between age and performance in the gain and loss conditions. A multiple regression again indicated a negative effect of age on PM and a framing × age interaction (as reported in the confirmatory analyses section), corroborating the robustness of this pattern. Notably, however, payoff type also moderated the relation between age and memory performance: The age × payoff-type interaction was significant, indicating that age-related decreases in PM performance were less pronounced for those older participants who donated more of their earnings, and this was particularly the case for the loss-frame condition (Supplement 6). This suggests that the avoidance of monetary losses in a task might be particularly relevant (and stabilise task performance) when older adults plan to donate some of their earnings to charity.

Relation between age and further cognitive and self-report variables

The exploration of further cognitive and self-report variables (see Table 1) indicated several systematic relations with chronological age and with memory performance that are noteworthy for future research: First, chronological age correlated negatively with the perceived importance to perform the laboratory PM task and the ongoing task. At the same time, perceived task importance correlated positively with PM in all conditions, which suggests that older adults were generally less motivated in the computerised lab-based tasks than younger adults (regardless of specific incentives that were at stake) and that age differences in lab-based PM could be partially due to these motivational differences (e.g. Hering et al., 2014; Peter & Kliegel, 2018; Schnitzspahn et al., 2011). Second, chronological age correlated strongly negatively with cognitive speed, which in turn correlated positively with PM performance. This suggests that fluid cognitive abilities are important predictors of successful event-based PM and may statistically account for substantial age-related variability (see Supplement 7). Third, age correlated moderately positively with self-reported prospective memory failures (in the Prospective and Retrospective Memory Questionnaire; Smith et al., 2000)—but these ratings were uncorrelated with PM performance in the present study. This points to possible dissociations between the performance in lab-based memory tasks and adults' self-reported memory failures in everyday situations (see Arnold & Bayen, 2019; Meeks et al., 2007, for similar findings and further discussion).

Discussion

How do gain-related and loss-related consequences impact memory performance? Based on a well-documented motivational shift from a primary gain orientation to a stronger loss-orientation across adulthood (e.g. Freund et al., 2012), this registered report tested whether gains and losses impact prospective memory (PM) performance differentially across adulthood. This was the case: Age-related differences in PM were qualified by a motivational incentive manipulation, indicating that gain and loss incentives have different impact on performance across adulthood (hypothesis H_1). Specifically, the present findings showed larger age differences in PM performance for participants in a gain-frame condition than in a loss-frame condition (in line with hypothesis $H_{3.1}$, but not with $H_{3.2}$). The pattern of memory performance in the present study dovetails with a loss-prevention view on memory functioning (e.g. Depping & Freund, 2013), suggesting that older adults show relatively better performance in situations that permit the prevention of losses (or negative consequences) than the achievement of gains, whereas an opposite pattern is expected for younger adults. The loss-prevention perspective thus predicts a crossover across adulthood in performance with gain-related versus loss-related consequences, in line with the present findings (see also Figure 1a for a schematic illustration). However, the pattern of performance in the present study is difficult to reconcile with the notion of an age-related positivity effect (cf. Levin et al., 2021), namely, that older adults might be relatively better at remembering intentions associated with gain-related (or positive) information than loss-related (or negative) information than younger adults, due to emotion-regulation goals.

Notably, age-related decreases in the impact of gains on cognitive performance (relative to the impact of losses) have also been observed in other areas of aging and neuroscience research: For example, Frank and Kong (2008) reported that participants' age in a probabilistic learning task correlated positively with their tendency to learn from negative (compared with positive) consequences of their decisions. Freund and Keil (2021) found in an associative learning paradigm that younger adults formed gain-related associations at a higher learning rate than loss-related associations, whereas the reversed learning pattern was found in older adults. Rutledge et al. (2016) reported that the number of risky options chosen in a preferential decision task involving potential gains—but not potential losses—decreased gradually over the lifespan. Such age-related asymmetries in the impact of gain and loss outcomes on learning and memory performance have been largely attributed to age-related decline in dopaminergic neuromodulation (e.g. Eppinger et al., 2011; Frank & Kong, 2008). Moreover, computational modelling has suggested that the attraction to potential reward declines with age (e.g. Rutledge et al., 2016). Taken together, such findings indicate that particularly the impact of gains and rewards on learning and remembering may decrease across adulthood (see also Freund & Keil, 2021; Horn & Freund, 2021a). The present registered report demonstrated such a pattern for the first time for prospective remembering in a laboratory setting.

Contrary to our expectations (H_4), however, the comparison of PM performance in the gain and loss conditions with the control condition (in which participants received a flat fee that was not contingent on performance), did not indicate a main effect of incentivizing. Whereas incentives enhanced younger adults' performance (relative to the control condition), older adults' performance was not affected by incentivization (if anything, it was descriptively even lower in the gains than control condition; see Table 2). Thus, the lack of a main effect of incentives is largely due to the strong age-related decreases in performance the gain condition, with concomitantly relatively stable performance across age in the control condition. The similar levels of performance across age in the control condition may appear surprising, but this pattern dovetails with several earlier aging studies on event-based PM (e.g. Einstein & McDaniel, 1990).

Specifically, the use of a small number of simple targets (three initial letters) and of a self-paced lexical-decision ongoing task (which potentially required little cognitive control) might have contributed to that finding. In line with this interpretation, older adults reached high levels of lexical-decision accuracy that did not differ from younger adults', in line with previous research (e.g. Ball & Aschenbrenner, 2018; Horn et al., 2013). However, older adults needed more time to make their ongoing decisions than younger adults (supporting the hypothesis H_5 of age-related slowing; e.g. Verhaeghen & Salthouse, 1997).

The present study further showed that the links between self-report measures of motivational orientation, perceived task importance, and memory performance, are complex. First, participants' self-reports of motivational orientation (towards gains, maintenance, and loss avoidance) correlated in expected directions with chronological age (cf. Ebner et al., 2006)—but not with PM performance. Instead, more specific measures of participants' monetary motivation (i.e. reported motivation to earn additional money/points in the cognitive task) correlated with PM and accounted for age-related variability in performance. The lack of clear links between self-reports of motivational orientation and PM, but concomitantly stronger correlations with more task-specific measures (e.g. of monetary motivation and of perceived PM-task importance), may suggest that the measures must be sufficiently specific to tap into the relevant motivational processes for a given cognitive task. Moreover, self-reports of motivational orientation towards gains did not correlate with task-specific monetary motivation ($r = .02$, $p = .80$) (correlations between age, performance, and all motivational variables are in the Supplement). Second, participants' ratings of their perceived importance of the PM task correlated with memory performance, but did not differ between the experimental incentive conditions. That is, importance ratings and motivational incentives were uncorrelated and had independent effects on PM (see also Horn & Freund, 2021a). This could suggest that importance ratings and the incentive effects reflect two different motivational components (i.e. people's intrinsic interest in performing the tasks may not be tied to the motivational incentive manipulations). Alternatively, people might not be able to report how incentives influence their behaviour (e.g. because they do not have accurate introspective access or are unaware of how gains and losses affect their performance). Consistent with this, previous research on motivated cognition suggests that people's explicit ratings of positive/negative valence, their physiological responses, and their task performance may diverge (e.g. Braver et al., 2014; Freund & Keil, 2021).

We do not mean to imply that age-related decreases in cognitive performance can be completely reversed when motivational incentives are sufficiently strong. For instance, in attention-demanding PM tasks, age-related decreases can be generally expected. Moreover, it is well documented that older adults perform less well than younger adults in event-based PM in the laboratory (e.g. Ballhausen et al., 2017; Horn et al., 2013; Schnitzspahn et al., 2012; Zuber & Kliegel, 2020). Specifically, for event-based PM tasks involving so-called *nonfocal* target events (in which the target features are not necessarily relevant for the ongoing-task decisions) theories of PM have assumed that engagement of attention-demanding processes is necessary, directed toward identifying targets (e.g. Horn & Bayen, 2015; McDaniel & Einstein, 2007; Scullin et al., 2010). In line with this, we also found a main effect of age on PM performance, and additional exploratory analyses indicated that measures of fluid cognitive abilities (cognitive speed) accounted for substantial age-related variability in event-based PM.

Finally, we found that the percentage of payoff that participants decided to retain did not differ between younger and older adults: Whereas achieving financial incentives for performance (monetary motivation) was less relevant for older than younger adults, chronological age was uncorrelated in the current study with the amount of payoff that participants decided to donate (versus to keep for themselves; Table 1). Such findings raise important questions about participants' social motives in laboratory tasks. Several studies have found that older adults show more prosocial behaviour (e.g. contributing to the public good) than younger or middle-aged adults (e.g. Freund & Blanchard-Fields, 2014), but other studies have found that chronological age and prosociality are not necessarily correlated (Best & Freund, 2021; Horn & Freund, 2021b). Systematic investigations of characteristics of the settings and tasks will be important to better understand age-related differences in social motivation across adulthood (see Bailey et al., 2021; Isaacowitz et al., 2021).

In conclusion, the present research examined the interplay between motivational incentives and prospective remembering across adulthood. In support of a loss prevention view on motivated cognition, our findings suggest that gain and loss outcomes have age-differential impact on how well people remember to do things. In particular, the relevance of reward and gain-related consequences for successful remembering appears to decrease with age. When framing of messages as gains or losses is used to promote behaviour in cognitive tasks, people's age matters.

Notes

1. Exploratory analyses are reported in a separate section of the text to clearly distinguish between confirmatory and exploratory research.
2. We thank an anonymous reviewer for the suggestion to consider the additional covariates "survey-assessed motivational orientation" and "type of payoff" in the present study, which are reported in the section "Exploratory Analyses" (see also Online Supplement 4 to 6).
3. The raw data from all participants in the present analyses (including the data from five participants whose data were discarded following the preregistered exclusion criteria) are available at doi.org/10.17605/osf.io/9pwcd. The data were collected after the in-principle acceptance of the stage-1 report (i.e., after 10 December 2019), from January to December 2020 (following local health and safety regulations); data collection had to be interrupted between mid-March and mid-July 2020 due to the COVID-19 pandemic.

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