Don't pay attention!

Paradoxical effects of monetary incentive on attentional performance in older adults

Ziyong Lin¹, Anne Berry², Cindy Lustig³

¹Max Planck Institute for Human Development, Center for Lifespan Psychology

²Psychology Department, Brandeis University

³Psychology Department and Neuroscience Program, University of Michigan

Note: This is a preliminary version of a manuscript currently being revised and updated for journal submission. Please do not cite without contacting the authors regarding any potential updates or corrections. We would also appreciate your comments and suggestions for improving the paper, or related work that you are doing that might be cited. The senior author can be contacted at clustig@umich.edu. Thank you, and we hope that you enjoy the paper.

CC license by attribution

Abstract

Adult aging is associated with reductions in attentional control, but performance may be influenced by factors including types of attention assessed (e.g. sustaining, resistance distraction) and participants' motivation. In Experiment 1, we used the Continuous Temporal Expectancy Task with Video Distractor (Berry, Li, Lin, and Lustig), a timing task to assess young and older adults' ability to sustain attention, and manipulated whether a nearby laptop was silent or playing videos to assess distractor vulnerability. Older adults outperformed young adults overall. Self-report measures suggested that lack of engagement by young adults drove this paradoxical age difference. Experiment 2 directly tested the effect of motivation via monetary incentives. The monetary incentive tended to improve the performance of young adults, but significantly reduced the performance of older adults. Incentive had its primary effects on focused attention and overall performance rather than specific effects on either sustained attention or distraction control.

Don't pay attention!

Paradoxical effects of monetary incentive on attentional performance in older adults

For researchers who work in an aging lab, it is probably common to find that older participants are “better behaved” compared to younger adults. They often show up for the appointment on time, read the consent form more carefully, and seem to care more about their performance. In addition to these anecdotal observations, it has been shown that older adults are more motivated than younger adults. Staub and colleagues(2014) showed that in a Go/No-Go task, older adults were able to maintain performance over time while younger adults showed time-on-task effects. Moreover, older adults reported a higher level of motivation to complete the task at hand compared to younger adults. Given the close link between attention and motivation, one may wonder how these age differences in motivation could account for performance differences in attention for young and older adults.

The ability to control attention is critical for performing various tasks in everyday life. The research literature on attention and aging has explored many aspects of attention (e.g. Drag & Bieliauskas, 2010; McDowd & Shaw, 2000). Findings on age differences in attentional control have been mixed depending on which aspects of attention are assessed (e.g. sustained attention vs resisting distraction), experimental paradigms and measurements. For example, Carriere and colleagues (2010) used a version of the continuous performance task (sustained attention to response task, SART) that showed older adults are slower but more accurate in their responses and that they exhibited a lower decrement in vigilance compared to young adults. Others found equivalent or impaired sustained attention performance in older adults compared to young adults (see Staub, Doignon-Camus, Despres, & Bonnefond, 2013, p. for a review). For

the ability to resist distraction, findings tended to be more consistent that older adults are typically more vulnerable than younger adults to distraction, whether internally or externally generated(Hasher & Zacks, 1988).

One way to examine whether variation in motivational states contribute to performance differences is to experimentally manipulate these states, such as by using a performance-based monetary incentive. Studies on effects of monetary incentive on attentional performance have mostly focused on young adults (e.g. Esterman, Reagan, Liu, Turner, & DeGutis, 2014; Locke & Braver, 2008; Small et al., 2005). Esterman and colleagues(2014) investigated effects of reward on accuracy, reaction time variability, and time-on-task effects in a continuous performance task. They found that while incentive did not impact time-on-task effects, participants in the incentive group showed greater overall performance and lower reaction time variability. Their finding suggests that effects of incentive may vary depending how attention is measured. Only very few studies have examined effects of incentive on younger and older adults. In a study by Spaniol and colleagues (2015), younger and older adults completed a monetary incentive delay task during fMRI. Both younger and older performed better with incentive, but younger demonstrated this improvement to a greater extent. The small number of studies limits our understanding on how incentive influence attentional control in older adults.

The purpose of the current study is to investigate how attentional performance may be influenced by factors including types of attention assessed, age, and participants' motivation. We used a paradigm which assesses multiple dimensions of attention and administered a self-report questionnaire which measures traits and states attention. The computerized task was the Continuous Temporal Expectancy Task (CTET, O'Connell et al., 2009)with a video distractor (Berry, Li, Lin, & Lustig, 2014). The CTET requires participants to monitor a stream of stimuli

which changes at a standard duration, and their task is to detect the trials that takes slightly longer. Participants' performance relies on the ability to focus attention on time. It has been shown to produce a rapid time-on-task effects within four minutes. We added a laptop computer to the side of the main task computer, either silent or playing videos, allowing to assess vulnerability to distraction (Berry, Li, et al., 2014). Recent work in our laboratory has shown that performance indexes related to different attentional functions (initial focus of attention, sustaining attention, and resistance to distraction) can be dissociated based on factors such as modality and genetics (Berry, Demeter, et al., 2014; Berry, Li, et al., 2014). In addition, we have also found that some sources of variation in performance are individual differences in attention-related traits and attention states during the task. Therefore, we expected to find converging evidence in the present study. In Experiment 1, young adults and older adults completed the computer task as well as self-report measures. We examined research questions 1) whether younger and older adults differ in their attentional performance; and 2) whether subjective self-report measures differ between younger and older adults. In Experiment 2, we manipulated motivation by providing performance-based monetary incentive, which allowed us to investigate 3) whether the effect of monetary incentive varies by age group; and 4) whether monetary incentive has different effects on different attentional functions. For both experiments, we predicted that performance of participants would decline over time and that performance would be impaired by external distraction, but that the time-on-task effect would not interact with effect of the distractor.

Experiment 1

Methods

Participants

Thirty two young and 32 older participants were included for the final analyses. Young adults (16 female, mean age = 18.63 years, range 18-21) were recruited from Introductory Psychology subject pool at the University of Michigan. Older adults (16 female, mean age = 70.38, range 61-82) were recruited from the Ann Arbor community. Older participants were offered \$10 per hour for their participation and young adults received course credits.

Participants were also screened to ensure physical and psychological health with no history of anxiety, depression, ADHD, or head injury, and no use of medications that affect cognition. The Extended Range Vocabulary Test Version 3 (ERVT; Educational Testing Service, 1976) was used for qualification by a scores of at least 9 out of a possible 48. The Mini Mental State Examination (MMSE; Cockrell & Folstein, 1988) was administrated to all older adults, and participants who scored lower than 27 were excluded (see Table 1 for demographic information). Individuals with poor performance (hit rate below 40% during the first minute of the No Distractor condition, and false alarms larger than 3 standard deviations above the mean) on the computer task were also excluded.

Materials

Continuous Temporal Expectancy Task with Video Distractor

As described by O'Connell and colleagues (2009), the CTET was previously used to assess lapses of sustained attention and was associated with neural measures of mind-wandering. The task was presented on a Dell PC computer using E-prime version 2.0.8.90 software (Schneider, Eschman, & Zuccolotto, 2002). During the task, a black and white grid with squares divided diagonally into halves rotated randomly at 90, 180, or 270 degrees. Participants were instructed to monitor a stream of visual stimuli with a standard trial of 800 msec and target trial of 1070 msec and press the space bar when they detected the target (Figure 1). Before beginning the experiment, participants were given 6 practice runs (3 targets each). To ensure participants understood their task, the duration difference between standard trials and target trials was exaggerated during the first practice (standard: 800msec; target: 1600). The duration difference for the remaining 5 practice trials was identical to testing runs. Participants had to achieve 100% on at least one run to proceed to the experiment. The experiment had 10 testing runs (4 min each) with 24 targets per run. Stimuli were in pseudo-randomly intermixed fashion, and standard trials between two targets presentations ranged from 7 to 17 trials (average of 10). A correct response (hit) was recorded if participants responded within 2.46s following the target offset. Responses outside this time window were coded as false alarms. At the end of each run, participants were given feedback on their performance and took a one-minute break.

We modified the CTET by adding an external distractor (Berry, Li, et al., 2014). For each participant, half of the runs were in the No Distractor condition, and half were in the Distractor condition. No Distractor and Distractor runs alternated, and their order was counterbalanced across participants. Both the No Distractor and Distractor conditions were implemented using a laptop computer to the left of the main task computer. For the No Distractor runs, the adjacent laptop presented a grey screen and remained silent. For the

Distractor runs, the laptop played a series of 30-second video clips with audio, which did not contain music or a strong rhythmic component. All materials and procedures were approved by the University of Michigan Institutional Review Board.

Questionnaires

Poor Attentional Control (PAC) scale. Participants completed 36 items from the Imaginal Processes Inventory (Singer & Antrobus, 1970). Items were statements about cognition and attention in everyday life. Participants rated these statements based on a five-point scale. As in previous papers from our group (Berry, Demeter, et al., 2014; Berry, Li, et al., 2014), final analyses focused on the 15 items from mind-wandering, boredom, and distractibility subscales, which make up the Poor Attentional Control (PAC) identified in a factor analysis (Huba, Singer, Aneshensel, & Antrobus, 1982).

Surprise quiz and post-experiment questionnaire. After the computer task, participants were given a quiz consisting of 15 multiple-choice questions to test their memory of the distractor video content, and a 5 question post-experiment questionnaire. On the post-experiment questionnaire, participants were asked to rate their level of mind-wandering, boredom, and distractibility during the task based on a scale from 1 to 5. The questions were created with similar form and content to items from PAC. As in our prior work (Berry, Demeter, et al., 2014; Berry, Li, et al., 2014), question 4 was used as a state measure of mind-wandering, question 3 as boredom, and question 5 as distractibility.

Analysis

Consistent with prior work (Berry, Demeter, et al., 2014; Berry, Li, et al., 2014; O'Connell et al., 2009), percent hits were the main dependent variable. Average minute-by-

minute hits (rate of correct detection of the target duration) were calculated for analyses of task performance. Analyses of signal detection measures yielded similar results. A mixed-design ANOVA was performed with the between-subject factor age group (young, old), and the within-subject independent variables time (minute 1, 2, 3, and 4) and distractor condition (No distractor, Distractor). In present studies and previous studies (Berry, Demeter, et al., 2014; Berry, Li, et al., 2014; O'Connell et al., 2009), time-on-task effects occurred within runs. No systematic differences between runs were found. Greenhouse-Geisser Correction was applied when sphericity was violated, and corrected degrees of freedom (rounded to the nearest integer), p , and F values were reported. Effect sizes for repeated measures were determined using generalized eta squared (η_G^2 , Olejnik & Algina, 2003), which was shown as a preferable measure compared to the partial eta squared (Bakeman, 2005). For comparison between two groups on specific measures, independent-sample t -tests were applied and Cohen's d values were reported. To test the relationship between task performance and subjective measures of attention, bivariate correlation analyses were conducted. These analyses were restricted to comparisons of theoretical interest and those consistent with the patterns in previous work. For correlation results, correlation coefficients and p values were reported.

Results

Continuous Temporal Expectancy Task Performance

As shown in Figure 2, the repeated measures ANOVA revealed a main effect of distraction, $F(1,62) = 70.43, p < .001, \eta_G^2 = .054$; participants performed significantly worse under the distractor condition. The main effect of time-on-task was also significant, $F(3,186) =$

43.23, $p < .001$, $\eta_G^2 = .046$; performance declined over 4 minutes. Contrary to the notion of declining cognitive functions in older adults, older adults actually performed better overall compared to young adults, $F(1, 62) = 5.73$, $p < .05$, $\eta_G^2 = .070$.

The interaction between distractor and age group was not significant, $F < 1$; size of the distractor effect did not differ by age group. The interaction between time and age group was statistically significant, $F(3, 186) = 4.89$, $p < .005$, $\eta_G^2 = .0054$, suggesting a steeper time-on-task performance decline in the young adult group. Follow-up analyses revealed that this interaction was not significant when only the two No Distractor conditions were compared, $F(3, 186) = 1.78$, $p = .153$, $\eta_G^2 = .0046$. Distraction interacted with time-on-task effects, $F(3, 186) = 3.46$, $p < .05$, $\eta_G^2 = .0039$. However, this effect was mainly driven by the atypically low performance of older adults in the first minute distractor block, $F < 1$ for No Distractor condition. About 40% of the older adults show an increase of more than 10% in their performance from minute 1 to minute 2. Still, this significant interaction between distractor and time was likely to be a chance finding and was not found in any of our other datasets with healthy young and older adults. The three way age group x distractor x time interaction did not approach statistical significance, $F = 1$.

Questionnaires

In terms of attention in everyday life (PAC scores), young participants rated items on mind-wandering and boredom significantly higher compared to older adults, $t(62) = 3.01$, $p < 0.01$, Cohen's $d = .75$; $t(62) = 2.23$, $p < 0.05$, Cohen's $d = .56$. Young adults also showed a trend of giving higher ratings on distractibility, $t(62) = 1.95$, $p = 0.056$, Cohen's $d = .49$. Ratings on the post-experiment questionnaire followed these patterns (Table 2): question 4 (mind-

wandering), $t(62) = 6.29, p < .001$, Cohen's $d = 1.57$; question 3(boredom), $t(62) = 8.46, p < .001$, Cohen's $d = 2.12$; question 5(distractibility), $t(62) = 5.60, p < .001$, Cohen's $d = 1.40$.

Young adults reported greater levels of mind-wandering, boredom, and distractibility during the task. Compared to older adults, young adults scored significantly higher on the surprise quiz, indicating that they remembered more content from the distractor videos, $t(62) = 6.76, p < .001$, Cohen's $d = 1.69$.

Correlations

In previous datasets from our lab with different conditions and populations, the PAC distractibility score correlated with the size of distractor effect ($r = .26 - .43$, Berry, Li, et al., 2014; Kim et al., 2013). In the present study, the correlation between PAC distractibility and the size of distractor effect was significant only when collapsing across age groups, $r = .25, p < .05$, a finding that was mainly driven by the older adults group, $r = .33, p = .062$. The young adult group showed this trend, but it did not reach significance, $r = .15, p = .40$. Young adults' overall performance correlated with PAC mind-wandering ($r = -.50, p < .01$), and distractibility ($r = -.37, p < .05$). As for older adults, performance correlated with PAC boredom ($r = -.42, p < .05$), and distractibility ($r = -.42, p < .05$). Overall, within each age group, correlations between everyday attention measures and task performance were in the expected direction with modest size. Upon collapsing across age groups, performance negatively correlated with trait mind-wandering, boredom, and distractibility, respectively, $r = -.50, p < .0001$; $r = -.41, p < .0001$; $r = -.42, p < .0001$ (Figure 3).

For correlations between post-experiment measures and performance, young adults' ratings on state mind-wandering and distractibility, respectively, negatively correlated with task

performance, $r = -.49, p < .005$; $r = -.55, p < .005$. For older adults, task performance negatively correlated with all state measures of attention (mind-wandering, boredom, distractibility) respectively, $r = -.58, p < .005$; $r = -.51, p < .005$; $r = -.48, p = .005$. These correlations remain significant after Bonferroni correction ($p < .008$), for a total of six comparisons (3 measures of state attention within each age group). Thus, the correlations between performance and task-specific measures of reported attention were relatively strong, which was consistent with the results of other datasets in our lab. Across the two age groups, self-reported mind-wandering, boredom, and distractibility negatively correlated with overall performance, $r = -.58, p < .0001$; $r = -.46, p < .0001$; $r = -.58, p < .0001$ (Figure 4).

As demonstrated in Table 2, young adults reported significantly more mind-wandering, boredom, and distractibility during the task compared to older adults. To test whether these differences in state attention may associate with attentional performance, reported state measures of mind-wandering, boredom, or distractibility were controlled, which eliminated the age difference in task performance, $F < 1$. These results suggest that young adults' poor performance might be related to boredom or lack of motivation during the task. Therefore, these age differences in attentional performance was likely to be the result of differences in motivation: older adults, who were sensitive to common stereotypes about aging, might be more motivated to "prove themselves" through good performance, whereas young adults without the same inherent motivation might have found the task boring and fatiguing, thus leading them to put forth less effort. In order to directly test this hypothesis, Experiment 2 was conducted with a manipulation for motivation. To achieve this, monetary incentive was added as an independent variable. Experiment 2 was conducted to investigate 1) whether monetary incentive affects attentional

performance, 2) what aspects of attention may be affected, and 3) whether these effects differ between young and older adults.

Experiment 2

Methods

Participants

Experiment 2 included 64 young adult and 64 older adult participants. All young adults (43 female, mean age = 20.23 years, range 18-23) were newly recruited from the University of Michigan. Thirty two older adults were newly recruited, and the data from the older adult participants in Experiment 1 were used as a comparison group (40 female, mean age = 70.70, range 60-83). All participants received \$10 per hour for their participation. Additionally, they had the potential to earn bonus pay of up to \$20 based on their performance. All screening criteria were the same as those in Experiment 1. Participants who were included in analyses had no history of anxiety, depression, ADHD, or head injury, no use of medications which affect cognition, and ERVT (Educational Testing Service, 1976) scores of at least 9 out of a possible 48. All older adults scored at least 27 out of 30 on the MMSE (Cockrell & Folstein, 1988).

Materials

All materials were identical to those in Experiment 1, with the addition of an incentive version of the task. This incentive manipulation was implemented using monetary reward. After each participant completed the practice runs of task, the experimenter informed the participant that he or she could earn up to \$20 bonus based on task performance, and that each error (either missing a target or making a false alarm) would cost them 20 cents. Twenty dollars were placed

in front of the participant at the beginning of the task. At the end of each run, participants received on-screen feedback regarding their task performance and bonus status. The experimenter administered monetary deduction at the end of each run.

Results

Statistical analyses for Experiment 2 were similar to those of Experiment 1.

Continuous Temporal Expectancy Task Performance

A mixed-design ANOVA was performed with time (minute 1, 2, 3, and 4) and distractor condition (No distractor, Distractor) as within-subject variables, and age group and monetary incentive as between-subject variables, using minute-by-minute task performance as the dependent variable. The main effect of age was significant, $F(1,124) = 4.56, p < .05, \eta_G^2 = .027$; however, young and older adults did not differ in their performance in No Distractor condition, $F(1,124) = 2.68, p = .10, \eta_G^2 = .017$. Distraction impaired performance for both young and older adults, $F(1,124) = 107.02, p < .001, \eta_G^2 = .054$, but the size of distractor effect was larger for older adults, $F(1,124) = 3.93, p = .050, \eta_G^2 = .0021$. A significant age group by monetary incentive interaction, $F(1,124) = 5.93, p < .05, \eta_G^2 = .035$, suggested that the monetary incentive might improve performance for young adults, $M = .7326$ vs $.7710, F < 1.20$, and significantly reduced performance for older adults, $M = .7409$ vs $.6455, F(1,62) = 5.37, p < .05, \eta_G^2 = .063$. Performance declined over time for all groups, $F(3,342) = 68.49, p < .001, \eta_G^2 = .049$. The time-on-task effect did not interact with the distractor effect, $F(3,342) = 1.92, p = .13, \eta_G^2 = .0012$, nor did any other two-way interactions reach statistical significance, $F < 1.30$. The only three-way interaction that approached significance was between distractor, time-on-task, and age group, F

$(3,342) = 2.91, p < .05, \eta_G^2 = .0019$. None of the other three-way or four-way interactions reached significance, $F < 1.40$.

Questionnaires

Questionnaires measures followed the general pattern observed in Experiment 1. Young participants rated all subjective attention items higher compared to older adult (see Table 2). Neither trait nor state attention measures differed between control groups and incentive groups, with one exception. Incentive older adults scored significantly higher on state attention question 4 (mind-wandering) compared to control older adults, $t(62) = 2.12, p < .05$, Cohen's $d = 0.53$. The pattern of the quiz of distractor video was also similar to that of Experiment 1, young adults remembered more content of the distractor video compared to older adults.

Correlations

Correlations between PAC distractibility and the size of distractor effect differed between the regular and incentive group. While the correlation in the control group showed a similar pattern and effect size to that of the Experiment 1, $r = .24, p = .05$, the incentive groups showed a negative correlation, $r = -.39, p < .01$. This negative correlation in the incentive condition was driven by the older adults group, $r = -.44, p < .05$.

For correlations between everyday trait attention measures and performance, participants without monetary incentive showed similar patterns to Experiment 1, but weaker effects, mind-wandering, $r = -.28, p < .05$; boredom, $r = -.34, p < .01$; distractibility, $r = -.32, p < .01$ (Figure 5). The same was true for correlations between post-experiment state attention measures and performance, mind-wandering, $r = -.45, p < .001$; boredom, $r = -.30, p < .05$; distractibility, $r = -.37, p < .01$ (Figure 6).

In the incentive condition, however, correlations between trait attention and performance disappeared, mind-wandering, $r = -.014$, $p = .91$; boredom, $r = -.044$, $p = .73$; distractibility, $r = .15$, $p = .23$. Correlations between state attention and performance were also reduced compared to the regular condition, mind-wandering, $r = -.030$, $p = .05$; boredom, $r = -.21$, $p = .096$; distractibility, $r = -.16$, $p = .20$ (Figure 7). Taken together, these correlation patterns suggest that the incentive manipulation altered the relationship between self-report measures and task performance. In other words, in the incentive condition, the self-report measures no longer predicted task performance.

General Discussion

Our results replicate findings from our previous studies (Berry, Demeter, et al., 2014; Berry, Li, et al., 2014). Both time-on-task and distraction reduce performance, but their effects are independent, suggesting that sustaining attention and resisting distraction may be independent abilities. The present research also reveals new findings that may shed light on how different aspects of attentional control differ in their sensitivity to age differences in ability and motivation.

First, we found in Experiment 1 that older adults performed better than young adults on measures of the initial focus of attention and the ability to maintain attention over time, although both age groups were equally vulnerable to distraction. Young adults in this condition reported significantly more mind-wandering and boredom compared to older adults. This lack of motivation may contribute to young adults' poor performance. The age difference in overall task performance was eliminated once we controlled for self-report state measures of mind-

wandering, boredom, or distractibility. This finding suggests that attentional and motivational states partly account for age differences in attentional performance.

Second, we replicated results from previous studies from our laboratory that self-report state and trait attentional measures negatively correlated with task performance, respectively (Berry, Demeter, et al., 2014; Berry, Li, et al., 2014). In addition, we found in Experiment 1 and the control group of Experiment 2 that older adults reported less mind-wandering and boredom compared to younger adults. The result that older adults were less likely to mind-wander is consistent with the literature (Giambra, 1989; Jackson, Weinstein, & Balota, 2013; Zavagnin, Borella, & De Beni, 2014). Ennis, Hess, and Smith (2013) have argued that older adults spend more effort to achieve a comparable level of performance to younger adults. This increased cost also increased the salience of task at hand to self, and thus reduce mind-wandering and task-unrelated thoughts. Other factors, such as personality, however, may influence mind-wandering. Conscientiousness has been associated with higher task engagement and lower mind-wandering. Older adults tended to be more conscientious, which may contribute to age differences in subjective measures (Jackson & Balota, 2012).

Third, we found in Experiment 2 that monetary incentive tended to improve the performance of young adults, but significantly reduced the performance of older adults. Compared to control group, older adults in the incentive group were now less able to focus attention, although their maintenance of attention over time and vulnerability to distraction remained the same. These finding suggests that monetary incentive may have differential effect on younger and older adults. There are several possible explanations for this paradoxical effect. The manipulation of monetary incentive was given in a negative light, focusing on errors participants might have made. Studies have shown that older adults performed significantly

better on low-stress days than high-stress days. Young adults did not show as large performance difference between high-stress and low-stress days (Sliwinski, Smyth, Hofer, & Stawski, 2006). These findings suggest that stress reduced older adults' attentional performance more so than that of young adults. This negative way of framing the incentive may induce stress for participants. Older adults became more concerned about making errors, perhaps a form of internal emotional distraction, and reduced performance. An alternative explanation is the overjustification effect, which occurs when a person's intrinsic motivation to perform a task is decreased by an external incentive (Lepper, Greene, & Nisbett, 1973). Although this effect was first discovered in children, it has been extended to other age group. A meta analysis found support for the overjustification effect across age (Tang & Hall, 1995). Older adults in our study tended to be more intrinsically motivated to perform well on the task. The monetary incentive may introduce an extrinsic goal, which may reduce the performance of older adults.

Fourth, we found in Experiment 2 that monetary incentive has its primary effects on focused attention and overall performance rather than specific effects on either sustained attention or distraction control. This finding is consistent with the results from Esterman and colleague's study (2014), suggesting that monetary incentive has a more general effect on attention. A previous study from our laboratory using the same paradigm found increased vulnerability to distraction in participants with a genetic variation, Ile89Val variant, affecting the high affinity choline transporter, which transports choline to the nerve terminal for the synthesis of acetylcholine. Ile89Val participants showed comparable performance in other attentional aspects, but specific vulnerability to distraction. Together, these results may suggest attentional aspects, such as time-on-task and distraction control, are less malleable.

In summary, the present research provided new empirical evidence for age differences in monetary incentive and attentional performance. Specifically, age differences in attentional performance may be associated with different levels of motivation in younger and older adults. Older adults tended to report less mind-wandering and boredom compared to younger adults. Monetary incentive affects younger and older adults differently: while it may improve performance in young adults, incentive significantly reduces performance in older adults. This paradoxical age differences may be driven by stress or motivation. Monetary incentive influenced focused attention and overall performance, but showed little effect on sustaining attention and distraction control. Age and individual differences in any of these aspects are important in our everyday life functions, such as incentive structure in the job setting; therefore, the present findings have marked practical implication regarding age, attention, and incentive in the real world.

Figure 1. Contious temporal expectancy task (CTET) with distraction. a. As described in Experiment 1 method section, participants were presented a rotating grid (the triangles rotated 90, 180, or 270° randomly) and asked to press the spacebar in response to the longer duration target (1070ms). b. The distractor manipulation was implemented using a laptop computer oriented 32° to the left of the task computer, and 65 cm from the participant. In the No Distractor condition, the laptop was silent and displayed a grey screen. In the Distractor condition, the laptop played a series of 30 second video clips, including the audio component.

Figure 2. Task performance is affected by age, distraction, and time-on-task. See Experiment 1 Result and Discussion section for statistical analyses. Markers represent mean proportion of hits for each minute; error bars represent standard error of the mean. Older adults performed better overall but both age groups were vulnerable to distraction.

Figure 3. Correlations between performance and self-reported trait measures (PAC scores) in Experiment 1. Across age groups, performance was negatively correlated with trait mind-wandering, boredom, and distractibility.

Figure 4.Correlations between performance and self-reported state measures (post-experiment ratings) in Experiment 1. Across age groups, performance was negatively correlated with state mind-wandering, boredom, and distractibility.

Figure 5. Task performance with the monetary incentive condition.

Figure 6. Correlations between performance and self-reported trait measures (PAC scores) in Experiment 2. For control groups, performance was negatively correlated with trait mind-wandering, boredom, and distractibility. Incentive eliminated the relationship between trait attention measure and performance.

Figure 7. Correlations between performance and self-reported state measures (post-experiment ratings) in Experiment 2. For control groups, performance was negatively correlated with state mind-wandering, boredom, and distractibility. Incentive reduced or eliminated the relationship between trait attention measure and performance.

Table 1

Demographic Means (SDs) for both Experiment 1 and 2.

Group	Age	Education	ERVT
<u>Experiment 1</u>			
Young Adults (n=32, 16 female)	18.63 (0.83)**	13.20(1.24) **	19.02(6.11) **
Older Adults (n=32, 16 female)	70.38(5.91)	17.11(8.95)	31.48(7.07)
<u>Experiment 2</u>			
Young Adults (n=64, 43 female)	20.23(1.04) ***	14.71(1.24)***	20.59(6.33) ***
Older Adults (n=64, 40 female)	70.70(6.66)	16.93(2.62)	31.49(9.10)

Note. All data are measured in means (SDs). ** $p < .01$, *** $p < .001$.

Table 2

Self-report of trait (PAC) and state (post-experiment) subjective attention, and quiz score for distractor video content.

<i>Experiment 1</i>			<i>Experiment 2</i>		
	Young	Old	Control Young	Incentive Young	Incentive Old
PAC Mind-Wandering					
mean	14.78**	12.34	14.38†	14.41††	11.66
SD	3.84	2.48	4.03	3.46	3.08
PAC Boredom					
mean	13.00*	11.03	13.34††	13.81††	11.22
SD	3.87	3.15	3.46	3.37	2.70
PAC Distractibility					
mean	15.53	13.59	15.63	14.84	13.34
SD	3.48	4.41	4.02	3.76	3.29
Exit questionnaire					
1. At times of this task, it was hard for me to keep my mind from wandering.					
mean	4.03***	2.38	3.56†††	3.34††	2.50
SD	0.86	1.21	1.08	1.10	1.30
2. (reverse scored) During the task, my thoughts seldom drifted from the subject before me.					
mean	3.75***	2.63	3.38†††	3.38	3.00
SD	0.88	1.31	1.16	1.10	1.24
3. I was easily bored during this task.					
mean	4.09***	1.88	3.63†††	3.06†	2.38
SD	1.09	1.01	1.13	1.50	1.21
4. I had difficulty in keeping my attention focused on this long, tedious task.					

mean	3.84***	2.09	3.56†††	3.31	2.75
<i>SD</i>	1.05	1.17	0.95	1.23	1.30
5. No matter how hard I tried to concentrate, I felt easily distracted by the videos playing					
mean	3.34***	2.00	3.16†††	2.71	2.34
<i>SD</i>	0.97	0.95	1.08	1.14	1.15
<i>Surprise quiz</i>					
% correct recognition of distractor content					
mean	74.57***	44.79	73.04†††	71.04†††	39.37
<i>SD</i>	18.42	16.78	23.37	17.32	26.36

Note. All data are measured in means (SDs).

For Experiment 1, differences between young and older adults, * $p < .05$, ** $p < .01$, *** $p < .001$.

For Experiment 2, differences between young and older adults within each condition (control, incentive), † $p < .05$, †† $p < .01$, ††† $p < .001$.

Reference

- Bakeman, R. (2005). Recommended effect size statistics for repeated measures designs. *Behavior research methods*, 37(3), 379-384.
- Berry, A. S., Demeter, E., Sabhapathy, S., English, B. A., Blakely, R. D., Sarter, M., & Lustig, C. (2014). Disposed to distraction: genetic variation in the cholinergic system influences distractibility but not time-on-task effects. *J Cogn Neurosci*, 26(9), 1981-1991. doi:10.1162/jocn_a_00607
- Berry, A. S., Li, X., Lin, Z., & Lustig, C. (2014). Shared and distinct factors driving attention and temporal processing across modalities. *Acta Psychol (Amst)*, 147, 42-50. doi:10.1016/j.actpsy.2013.07.020
- Carriere, J. S., Cheyne, J. A., Solman, G. J., & Smilek, D. (2010). Age trends for failures of sustained attention. *Psychol Aging*, 25(3), 569-574. doi:10.1037/a0019363
- Cockrell, J. R., & Folstein, M. F. (1988). Mini-Mental State Examination (MMSE). *Psychopharmacol Bull*, 24(4), 689-692.
- Drag, L. L., & Bieliauskas, L. A. (2010). Contemporary review 2009: cognitive aging. *J Geriatr Psychiatry Neurol*, 23(2), 75-93. doi:10.1177/0891988709358590
- Ennis, G. E., Hess, T. M., & Smith, B. T. (2013). The impact of age and motivation on cognitive effort: implications for cognitive engagement in older adulthood. *Psychol Aging*, 28(2), 495-504. doi:10.1037/a0031255
- Esterman, M., Reagan, A., Liu, G., Turner, C., & DeGutis, J. (2014). Reward reveals dissociable aspects of sustained attention. *J Exp Psychol Gen*, 143(6), 2287-2295. doi:10.1037/xge0000019
- Giambra, L. M. (1989). Task-unrelated-thought frequency as a function of age: a laboratory study. *Psychol Aging*, 4(2), 136-143.
- Hasher, L., & Zacks, R. T. (1988). Working memory, comprehension, and aging: A review and a new view. In G. H. Bower & G. H. Bower (Eds.), *The psychology of learning and motivation: Advances in research and theory*, Vol. 22. (pp. 193-225). San Diego, CA, US: Academic Press.
- Huba, G. J., Singer, J. L., Aneshensel, C. S., & Antrobus, J. S. (1982). *Short imaginal processes inventory*: Research Psychologists Press Port Huron, MI.
- Jackson, J. D., & Balota, D. A. (2012). Mind-wandering in Younger and Older Adults: Converging Evidence from the Sustained Attention to Response Task and Reading for Comprehension. *Psychol Aging*, 27(1), 106-119. doi:10.1037/a0023933
- Jackson, J. D., Weinstein, Y., & Balota, D. A. (2013). Can mind-wandering be timeless? Atemporal focus and aging in mind-wandering paradigms. *Front Psychol*, 4, 742. doi:10.3389/fpsyg.2013.00742
- Kim, K., Wu, T., Syed, N., Müller, M., Bohnen, N., Sarter, M., & Lustig, C. (2013). *Spared and impaired aspects of attention in Parkinson's disease: Distractor vulnerability correlates with lower cortical cholinergic innervation*. Paper presented at the Society for Neuroscience, San Diego, CA.
- Lepper, M. R., Greene, D., & Nisbett, R. E. (1973). Undermining children's intrinsic interest with extrinsic reward: A test of the "overjustification" hypothesis. *Journal of Personality and Social Psychology*, 28(1), 129.
- Locke, H., & Braver, T. (2008). Motivational influences on cognitive control: Behavior, brain activation, and individual differences. *Cognitive, Affective, & Behavioral Neuroscience*, 8(1), 99-112. doi:10.3758/CABN.8.1.99

- McDowd, J. M., & Shaw, R. J. (2000). Attention and aging: A functional perspective. In F. I. M. C. T. A. Salthouse (Ed.), *The handbook of aging and cognition (2nd ed.)* (pp. 221-292). Mahwah, NJ, US: Lawrence Erlbaum Associates Publishers.
- O'Connell, R. G., Dockree, P. M., Robertson, I. H., Bellgrove, M. A., Foxe, J. J., & Kelly, S. P. (2009). Uncovering the neural signature of lapsing attention: electrophysiological signals predict errors up to 20 s before they occur. *J Neurosci*, 29(26), 8604-8611. doi:10.1523/jneurosci.5967-08.2009
- Olejnik, S., & Algina, J. (2003). Generalized eta and omega squared statistics: measures of effect size for some common research designs. *Psychol Methods*, 8(4), 434-447. doi:10.1037/1082-989X.8.4.434
- Schneider, W., Eschman, A., & Zuccolotto, A. (2002). *E-Prime: User's guide*: Psychology Software Incorporated.
- Service, E. T. (1976). Kit of factor-referenced tests. New Jersey: Princeton.
- Singer, J., & Antrobus, J. (1970). Manual for the imaginal Processes Inventory. *Princeton, NJ: Educational Testing Service*.
- Sliwinski, M. J., Smyth, J. M., Hofer, S. M., & Stawski, R. S. (2006). Intraindividual coupling of daily stress and cognition. *Psychol Aging*, 21(3), 545-557. doi:10.1037/0882-7974.21.3.545
- Small, D. M., Gitelman, D., Simmons, K., Bloise, S. M., Parrish, T., & Mesulam, M. M. (2005). Monetary incentives enhance processing in brain regions mediating top-down control of attention. *Cereb Cortex*, 15(12), 1855-1865. doi:10.1093/cercor/bhi063
- Spaniol, J., Bowen, H. J., Wegier, P., & Grady, C. (2015). Neural responses to monetary incentives in younger and older adults. *Brain Res*, 1612, 70-82. doi:10.1016/j.brainres.2014.09.063
- Staub, B., Doignon-Camus, N., Bacon, E., & Bonnefond, A. (2014). The effects of aging on sustained attention ability: an ERP study. *Psychol Aging*, 29(3), 684-695. doi:10.1037/a0037067
- Staub, B., Doignon-Camus, N., Despres, O., & Bonnefond, A. (2013). Sustained attention in the elderly: what do we know and what does it tell us about cognitive aging? *Ageing Res Rev*, 12(2), 459-468. doi:10.1016/j.arr.2012.12.001
- Tang, S.-H., & Hall, V. C. (1995). The overjustification effect: A meta-analysis. *Applied Cognitive Psychology*.
- Zavagnin, M., Borella, E., & De Beni, R. (2014). When the mind wanders: Age-related differences between young and older adults. *Acta Psychol (Amst)*, 145, 54-64. doi:<http://dx.doi.org/10.1016/j.actpsy.2013.10.016>