Motivation and Emotion (2024) 48:807–816
https://doi.org/10.1007/s11031-024-10092-z

ORIGINAL RESEARCH

Financial and prosocial rewards differentially enhance cognition in younger and older healthy adults

Nadine Schmidt[1,2] · Marta Menéndez-Granda[1,2] · Patric Wyss[1,3,4] · Michael Orth[1] · Sebastian Horn[5] · Matthias Kliegel[6,7,8] · Jessica Peter[1]

Accepted: 14 August 2024 / Published online: 3 September 2024

Abstract

The prospect of a reward can enhance cognitive performance. For younger men financial gains, and for older adults and women prosocial rewards, seem particularly motivating. We therefore investigated whether adding a prosocial component to a financial reward enhanced cognitive performance and, if so, whether this depended on age or sex. We randomly assigned 571 participants to one of three reward types (financial reward, prosocial reward, or a combination of both) in a monetary incentive delay task. We used linear effects modelling to examine effects of age, sex, or reward type on trial accuracy, response time, and total performance. The prospect of a combined financial and prosocial reward increased performance in all participants with the increase of response speed particularly pronounced in younger adults. Only in men, a sole financial reward increased performance. Our study highlights the importance of choosing rewards wisely when designing studies that examine their influence on cognitive performance.

Keywords Monetary incentive delay task · Donation · Age difference · Sex difference

Introduction

The brain's reward system encourages behaviour associated with a reward and discourages behaviour leading to punishment. It is not the reward itself, but the expectation of a reward that strongly influences behaviour. Hence, the prospect of a reward increases the cognitive effort invested in behaviour e.g., Di Rosa et al., 2015; Manga et al., 2020; Spaniol et al., 2014; Tonin & Vlassopoulos, 2014). Reward, however, can take many forms and it is not fully understood which type of reward works best. For example, in older adults, a social reward may lead to stronger cognitive effort than a financial reward because of age-related changes in the value attributed to them (Ferdinand & Czernochowski, 2018; Freund & Blanchard-Fields, 2014). In addition, older adults seem more prosocial than younger adults as they donate more to charity, both in real life and in the laboratory (Cutler et al., 2021; Freund & Blanchard-Fields, 2014; *Spendenreport Schweiz 2022*, 2022; but see Gong et al., 2019; Horn & Freund, 2021). Women may also differ from men as they are more prosocial (Cuter et al., 2021) and donate more to charity (Mesch et al., 2011; Piper & Schnepf, 2008; *Spendenreport Schweiz 2022*, 2022; Tonin & Vlassopoulos, 2014). It is unclear, however, whether the

✉ Jessica Peter
jessica.peter@unibe.ch

1 University Hospital of Old Age Psychiatry and Psychotherapy, University of Bern, Bern, Switzerland

2 Graduate School for Health Sciences, University of Bern, Bern, Switzerland

3 Institute of Social and Preventive Medicine, University of Bern, Bern, Switzerland

4 School of Applied Psychology, University of Applied Sciences and Arts Northwestern Switzerland, Olten, Switzerland

5 Department of Psychology, University of Zurich, Zurich, Switzerland

6 Cognitive Aging Lab (CAL), Faculty of Psychology and Educational Sciences, University of Geneva, Geneva, Switzerland

7 Centre for the Interdisciplinary Study of Gerontology and Vulnerability, University of Geneva, Geneva, Switzerland

8 Swiss Centre of Expertise in Life Course Research, LIVES Centre, Lausanne and Geneva, Carouge, Switzerland

opportunity to donate money to charity modulates cognition and if so, whether this is similar in younger and older adults or in men and women. If prosocial behaviour were specifically motivating for older adults and women, adding a prosocial component (i.e., donation) to a financial reward may be particularly useful to improve cognition in these populations.

In the lab, the monetary incentive delay task (Knutson et al., 2000; Wang et al., 2017), in which participants can earn a reward if they react both accurately and quickly, allows examining the influence of reward on cognitive performance. This widely used task with which reward processing can be examined was developed based on instrumental conditioning paradigms employed in animal studies (Schultz et al., 1997; Knutson et al., 2000). It consistently activates brain regions known to be associated with reward (e.g., the striatum) across different age groups. Using this task, some studies found that younger adults responded faster and more accurately than older adults when a financial reward was used (Dhingra et al., 2020; Spaniol et al., 2015; but see Opitz et al., 2022; Rademacher et al., 2014; Vink et al., 2015). Likewise, men responded faster than women with financial reward (Spreckelmeyer et al., 2009; Wang et al., 2017; but see Dhingra et al., 2021). It would be important to add a prosocial component to a financial reward to test whether task performance improves similarly in younger and older men or women. This is an important question since the ability to tailor rewards according to age or sex may improve the experimental set-up used to study the underlying behaviour modification.

In the present study, we therefore tested the effects of three reward types (financial reward; prosocial reward [i.e., donation], or a combination of both) on performance enhancements in younger and older men and women. We hypothesized that in younger adults (particularly men) performance enhancement are stronger with a financial than with a prosocial reward, or a combination. In addition, we hypothesized that prosocial rewards are most effective for enhancing older adults' performance. Similarly, we hypothesized that women are particularly motivated by a prosocial reward and consequently, their responses become faster and more accurate.

Table 1 Socio-demographic data (mean ± standard deviation) for the sample of younger and older adults receiving different types of reward (financial, prosocial, or a combination)

	Reward type		
	Prosocial	Combined	Financial
Younger adults (*n* = *280*)			
n (female/male)	93 (56/37)	87 (45/42)	100 (56/44)
Age (years)	25.86 ± 2.95	24.79 ± 3.37	24.89 ± 3.25
Education (years)	14.3 ± 1.53	13.3 ± 1.4	14.2 ± 1.75
Health	4.1 ± 0.68	4.2 ± 0.61	4.25 ± 0.76
Donation frequency	1.9 ± 0.66	1.9 ± 0.60	1.9 ± 0.66
Thrift	2.3 ± 0.73	2.3 ± 0.84	2.4 ± 0.80
Financial situation	2.5 ± 0.70	2.4 ± 0.89	2.3 ± 0.71
Older adults (*n* = *224*)			
n (female/male)	79 (27/52)	71 (26/45)	74 (31/43)
Age (years)	67.61 ± 5.23	68.49 ± 5.09	68.12 ± 5.22
Education (years)	14.2 ± 1.82	14.4 ± 1.58	14.3 ± 1.64
Health	3.8 ± 0.64	4.0 ± 0.71	4.0 ± 0.56
Donation frequency	2.3 ± 0.62	2.4 ± 0.63	2.2 ± 0.63
Thrift	2.5 ± 0.77	2.6 ± 0.88	2.5 ± 0.93
Financial situation	2.3 ± 0.66	2.3 ± 0.77	2.3 ± 0.85

Note Higher values indicate better health, lower need to keep expenses low, higher donation frequency and lower satisfaction with financial situation

Methods and materials

Participants

We initially recruited $N = 571$ healthy volunteers for this online study. We randomly assigned them to one of three reward types (financial reward; prosocial reward [donation], or a combination of both), stratified by age and sex. We excluded 66 participants since task accuracy was <25%. Another participant had to be excluded due to missing data. The final sample consisted of 280 younger adults (between 20 and 30 years of age) and 224 older adults (between 60 and 80 years of age; Table 1). All participants were fluent in German and were recruited by a panel provider (i.e., Respondi Cologne, Germany, https://www.respondi.com). No formal ethics approval was required for this study as confirmed by a formal inquiry to the Cantonal Ethics Committee Bern, Switzerland[1]. All participants provided informed consent and received credits on the panel platform as reimbursement. These credits (and their reward earnings) were provided to them either with vouchers for online shops or with money that would be transferred to their bank account.

Study procedure

Each participant received a personalised link by the panel provider. By clicking on that link, the participants were first asked to state their sex and year of birth. Then the monetary incentive delay task followed. After completion, the participants were asked to rate their current economic situation and their health (5-point scale, ranging from 1 = 'very bad' to 5 = 'very good') as well as their donation frequency

[1] The Cantonal Ethics Committee Bern confirmed that this research does not fall under the Federal Act on Research involving Human Beings since we did not acquire any personal data from any of the participants at any time.

(3-point scale, ranging from 1 = 'never' to 3 = 'regularly'). Then, we asked them whether they agreed to the statements 'I need to keep my expenses low' and 'I worry about my financial situation' (4-point scale, ranging from 1 = 'true' to 4 = 'not true'; Table 1), and participants in the conditions with a prosocial reward had to decide to which charity they wished to donate money (i.e., 'Doctors without borders', 'UNICEF', 'World Wildlife Fund'). The experiment lasted approximately 20 min.

Monetary incentive delay task

We presented the task with PsychoPy (v2020.1.3) hosted on Pavlovia, which is a secured server for running experiments online (https://www.pavlovia.org). We used an adapted version of the monetary incentive delay task (Wang et al., 2017) that consists of a baseline block and a reward block. During the baseline block, participants needed to respond as quickly as possible to triangles or squares. Whenever a triangle appeared, they needed to press the left arrow key, while for squares, they needed to press the right arrow key. Participants were told that they would receive feedback whether they responded correctly (i.e., green tick for a correct response, red cross for an incorrect or missed response). After a short training of 20 trials during which the participants needed to answer correctly at least twice, the baseline block began. Each trial started with a fixation cross presented in the centre of the screen for 0.6–1.0 s. Then, either of the two stimuli appeared for 0.8 s, followed by a fixation cross (for 1.4–1.8 s) and feedback (0.5 s). After 20 trials, the baseline block ended, and the mean response time of all correct answers was calculated. Next, the reward block followed (Fig. 1). Again, they needed to press the left or right arrow key for triangles or squares. In contrast to the baseline condition, however, they were told that for some trials it would now be possible to gain points that would later be transformed into a reward. Depending on the reward condition, the participants were either informed that a reward can be earned (financial condition), that half of the reward can be earned, and the other half would be donated (combined condition), or that all the earnings would be donated (prosocial condition). A circle with a horizontal line indicated reward trials. In these trials, they could achieve a point for a correct answer that was faster than their mean baseline reaction time. Each point was equivalent to 0.5 Swiss francs. Comparable to previous studies (e.g., Wang et al., 2017), participants needed a minimum of 29 points to finally receive the reward (i.e., 60% of 48 trials). A circle without a horizontal line indicated control trials where it was not possible to accumulate points. After a short training, the reward block started: First, a fixation cross was shown for 0.5 s. Then, a trial type indicator (i.e., either an empty circle or a circle with a horizontal line) appeared for 1 s, followed by a fixation cross and the stimulus (i.e., a square

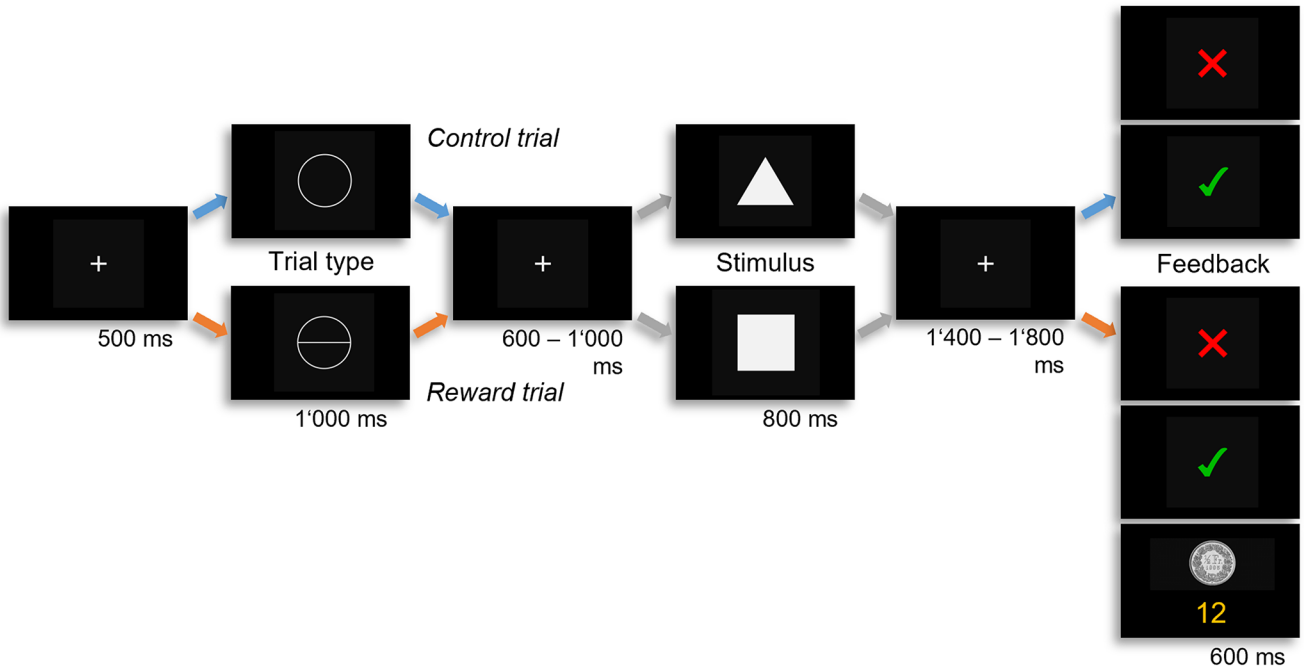

Fig. 1 Illustration of the monetary incentive delay task used in this study. We presented triangles or squares preceded by an empty circle (indicating a control trial) or by a circle with a horizontal line (indicating a reward trial). Only during reward trials, participants had the possibility to earn a reward by responding correctly and faster as during a baseline block. After their response, they received feedback whether the response was correct (green tick) or not (red cross) and fast enough to receive the reward (coin). Below the coin, we presented the number of coins received so far

or triangle). Trial type indicators and stimuli were presented in randomized order. Feedback was given depending on the trial type: For control trials, feedback was identical to the baseline block (i.e., red cross or green tick). For reward trials, a red cross was shown if the answer was wrong or too late. A green tick was presented if the answer was correct but slower than the baseline response time and a 50-Rappen coin (=0.5 Swiss Francs) appeared if the answer was correct and faster than the baseline response time. The sum of all accumulated points was shown below the coin. The reward block consisted of 96 stimuli (50% reward trials). The participants were able to achieve 48 points in total and thus gain a maximum of 24 Swiss francs. At the end of the experiment, the sum of all achieved points was shown on the screen. If that sum was ≥29, the participants received the reward. Responses that were faster than 146 ms were excluded from statistical analysis (Berger & Kiefer, 2021; Whelan, 2008).

Statistical analysis

We used three outcome measures to assess the effect of reward type on performance improvement from control to reward trials. First, regardless of the time it took the participants to respond we assessed response accuracy per trial. The second outcome was the response time for trials with correct responses. Third, we determined an overall performance score that is the number of correct responses to reward trials that were faster than the mean baseline response time.

For the outcome measures of response time and trial accuracy, we were particularly interested in how age, sex, and reward type modulated performance changes from control to reward trials. Thus, we tested whether there was a change in trial accuracy or response times depending on trial type, reward type, age, sex, or their interactions. We used a generalized linear mixed model with binomial distribution and logit link function for trial accuracy (dichotomous variable with 0 for incorrect or missed and 1 for correct responses) and a linear mixed effects model for response times (continuous variable). Compared to a repeated measures analysis of variance, mixed effects models can be more powerful and useful in analysing unbalanced, nested data that contain missing values. In this study, the mixed models allowed us to examine effects of sex, age as well as trial type and reward type on task performance at trial level (i.e., one observation per trial) while at the same time controlling for hierarchical dependencies. Age (younger or older adults), sex (male or female), trial type (control or reward), and reward type (financial, prosocial, combination) were included as interacting fixed effects. We added baseline performance (either trial accuracy or response time) as well as trial number as fixed effects. The models included participant-specific random effects for the intercept and the effect of trial type. Finally, we tested whether the participants achieved different total performance scores depending on reward type, age, or sex (or their interactions) using a multivariate linear regression model. As these scores were aggregated (one measurement per subject and not per trial), there was no need to model a hierarchical data structure and the assumed independence between observations were met.

We used marginal F-tests for linear models or likelihood ratio tests (χ^2 distributed test-statistic) for binominal logit mixed models to test the significance of the predictive value of each factor. For significant factors or interactions, post-hoc pairwise t- or z-tests of estimated marginal means were examined. Interactions were further analysed by running contrasts between estimated means. For logistic models, estimated means on the logit scale were transformed to probabilities. For non-significant findings, we calculated Bayes Factors using BIC-approximation (Raftery, 1999; Wagenmakers, 2007). No priors need to be specified with this approach. Since we were primarily interested whether reward influenced cognition, baseline task performance and other results will be reported in the Supplement. Full equations of each model as well as explained variance of each model can also be found in the Supplement.

We used R with RStudio (Version 2022.02.3) for statistical analysis and considered $p < .05$ statistically significant. We used the packages lme4 (Bates et al., 2015), lmerTest (Kuznetsova et al., 2017), emmeans (Lenth et al., 2022) and MuMIn (Barton, 2022). We corrected for multiple comparisons using Bonferroni's method. Degrees of freedom were estimated with Satterwhite's method.

Results

Within the two age groups, participants in each reward condition (financial, prosocial, combined) were similar in age and sex as well as their perceived health, donation frequency, and satisfaction with their financial situation (Table 1). Older adults rated their subjective health to be lower than that of younger adults. In addition, their donation frequency was higher than that of younger adults. There were no significant differences within younger or older adults between reward conditions. Results of all F and χ^2 tests for examination of effects on trial accuracy, response time and performance score as well as all related post-hoc tests can be found in the Supplement 1.

Trial accuracy

Financial reward with and without a prosocial component enhanced accuracy

We found a significant fixed effect for trial type ($\chi^2_{(1)} = 31.59$, $p < .001$). The probability to respond correctly was significantly higher in reward trials ($P = .95$, SE = 0.003) than in control trials ($P = .93$, SE = 0.003). This indicates that trial accuracy increased with a reward. Additionally, there was a significant interaction between reward type and trial type ($\chi^2_{(2)} = 7.65$, $p = .022$). Post-hoc tests revealed that trial accuracy was significantly higher in reward trials than in no reward trials in the combined condition ($\beta = -0.41$, SE = 0.08, $z = -4.9$, $p < .001$) and the financial condition ($\beta = -0.263$, SE = 0.08, $z = -3.5$, $p < .001$), but not in the prosocial condition ($p = .157$). When contrasting this effect between the three reward types, we found a significant effect only for the contrast between combined and prosocial condition ($z = 2.71$, $p = .018$) but not between any other condition ($p > .293$). We next examined whether the increase in trial accuracy differed in younger and older participants. We found no significant effect for the interaction between age group and trial type ($p = .882$, $BF_{10} = .005$) or between age group, trial type, and reward group ($p = .448$, $BF_{10} < .001$). This indicates that we found no evidence to suggest that trial accuracy increased differently in younger and older adults with a reward (Fig. 2).

Women responded to financial reward only when it included a prosocial component

We went on to examine whether women and men differed in their performance increases motivated by a reward depending on its type. We found a significant interaction between trial type and sex ($\chi^2_{(1)} = 8.89$, $p = .003$). In men ($\beta = -0.39$, SE = 0.06, $z = -6.34$, $p < .001$) accuracy improved significantly with a reward, while only a trend was observed for women ($\beta = -0.13$, SE = 0.07, $z = -1.88$, $p = .060$). This effect of better performance due to a reward was significantly stronger for men than for women ($\beta = -0.27$, SE = 0.09, $z = -2.95$, $p = .003$). There was also a significant interaction for sex, trial type, and reward type (χ^2 (2) = 6.18, $p = .045$, Fig. 3). Post-hoc tests revealed that women showed performance enhancements in the combined condition ($\beta = -0.28$, SE = 0.128, $z = -2.19$, $p = .029$) but not in the other two conditions (all $p > .338$). In men, in contrast, trial accuracy was enhanced in the combined condition ($\beta = -0.535$, SE = 0.107 $z = -5.02$, $p < .001$) and the financial condition ($\beta = -0.534$, SE = 0.108, $z = -4.95$, $p < .001$), but not in the prosocial condition ($p = .305$). These results indicate that trial accuracy improved in men when the reward included a financial component while in women a combination of a financial and a prosocial reward was required. Analysing the age groups independently, we also found that younger men responded more accurately with a reward ($p = .014$; Table S26), and there was a similar trend in older men in the older adult group ($p = .086$). In addition, in younger adults, accuracy of responses improved differently depending on reward type ($p = .062$; Table S26). This indicates that effects we observe may be more pronounced in younger than older men.

Response times

In younger adults, responses became faster with a reward than in older adults

We found a significant effect of trial type ($F_{(1, 500.5)} = 201.32$, $p < .001$) as responses were faster in reward trials (M = 0.496,

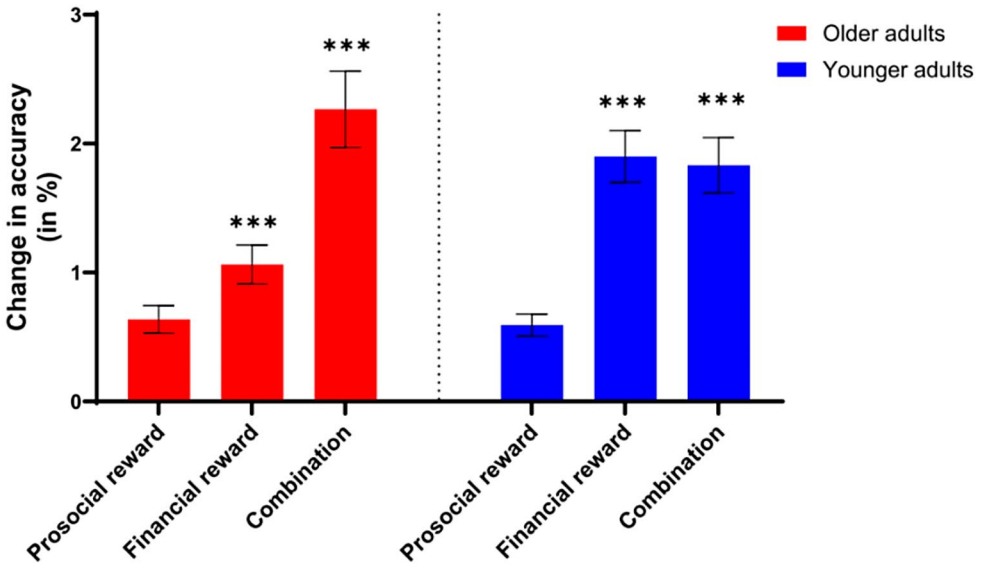

Fig. 2 Increase in trial accuracy (in %) with rewards in younger (blue) and older (red) adults. The reward was either prosocial (donation), financial, or a combination of both (half of the money was donated). Higher scores indicate an improvement. Error bars indicate standard errors of the mean. Significant at $p < .001$***

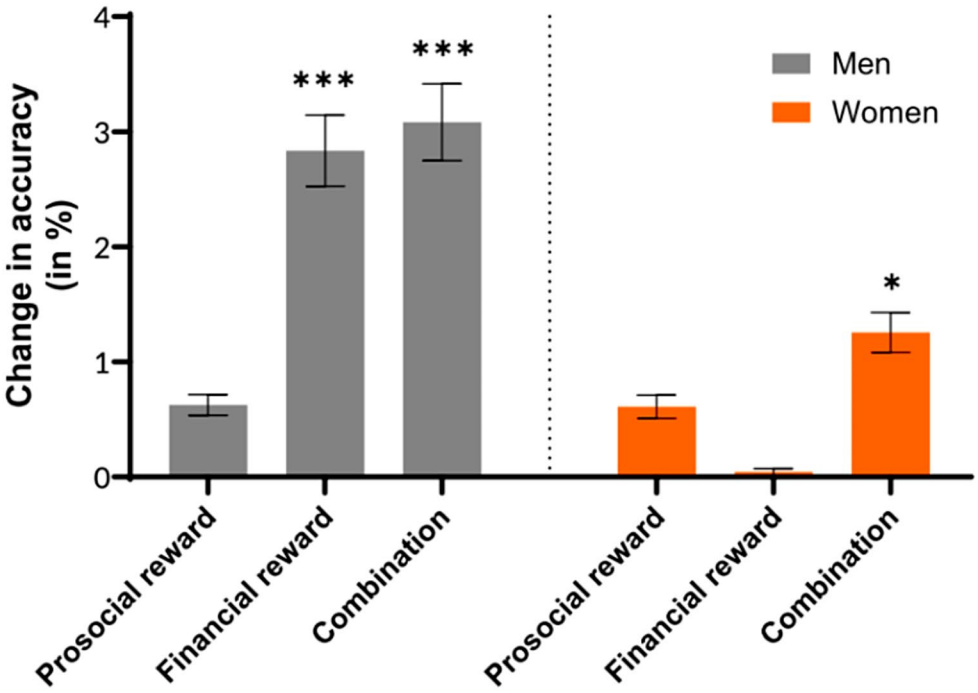

Fig. 3 Increase in trial accuracy (in %) with reward in men (grey) and women (orange). The reward was either prosocial (donation), financial, or a combination of both (half of the money was donated). Higher scores indicate an improvement. Error bars indicate standard errors of the mean. Significant at $p < .05$*, $p < .001$***

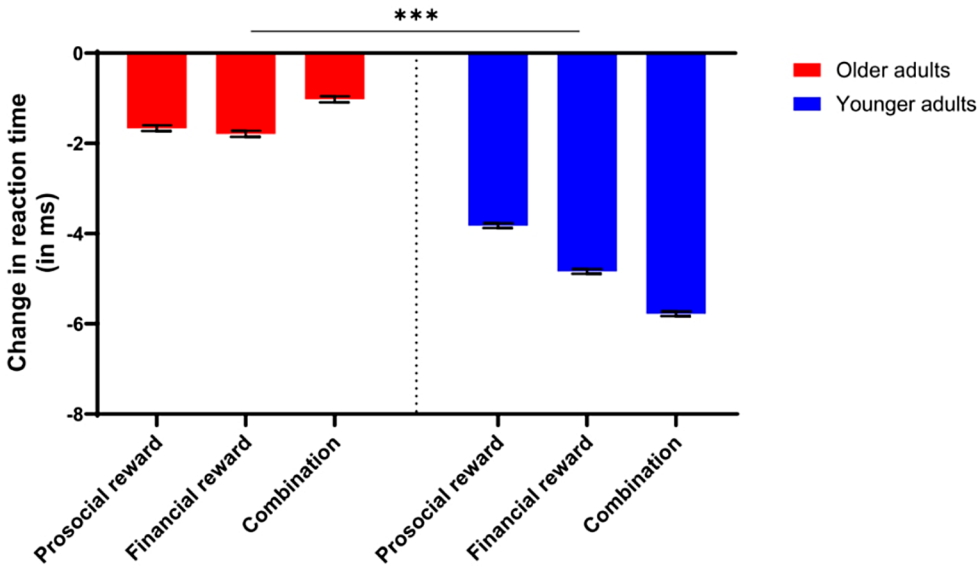

Fig. 4 Change in response times with reward in younger (blue) and older (red) adults. The reward was either prosocial (donation), financial, or a combination of both (half of the money was donated). Negative values indicate an improvement. Error bars indicate standard errors of the mean. Significant at $p < .001$***

SE = 0.003) than in control trials (M = 0.528, SE = 0.003). In addition, we found a significant interaction between age and trial type ($F_{(1,500.6)} = 55.81$, $p < .001$), since younger adults (β = 0.048, SE = 0.003) became even faster when gaining a reward was possible than older adults (β = 0.015, SE = 0.004, Fig. 4). We did not find a significant effect of reward type ($p = .401$, $BF_{10} < 0.001$) nor significant interactions of reward type and age ($p = .219$, $BF_{10} < .001$), sex and reward type ($p = .184$, $BF_{10} < .001$), or sex and trial type ($p = .066$, $BF_{10} = .012$). The results indicate that regardless of the type of reward, all participants became faster when a reward was provided with younger adults responding particularly quickly.

Total performance score

Adding a prosocial component to a financial reward worked best to enhance performance

We found a main effect of reward type ($F_{(2,492)} = 3.21$, $p = .041$) as scores were highest in the combined condition (M = 25.8, SE = 0.916), followed by the financial (M = 24.1, SE = 0.869), and then the prosocial condition (M = 22.7, SE = 0.892). Post-hoc tests revealed a significant difference

between the prosocial and the combined condition ($t_{(492)}$ = -2.465, p = .037) but not between the other conditions (all p > .379). We did not find a significant interaction between reward type and age (p = .575, BF_{10} = .002) or reward type and sex (p = .207, BF_{10} = .004). This indicates that regardless of age or sex, adding a prosocial component to financial reward worked best to enhance performance.

Discussion

In line with previous studies, we observed that, in general, providing a reward enhanced participants' performance (e.g., Di Rosa et al., 2015; Manga et al., 2020; Spaniol et al., 2014; Tonin & Vlassopoulos, 2014). In addition, we found that adding a prosocial component to a reward worked particularly well to boost performance. Our results contribute to the current understanding of what increases cognitive effort invested in task performance.

First, participants were particularly motivated when they donated half of the money they won to charity and kept the other half themselves. We found no evidence to support that age affected the influence of this combined reward on performance. This suggests there may not be such a difference between younger and older people as proposed before with younger adults primarily increasing their performance when receiving financial rewards and older adults when receiving prosocial rewards (Cutler et al., 2021; Freund & Blanchard-Fields, 2014; Mayr & Freund, 2020; *Spendenreport Schweiz 2022*, 2022).

Second, men (particularly younger men) and women differed in their response to rewards. Men's accuracy increased most in the financial condition, but they also improved in the combined condition. Women, however, improved only in the combined condition. This indicates that for both sexes, financial reward improves performance, but it must contain a prosocial component for women to be effective. There is evidence to suggest that in women, generosity is tied to social expectations. Women expect that other women are generous (Aguiar et al., 2009), and they fear negative consequences when they do not live up to this social norm (Heilman & Okimoto, 2007). Thus, women may internalize a propensity for altruism which should have led to the strongest effects in the prosocial condition. Our results, however, indicate that even if they had a tendency for altruism that did not alone lead to greater cognitive effort in the prosocial condition (see also Tonin & Vlassopoulos, 2014; Yang et al., 2017) but only when an additional financial reward was offered. One possible explanation could be that only the combined condition allowed women to maximize their financial gains without the concern of facing negative consequences for selfishness as half of their earnings were still donated. Men, on the other hand, may be less influenced by expectations to behave prosocial. Therefore, they may have tried to maximize their outcome in both the financial and the combined condition. Since we did not assess *why* women or men enhanced performance in a specific condition, we can only speculate about what influenced their change in cognitive performance. A possible next step could therefore be to assess fear of negative consequences for non-compliant behaviour. We would assume that women who expect penalties would be most motivated to gain prosocial rewards, while women who do not expect penalties would rather increase their efforts in a financial condition or a combined condition.

We observed an interaction between sex, reward type, and trial type only for trial accuracy. There was no such interaction for response times. Accuracy independent of speed, speed independent of accuracy, and a combination of swift and accurate responses may reflect the activity of different brain regions and networks. Hence, it is important to examine different outcome measures in monetary incentive delay paradigms as they may result from different neuronal processes. It has been shown, for example, that lower prefrontal activity shortly before stimulus presentation was associated with higher accuracy, while higher activity in the supplementary motor area just before stimulus presentation was linked to quicker responses (Perri et al., 2014). The results of our study may thus suggest that right prefrontal activity was lowest in men when a financial reward or a combined reward was provided. To test these assumptions in future studies, it will be important to test neural correlates of accuracy or speed in men and women in a similar task taking advantage of the different reward types.

Third, our results indicate that a reward had a greater motivational effect on performance in younger than in older adults as their response time improved more. Older adults are, in general, slower than younger adults (Forstmann et al., 2011). It has been suggested that older adults place greater emphasis on accuracy than on speed. In addition to a strategic choice, degeneration of white matter connections between cortex and striatum might be another reason for age-related slowing. Striatal activation releases the cortex to respond faster (but possibly less accurate). White matter integrity in cortico-striatal tracts that connect movement related areas to the striatum seems to be reduced in older adults thus limiting the maximum speed with which they can respond more than in younger adults. Older adults still managed to improve their speed with a reward. However, the extent of their improvement was significantly smaller than that of younger adults (see also Dhingra et al., 2020; Manga et al., 2020; Spaniol et al., 2015; Thurm et al., 2018; but Rademacher et al., 2014; Spaniol et al., 2014). Another factor might be a reduced sensitivity to rewards in older

adults due to age-related changes in the dopamine dependent reward system (Dreher et al., 2008; Seaman et al., 2019). However, it would be important to test why this was evident in response times but not in terms of accuracy. Future studies may consider using a similar experimental design as in our study for MRI investigations. Additionally, incorporating a questionnaire that directly queries participants about their priorities, i.e., accuracy or speed, could provide valuable insights. Such an approach could help discern whether the relatively smaller improvements in older adults are indeed a function of age-related white matter changes or due to strategic choices (or a combination of both).

Fourth, we observed a differential reward-related pattern for trial accuracy changes in men and women. The increase of accuracy was less pronounced in women than men when a reward was provided. This supports previous findings of lower reward sensitivity in women (Dhingra et al., 2021; Spreckelmeyer et al., 2009; Wang et al., 2017) possibly linked to the dopaminergic reward system (Hahn et al., 2021; Soutschek et al., 2017).

Limitations

Our study was an online study and therefore, the experiments are likely less well standardized than in the laboratory. We implemented control procedures and excluded participants with very low task performance. However, it is possible that some participants were distracted during task performance, and technical challenges, e.g., poor internet connection or the computers that were used. Repeating the experiment under controlled conditions in the laboratory is therefore necessary. Another limitation might be that the participants were not able to decide whether they would like to donate some of their earnings. Rather than randomly assigning them to a condition, we could have let them pick and choose. Finally, it could be that they found the combined condition particularly fair and hence, put more cognitive effort in answering correctly. So it could be that assumed fairness rather than reward influences task performance. Adding a question to this end at the end of the experiments could provide more insight.

Conclusions

It has been suggested that prosocial rewards enhance cognitive effort in older adults and women as they are more altruistic and attribute value to prosocial motives rather than to financial. Our results contradict that as no evidence was found to support that age affected the influence of different reward types on performance or that women improved stronger than men for the potential benefit of others. Instead, they did so only when both they and others benefitted equally. Indeed, the only group that tried to maximize their financial gains alone was that of younger men. The only difference that we observed regarding age was that the increase of response speed due to reward was particularly pronounced in younger adults. The results of our study have important conceptual and methodological implications as they highlight the importance of choosing a reward adjusted to age, sex, and performance outcome. The ability to tailor rewards according to age, sex, or performance outcome may improve the experimental set-up used to study the underlying behaviour modification. In addition, theories of prosocial behaviour (for example, when and why people donate to charity or help others; Mayr & Freund, 2020) need to consider that altruism or generosity, though valuable in society, may not on its own enhance cognitive performance. Understanding the boundaries and contexts within which they operate in relation to cognitive abilities is crucial for a comprehensive understanding of human behaviour.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s11031-024-10092-z.

Acknowledgements We thank all participants for their time and support of the study.

Author contributions *Conceptualization*: Sebastian Horn, Matthias Kliegel, Jesscia Peter; *Methodology*: Marta Menéndez-Granda, Jessica Peter, Nadine Schmidt, Patric Wyss; *Formal analysis and investigation*: Marta Menéndez-Granda, Jessica Peter, Nadine Schmidt, Patric Wyss; *Visualization*: Jessica Peter, Nadine Schmidt; *Writing - original draft preparation*: Marta Menéndez-Granda, Michael Orth, Jessica Peter, Nadine Schmidt; *Writing - review and editing*: all authors; *Resources*: Nadine Schmidt; *Supervision*, *Funding acquisition and Project administration*: Jessica Peter.

Funding Open access funding provided by University of Bern. JP has received funding from the Swiss National Science Foundation (grant number 185195).
Open access funding provided by University of Bern

Data availability The datasets generated and analysed for this publication are available online: https://boris-portal.unibe.ch/entities/product/51000f8c-f745-42c5-a40f-a967cf223522.

Declarations

Ethical approval No formal ethics approval was required for this study as confirmed by a formal inquiry to the Cantonal Ethics Committee Bern, Switzerland.

Informed consent Informed consent was obtained from all individual participants included in the study.

Competing interests There are no conflicts of interest.

References

Aguiar, F., Brañas-Garza, P., Cobo-Reyes, R., Jimenez, N., & Miller, L. M. (2009). Are women expected to be more generous? *Experimental Economics*, *12*(1), 93–98. https://doi.org/10.1007/s10683-008-9199-z

Barton, K. (2022). Package 'MuMIn': Multi-Model Inference (1.46.0) [Software]. https://rdocumentation.org/packages/MuMIn/versions/1.46.0

Bates, D., Mächler, M., Bolker, B., & Walker, S. (2015). Fitting Linear mixed-effects models using lme4. *Journal of Statistical Software*, *67*(1). https://doi.org/10.18637/jss.v067.i01

Berger, A., & Kiefer, M. (2021). Comparison of different response time outlier exclusion methods: A Simulation Study. *Frontiers in Psychology*, *12*, 675558. https://doi.org/10.3389/fpsyg.2021.675558

Cutler, J., Nitschke, J. P., Lamm, C., & Lockwood, P. L. (2021). Older adults across the globe exhibit increased prosocial behavior but also greater in-group preferences. *Nature Aging*, *1*(10), 880–888. https://doi.org/10.1038/s43587-021-00118-3

Dhingra, I., Zhang, S., Zhornitsky, S., Le, T. M., Wang, W., Chao, H. H., Levy, I., & Li, C. S. R. (2020). The effects of age on reward magnitude processing in the monetary incentive delay task. *Neuroimage*, *207*, 116368. https://doi.org/10.1016/j.neuroimage.2019.116368

Dhingra, I., Zhang, S., Zhornitsky, S., Wang, W., Le, T. M., & Li, C. S. R. (2021). Sex differences in neural responses to reward and the influences of individual reward and punishment sensitivity. *BMC Neuroscience*, *22*(1), 12. https://doi.org/10.1186/s12868-021-00618-3

Di Rosa, E., Schiff, S., Cagnolati, F., & Mapelli, D. (2015). Motivation–cognition interaction: How feedback processing changes in healthy ageing and in Parkinson's disease. *Aging Clinical and Experimental Research*, *27*(6), 911–920. https://doi.org/10.1007/s40520-015-0358-8

Dreher, J. C., Meyer-Lindenberg, A., Kohn, P., & Berman, K. F. (2008). Age-related changes in midbrain dopaminergic regulation of the human reward system. *Proceedings of the National Academy of Sciences*, *105*(39), 15106–15111. https://doi.org/10.1073/pnas.0802127105

Ferdinand, N. K., & Czernochowski, D. (2018). Motivational influences on performance monitoring and Cognitive Control across the Adult Lifespan. *Frontiers in Psychology*, *9*, 1018. https://doi.org/10.3389/fpsyg.2018.01018

Forstmann, B. U., Tittgemeyer, M., Wagenmakers, E. J., Derrfuss, J., Imperati, D., & Brown, S. (2011). The speed-accuracy tradeoff in the Elderly Brain: A structural model-based Approach. *The Journal of Neuroscience*, *31*(47), 17242–17249. https://doi.org/10.1523/JNEUROSCI.0309-11.2011

Freund, A. M., & Blanchard-Fields, F. (2014). Age-related differences in altruism across adulthood: Making personal financial gain versus contributing to the public good. *Developmental Psychology*, *50*(4), 1125–1136. https://doi.org/10.1037/a0034491

Gong, X., Zhang, F., & Fung, H. H. (2019). Are older adults more willing to Donate? The roles of Donation Form and Social Relationship. *The Journals of Gerontology: Series B*, *74*(3), 440–448. https://doi.org/10.1093/geronb/gbx099

Hahn, A., Reed, M. B., Pichler, V., Michenthaler, P., Rischka, L., Godbersen, G. M., Wadsak, W., Hacker, M., & Lanzenberger, R. (2021). Functional dynamics of dopamine synthesis during monetary reward and punishment processing. *Journal of Cerebral Blood Flow & Metabolism*, *41*(11), 2973–2985. https://doi.org/10.1177/0271678X211019827

Heilman, M. E., & Okimoto, T. G. (2007). Why are women penalized for success at male tasks? The implied communality deficit. *Journal of Applied Psychology*, *92*(1), 81–92. https://doi.org/10.1037/0021-9010.92.1.81

Horn, S. S., & Freund, A.M. (2021). Adult age differences in remembering gain- and loss-related intentions. *Cognition and Emotion*, *35*(8):1652–1669. https://doi.org/10.1080/02699931.2021.1986375

Knutson, B., Westdorp, A., Kaiser, E., & Hommer, D. (2000). FMRI Visualization of Brain Activity during a Monetary Incentive *Delay Task NeuroImage*, 12(1), 20–27. https://doi.org/10.1006/nimg.2000.0593.

Kuznetsova, A., Brockhoff, P. B., & Christensen, R. H. B. (2017). lmerTest Package: Tests in Linear mixed effects models. *Journal of Statistical Software*, *82*(13). https://doi.org/10.18637/jss.v082.i13

Lenth, R. V., Bolker, B., Buerkner, P., Giné-Vázquez, I., Herve, M., Jung, M., Love, J., Miguez, F., Riebl, H., & Singmann, H. (2022). Estimated Marginal Means, aka Least-Squares Means (1.7.5) [Software]. https://github.com/rvlenth/emmeans

Manga, A., Vakli, P., & Vidnyánszky, Z. (2020). The influence of anticipated monetary incentives on visual working memory performance in healthy younger and older adults. *Scientific Reports*, *10*(1), 8817. https://doi.org/10.1038/s41598-020-65723-5

Mayr, U., & Freund, A. M. (2020). Do we become more prosocial as we Age, and if so. *Why? Current Directions in Psychological Science*, *29*(3), 248–254. https://doi.org/10.1177/0963721420910811

Mesch, D. J., Brown, M. S., Moore, Z. I., & Hayat, A. D. (2011). Gender differences in charitable giving: Gender differences in charitable giving. *International Journal of Nonprofit and Voluntary Sector Marketing*, *16*(4), 342–355. https://doi.org/10.1002/nvsm.432

Opitz, L., Wagner, F., Rogenz, J., Maas, J., Schmidt, A., Brodoehl, S., & Klingner, C. M. (2022). Still wanting to Win: Reward System Stability in Healthy Aging. *Frontiers in Aging Neuroscience*, *14*, 863580. https://doi.org/10.3389/fnagi.2022.863580

Perri, R. L., Berchicci, M., Spinelli, D., & Di Russo, F. (2014). Individual differences in response speed and accuracy are associated to specific brain activities of two interacting systems. *Frontiers in Behavioral Neuroscience*, 8. https://doi.org/10.3389/fnbeh.2014.00251

Piper, G., & Schnepf, S. V. (2008). Gender differences in charitable giving in Great Britain. *VOLUNTAS: International Journal of Voluntary and Nonprofit Organizations*, *19*(2), 103–124. https://doi.org/10.1007/s11266-008-9057-9

Rademacher, L., Salama, A., Gründer, G., & Spreckelmeyer, K. N. (2014). Differential patterns of nucleus accumbens activation during anticipation of monetary and social reward in young and older adults. *Social Cognitive and Affective Neuroscience*, *9*(6), 825–831. https://doi.org/10.1093/scan/nst047

Raftery, A. E. (1999). Bayes Factors and BIC. *Sociological Methods & Research*, *27*, 411–427.

Schultz, W., Dayan, P., & Montague, P. R. (1997). A neural substrate of prediction and reward. *Science*, *275*, 1593–1599.

Seaman, K. L., Smith, C. T., Juarez, E. J., Dang, L. C., Castrellon, J. J., Burgess, L. L., Juan, S., Kundzicz, M. D., Cowan, P. M., Zald, R. L., D. H., & Samanez-Larkin, G. R. (2019). Differential regional decline in dopamine receptor availability across adulthood: Linear and nonlinear effects of age. Human Brain Mapping, hbm.24585. https://doi.org/10.1002/hbm.24585

Soutschek, A., Burke, C. J., Raja Beharelle, A., Schreiber, R., Weber, S. C., Karipidis, I. I., ten Velden, J., Weber, B., Haker, H., Kalenscher, T., & Tobler, P. N. (2017). The dopaminergic reward system underpins gender differences in social preferences. *Nature Human Behaviour*, *1*(11), 819–827. https://doi.org/10.1038/s41562-017-0226-y

Spaniol, J., Schain, C., & Bowen, H. J. (2014). Reward-enhanced memory in younger and older adults. *The Journals of Gerontology Series B: Psychological Sciences and Social Sciences*, *69*(5), 730–740. https://doi.org/10.1093/geronb/gbt044

Spaniol, J., Bowen, H. J., Wegier, P., & Grady, C. (2015). Neural responses to monetary incentives in younger and older adults. *Brain Research*, *1612*, 70–82. https://doi.org/10.1016/j.brainres.2014.09.063

Spendenreport Schweiz (2022 (4)). (2022). Swissfundraising und Stiftung Zewo. https://zewo.ch/de/der-spendenreport/

Spreckelmeyer, K. N., Krach, S., Kohls, G., Rademacher, L., Irmak, A., Konrad, K., Kircher, T., & Gründer, G. (2009). Anticipation of monetary and social reward differently activates mesolimbic brain structures in men and women. *Social Cognitive and Affective Neuroscience*, *4*(2), 158–165. https://doi.org/10.1093/scan/nsn051

Thurm, F., Zink, N., & Li, S. C. (2018). Comparing effects of reward anticipation on working memory in younger and older adults. *Frontiers in Psychology*, *9*, 2318. https://doi.org/10.3389/fpsyg.2018.02318

Tonin, M., & Vlassopoulos, M. (2014). Corporate Philanthropy and Productivity: Evidence from an Online Real Effort Experiment. CESifo Working Paper No. 4778.

Vink, M., Kleerekooper, I., van den Wildenberg, W. P. M., & Kahn, R. S. (2015). Impact of aging on frontostriatal reward processing: Impact of aging. *Human Brain Mapping*, *36*(6), 2305–2317. https://doi.org/10.1002/hbm.22771

Wagenmakers, E-J. (2007). A practical solution to the pervasive problems of p values. *Psychonomic Bulletin & Review*, *14*, 779–804.

Wang, D., Liu, T., & Shi, J. (2017). Development of Monetary and social reward processes. *Scientific Reports*, *7*(1), 11128. https://doi.org/10.1038/s41598-017-11558-6

Whelan, R. (2008). Effective Analysis of Reaction Time Data. *The Psychological Record*, 58(3), 475–482. https://doi.org/10.1007/BF03395630.

Yang, J., Ming, X., Wang, Z., & Adams, S. M. (2017). Are Sex effects on ethical decision-making fake or real? A Meta-analysis on the contaminating role of Social Desirability Response Bias. *Psychological Reports*, *120*(1), 25–48. https://doi.org/10.1177/0033294116682945