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Comparing the effectiveness of individualistic, altruistic, and competitive incentives in motivating completion of mental exercises☆

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Abstract

This study examines the impact of individually oriented, purely altruistic, and a hybrid of competitive and cooperative monetary reward incentives on older adults' completion of cognitive exercises and cognitive function. We find that all three incentive structures approximately double the number of exercises completed during the six-week active experimental period relative to a no incentive control condition. However, the altruistic and cooperative/competitive incentives led to different patterns of participation, with significantly higher inter-partner correlations in utilization of the software, as well as greater persistence once incentives were removed. Provision of all incentives significantly improved performance on the incentivized exercises. However, results of an independent cognitive testing battery suggest no generalizable gains in cognitive function resulted from the training.

Keywords

Cognitive exercises; Incentives; Social incentives; Behavioral economics; Health behaviors

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1. Introduction

With a rapidly aging United States population, cognitive decline is a substantial concern both in terms of population health and healthcare costs. In recent years, Alzheimer's disease has become the sixth most prevalent cause of death in the United States, accounting for an estimated direct cost of care of approximately $150 billion per year (Mebane-Sims, 2009). Further, much of the cost of overall age-related cognitive decline is a result of milder forms of decline. By the sixth decade of life, losses in domains including reaction time, working memory, and attention are widespread (Bäckman et al., 2006; Park and Payer, 2006; Rogers and Fisk, 2006). These declines are associated with decrements in functional performance on instrumental activities of daily living, such as problem solving and financial management (Marsiske and Margrett, 2006; Finucane et al., 2005; Owsley et al., 2002).

As physical exercise can stave off some of the physical declines associated with aging, it is possible that cognitive exercises can reduce the rate of cognitive decline, promote healthy longevity, and reduce healthcare costs. Despite this potential, research examining the effectiveness of cognitive exercises in producing functional improvement on daily tasks or capabilities beyond performance on the exercises has generally been discouraging (Jaeggi et al., 2008). However, these disappointing effects may stem in part from low rates of adherence to training programs and the lack of cost-effective approaches to improving sustained and intensive adherence to these regimens. For example, the most comprehensive test of cognitive exercises, the ACTIVE study, had an overall budget of $15 million for 2802 enrolled participants, or approximately $5000 per participant over 24 months (Ball et al., 2002).

Individual monetary incentives have proven an effective motivator to promote a variety of healthy behaviors including weight loss, smoking cessation, adherence to medication regimens, and physical exercise in younger populations (e.g., Charness and Gneezy, 2009; Perez et al., 2009; Volpp et al., 2009; Cawley and Price, 2011; John et al., 2011; Halpern et al., 2015). Yet, little is known about whether such incentives can effectively promote engagement with cognitive training among older populations who may have different discount rates, beliefs about the costs and benefits of the training, and reasons to engage. Additionally, this line of research faces concerns about the crowd-out of intrinsic motivation to engage in healthy behaviors. One potential force which could act to counter-balance such effects are social motivations such as competition and reciprocity (Gneezy and Rustichini, 2000; Benabou and Tirole, 2003; Heyman and Ariely, 2004). The importance of peer effects and social motivations in altering behavior has been documented in a number of domains such as labor supply and financial decision making (Kaur et al., 2010, 2011; Bandiera et al., 2010; Duflo and Saez, 2003).

Social incentives may also be of particular interest in the health domain and among aging populations because many health behaviors (e.g. eating) have strong social elements and social ties remain important throughout the lifespan (Lieberman, 2013). Although evidence within the health domain is limited, two recent studies coauthored by two of the authors of this paper found beneficial effects of social incentive programs. In the first study, veterans with poorly managed diabetes were either paid direct incentives for controlling their diabetes, or were paired with a peer-mentor whose diabetes had been, but no longer was, poorly controlled. Although both interventions led to improvement, the peer mentoring program was significantly more successful at lower cost (Long et al., 2012). In the second study, employees were given either individualistic rewards or organized into small groups in which joint rewards were allocated to group-members who lost weight. While the group incentive scheme was significantly more effective in motivating weight loss, it also provided higher rewards ex post, so it failed to provide a clean comparison of social and non-social incentives of similar value (Kullgren et al., 2013). No studies that we are aware of, including the two just noted, have systematically compared the impact of social and non-social incentives of similar magnitude on desired health behaviors and, in particular, cognitive training among older adults.

Incentives that play on social motives could also potentially enhance cost-effectiveness by providing motivation that is disproportionate to the underlying magnitude of objective incentives. People will, for example, often reciprocate small gifts, such as the address labels provided by charities, or the flowers handed out by Hare Krishnas, with much larger return favors (Cialdini, 2006; Fehr and Gächter, 2000). Likewise, even in the absence of differential material incentives, pure completion and the feelings of "winning" or "losing" can substantially alter behavior and generate significant levels of effort (Delgado et al., 2008). The social forces generated by teams or groups can also significantly increase effort and reduce the cost to produce a given amount of output (Nalbantian and Schotter, 1997; Babcock et al., 2015). By playing on such non-pecuniary motives, social incentives have, at least in theory, the potential to produce more substantial and long-run behavioral changes at lower cost than individualistic incentives.

Hence, this paper provides a test of the comparative effectiveness of individualistic and socially oriented monetary incentives in motivating online cognitive training via a randomized controlled trial among 312 older adults. An online platform was chosen to promote engagement with cognitive training due to three key benefits. First, and perhaps most importantly, use of a web-based cognitive training task facilitates accurate, high frequency data collection as well as high frequency feedback and incentive provision, features which are often difficult to achieve in research of this type. For example, studies examining the impact of incentives on gym usage have generally focused on attendance, measured by sign-ins; it is much more difficult to monitor how much exercise participants complete after signing in. Second, the online platform provides an opportunity to examine the long run impacts of the provision of incentives for cognitive training with minimal experimental demand effects. In this study, for example, the active study period in which incentives are provided lasted six weeks. However participants were given one year of continued access to the cognitive training exercises following the completion of the study, which made it possible to track continued engagement with the exercises after the removal of incentives.

Finally, beyond the benefits of accurate measurement of adherence over time, a desirable feature of an online intervention is that, if found beneficial, it would be much more easily scalable than most other interventions which have been studied. Scalability is facilitated due to the ease of replicating a web-based intervention relative to interventions utilizing physical facilities and/or personnel. More than two-thirds of adults in the United States have a smart-phone, and older adults are using computers and smart phones at ever increasing rates (Nielsen, 2014; United States Census Bureau, 2013; Wagner et al., 2010; Zickuhr and Madden, 2012). Hence, these technologies have the potential to reach individuals of all ages and promote healthy habits, including both cognitive training and other behaviors, on a daily basis at low cost and in an automated fashion.

During the six-week active study period participants in all four conditions, including the Control, were randomly paired and provided access to the cognitive training software including daily information about the number of exercises completed (and, if relevant, the earnings) by themselves and by their partner. While access to the software was free in all conditions, participants in the Control condition did not receive monetary incentives for completing cognitive training exercises. Participants in the three treated conditions were, however, eligible for additional incentives with varying structures. In the individual incentives condition, referred to as the Atomistic treatment, participants were provided with a flat payment per exercise. In the Altruistic treatment, individuals were paid as a function of the number of exercises completed by their partner. In the Cooperative/Competitive treatment, teams of two were randomly paired to form quads, and each of the teams was compensated as a positive function of the fraction of the exercises completed by that team and negative function of the fraction of the exercises completed by the opposing team. The magnitude of the incentives provided in the three treatment conditions were designed to be as similar as possible, so as to provide a clean test of their relative effectiveness in motivating engagement with the cognitive training. Further details regarding the exact payment structures are provided in Section 2.4.

We find that the use of any monetary incentives, whether direct or socially motivated, approximately doubled engagement with the cognitive training exercises. Surprisingly, Altruistic treatment and Cooperative/Competitive treatment (both of which had much lower average marginal benefit per exercise to the individual engaging in the exercise) generated gains in the number of exercises completed that are statistically indistinguishable from those in the Atomistic condition.

Yet despite similar gains in exercises completed across incentivized treatments, we observe very different patterns of engagement in pairs of participants across the experimental treatments. We also found that utilization of the software led to substantial improvements on scores in the majority of the incentivized exercises, with greater gains among treated individuals. However, the gains did not typically generalize to broader improvements in measures of cognitive function as captured by performance on a validated cognitive testing battery examining three distinct domains of functioning as well as an overall global measure of functioning.

Finally, to investigate the crowd-out of intrinsic motivation, we examine utilization of the training software following the completion of the experimental period. Despite dramatic declines across all experimental groups, there were significant differences in the rate of decline across conditions. During the five month follow up period, roughly twice as many exercises were completed by participants in the socially oriented treatments than by participants in the Atomistic and Control conditions.

2. Experimental design

2.1. Participants

Three hundred and twelve participants between the ages of fifty-five and eighty were recruited from adult education classes, churches, prior unrelated studies, Craig's List, and community centers in Pittsburgh PA. All participants were screened either in person or by phone prior to entering the study. Individuals were excluded from the study if they had a history of stroke, dementia, Parkinson's or Huntington's Disease, Multiple Sclerosis, major psychiatric disorders, or were using medications to enhance cognitive ability. To participate in the study, individuals had to score at least 26 on the Telephone Interview for Cognitive Status-40 (TICS-40) [roughly equivalent to scoring 27 or above on the Mini-Mental State Exam (MMSE) (Fong et al., 2009)], to have fluent written and spoken English, proficiency with a computer, internet access, and ability to attend a training session and testing sessions at the beginning and end of the active experimental period in the office in Pittsburgh, PA These criteria were chosen to select individuals likely to be invested in improving cognitive function, while preventing ethical questions and attrition associated with enrolling participants experiencing cognitive declines or in ill health. Baseline participant characteristics are presented in Table 1.

With fewer than one in twenty significant differences between conditions, this table suggests that the randomization was successful in producing comparable samples in each of the four conditions. The final column of Table 1 presents comparable values from the United States population during the same time period. Participants in this study were relatively representative of older adults on many demographic characteristics such as age and retirement status. However, participants in this study were, on average, more educated (80% with a BA or more versus 25% in the population at large) and higher earning (median income of $50,000–74,999 versus 46,080 in the population generally) (Current Population Survey (CPS), 2015).

2.2. Experimental timeline and online platform

After being screened and completing the informed consent process, participants visited the lab and completed an enrollment survey and a 45-min baseline battery of computer-based cognitive tests utilizing the NeuroTrax software[1]. Following the cognitive testing, participants were randomly paired (and, when relevant, grouped) and assigned to an experimental condition. Participants also completed an in-person training session to familiarize them with: (1) the cognitive exercise software, including the exercises themselves, (2) the website's messaging features which allowed them to communicate directly with their partner(s), and (3) the information available through the website (their performance, their partner's performance, and, when relevant, each person's earnings). Participants in the treatment groups were also given extensive instruction, in verbal,

[1]Additional details regarding this testing battery are provided in Section 2.3.

mathematical, and graphical form, about the monetary incentive structure to which they were randomized. During the six-week study period all participants received free access to the cognitive training software and daily emails regarding their own and their partner's/ group's engagement. Earnings information was also provided in these emails for all conditions except the Control. In addition, all participants, including those in the Control group, could access information regarding their own use of the software as well as their partner's use of the software via the website at any time. This information was updated in real time. At the end of the study period, participants completed an alternate version of the cognitive testing battery completed at intake and an exit survey[2]. After the active study period all participants were given continued free access to the cognitive training software, and usage was monitored; however no further emails were sent, no information about the partner's utilization of the software was available, and no further payments were made for use of the software. Fig. 1 details the participant timeline.

2.3. Cognitive training and cognitive testing software

The exercises used in the training software were provided by Lumosity, a firm that provides online cognitive training exercises. The firm collaborates with cognitive science researchers from a variety of well-respected institutions in developing their training exercises. The firm also collaborates with researchers to evaluate their training tools and has found some positive results. However, the majority of the peer-reviewed evidence has focused on smaller samples or specific populations such as chemotherapy treated cancer survivors (e.g., Finn and McDonald, 2011; Kesler et al, 2013)[3]. Yet, over 70 million individuals use this platform, and many other platforms are also in use around the world. A better understanding of the consequences of sustained training on these activities among a more typical population provides valuable information about whether these platforms can be used to improve cognitive function or stave off cognitive decline.

A subset of 11 exercises drawn from Lumosity's training materials were used in this study. These exercises targeted five primary cognitive domains: spatial orientation, problem solving, memory, executive function, and reaction time. The average exercise took approximately 2 to 3 min to complete; however the range in duration was approximately 1 to 10 min depending on the exercise and the individual's skill level. To ensure that participants were exposed to the full range of exercises, the eleven exercises were presented in a quasi-random order which was changed daily.

The cognitive testing battery used in this study was developed by NeuroTrax and has been used in over 75 published peer-reviewed studies. The battery been validated as a metric to detect declines in cognitive function among both older adults and the elderly (Dwolatzky et al., 2003; Doniger et al., 2006). It is able to significantly discriminate between healthy adults and those with mild cognitive impairment. NeuroTrax discriminability is comparable to traditional testing batteries in memory, attention, motor skills, processing speed, executive

[2]The cognitive tests taken at enrollment and the completion of the active experimental period are identical in nature and design, however the stimuli vary between versions to minimize test-retest effects. Correlation in performance across versions is very high (see the Neurotrax website for more details).
[3]More information is available at www.lumosity.com.

function, visual spatial skills, and problem solving. The test-retest reliability is also high: $r = 0.84$ for memory, $r = 0.80$ for executive function, $r = 0.68$ for Processing Speed, and $r = 0.79$ for attention (Schweiger et al., 2003)[4]. These features make it well suited to study potential changes in functioning resulting from the training regimen in our study. The testing battery used in this study relied on nine tests focused on memory, executive function, attention, and processing speed. While reaction time is not considered a distinct domain in the NeuroTrax testing, it is used as an underlying metric in processing speed and attention tests. Due to time constraints during testing, tests explicitly targeting problem solving and spatial reasoning were omitted from the battery.

After a participant completes the testing battery, the software generates scores within each cognitive domain tested based on performance metrics from the underlying tasks. Additionally, the scores within each domain are averaged into a single "global" cognitive score which serves as a measure of overall performance on the battery. These scores are normalized according to age and education specific values in cognitively healthy individuals. Further details of this process are provided on the NeuroTrax website, (http://www.neurotrax.com).

2.4. Experimental treatments

Payment formulas for all experimental conditions are presented in Table 2. Individuals assigned to the Control group were provided with free access to the cognitive training software, messaging service to communicate with their partner, and emails, but were not given any monetary incentives to utilize the software. All other conditions were provided with incentives to complete up to 30 exercises, or roughly 1 h of training, per day. An hour of training was targeted to encourage a level of training high enough to detect effects on cognitive function, should one exist, while capping incentivized involvement at a length of time judged to be potentially sustainable [5].

The maximum daily earnings in all treated conditions was $5. This value was chosen primarily based on the values provided in other studies which successfully promoted preventive health behaviors (e.g., see reviews by Marteau et al, 2009; DeFulio and Silverman, 2012; Jeffery, 2012). However, given the range of payments proven successful in the literature and the variety of tasks involved, some discretion was required. Hence, the total daily compensation of $5 was arrived at by balancing a level which participants were likely to find motivating given the time commitment, but which could still be financially sustainable in the context of wellness programs.

Given the maximum payment of $5, participants in the Atomistic treatment were provided with a flat rate monetary incentive of approximately $0.17 per exercise for completing up to 30 exercises. Participants in the Altruistic treatment were compensated at the same rate of $0.17 per exercise. However, their compensation depended on the number of exercises

[4]More information is available at http://www.neurotrax.com.

[5]Ball et al. (2002) present one of the few examples of a successful cognitive training intervention in older adults. We base our estimated required training on this example. Training in this study consisted of 10 sessions lasting 60–75 min conducted over 5 to 6 weeks. However, participants in this study trained only one cognitive domain. Participants in our study trained on multiple domains, with some tasks training multiple domains simultaneously. Hence, we targeted roughly similar overall levels of training per domain.

completed by their partner rather than of their own level of participation. Hence, while participants in this treatment could potentially improve their cognitive health via the training, they received no direct financial benefit from completing additional exercises.

Finally, participants in the Cooperative/Competitive treatment were paired with a partner to form a team, and two pairs/teams were matched to form a group of four. The incentives in this treatment were designed to encourage cooperation between members of the teams and competition between the teams. To accomplish this, individuals in this treatment were compensated as a function of both the relative level of participation between the two teams and the total number of exercises completed by the team with the highest level of participation. Specifically, the total amount of money available to be distributed among the group of four was the maximum number of exercises completed by either team multiplied by $0.34. The money was then allocated between the two teams in direct proportion to the number of exercises completed by each team. Each member of a team/pair received the same compensation for a given day. This design provides a strictly positive marginal payment for the individual completing the activity and also for their partner (up to the 30 exercise per participant limit, consistent with the other treatments). However, the marginal payment for one exercise by one member of the team varied significantly and ranged from less than $0.01 to $0.17 per partner based on the performance of both teams[6]. Due to the fact that the payment from each exercise is split between members of the team, individuals in the Cooperative/Competitive treatment receive a weakly lower payment per exercise for themselves than individuals in the Atomistic treatment. But, to keep the total possible payments the same, this difference is compensated for by the fact that when an individual's partner completes an exercise, that individual receives a payment without having completed any exercises. This structure encouraged cooperation among team members (each team member's work benefits the other; both had to participate to get the maximum possible earnings), but competition between the two teams (once the maximum number of exercises was reached by either team the payments became zero-sum across the group).

3. Results

3.1. Completion of exercises

There is a large main effect of treatment on engagement with the cognitive exercises. Individuals in the no payment Control completed an average of 11.7 exercises per day (roughly 30 min of daily engagement with the software). Individuals in each of the treatment groups completed approximately twice that number, a large and statistically significant increase (see Table 3 and Fig. 2)[7]. The increase in engagement in the treatment groups is

[6]Note that a marginal payment of $0.34 for the team as a whole is a marginal payment of $0.17 for each member of the team. Marginal payments are high when one team has not completed any exercises but the other team has not yet reached the 30 exercise per participant limit so the total amount available is growing but is only allocated to one team. On the other hand, marginal payments are low when one team has completed the maximum incentivized number of exercises and the other has completed very few because the total amount to be distributed does not grow when the low playing team engages, but the fraction reallocated toward the low engagement team is small. Despite the variability in the marginal payments in this condition, the median payment per exercise per team in this condition was $0.17.

[7]As expected given the well-balanced randomization, results were qualitatively similar with and without controlling for baseline characteristics. Hence, additional covariates are omitted to simplify regression results. All regressions were clustered at the level of the pair for the Control, Atomistic, and Altruistic conditions and at the level of the group (two teams each consisting of a pair) for the Cooperative/Competitive condition.

statistically indistinguishable across the three treatment arms, with an average of 23.1, 22.4, and 25.5 exercises per day for the Atomistic, Altruistic, Atomistic, and Cooperative/ Competitive groups, respectively. This result is particularly striking given that participants in the Altruistic and Cooperative/Competitive conditions received significantly lower direct benefits for completing exercises than individuals in the Atomistic treatment. Direct payments to the individual completing the exercise in the Atomistic condition strictly dominate those of individuals in the Altruistic condition, who receive zero direct benefit, and weakly dominate those of individuals in the Cooperative/Competitive condition, who receive a median payment roughly half as large as those in the Atomistic condition due to the fact that the same marginal payment in split across the members of the team[8].

Given that both frequency and intensity of exercise may play a role in generating improvements in cognitive function, we also investigate the potential margins of adjustment underlying this dramatic overall increase in the number of exercises completed to determine whether the incentives were effective at increasing both these margins. Reassuringly, the results indicate that the increase is due to the combined effect of both extensive margin changes (i.e. more regular use of the software) and intensive margin changes (i.e. greater participation conditional on logging into the website). Distributional information for the number of exercises completed is presented in Table 4. Individuals in the Control group logged in 65.8 percent of the days while participants in the Altruistic, Atomistic, and Cooperative/Competitive groups logged on 81.0 percent, 80.3 percent, and 87.5 percent of the days, respectively. Conditional on logging in and completing any exercises, the mean number of exercises completed in each group was 17.8 (Control), 27.7 (Atomistic), 28.8 (Altruistic), and 29.1 (Cooperative/Competitive). Hence, in addition to the large impact on daily use of the software, the treatments dramatically increased the number of exercises completed once logged in.

As shown in Figs. 3a–d and Fig. 4, the higher average completion of exercises in the treatment groups is driven in large part by the substantial fraction of individuals completing exactly the maximum number of incentivized exercises, 30. While the most immediately striking feature of these figures is the large mass of individuals completing exactly 30 exercises in the treatment groups, the treatments increased the number of individuals completing more than the monetarily incentivized number of activities. Specifically, the treatment raised the fraction of participant-days above 30 exercises from 9.0 percent in the Control group to 19.2 percent, 21.4 percent, and 28.7 percent of the Altruistic, Atomistic, and Cooperative/Competitive groups, respectively.

Although the incentives offered in the three treatment groups had similarly large main effects on the average number of exercises completed per day, treatment assignments had differential impacts on the within-pair patterns of engagement, varying in accordance with the degree to which incentives depended on the behavior of the person with whom the

[8]While the marginal payment in the Cooperative/Competitive condition was variable, and depended on the level of utilization of both teams, the mean payment per exercise per team ($0.23) was quite similar and the median payment per exercise per team ($0.17) was nearly identical to the other compensated treatments. However, the fact that this total marginal payment is split equally across the members of the team results in direct payments to the individual completing the exercise about half as large as those in the Atomistic condition.

participant was paired. Individuals assigned to the Control group have no financial interaction or interdependency; however play between partners is still correlated ($r = 0.15$, $p = 0.09$), providing evidence for modest peer effects resulting purely from the daily emails regarding how many exercises were completed by each member of the pair. In the Atomistic treatment in which financial rewards are again unrelated to the partner's engagement, the correlation between partner's daily use of the software is very similar ($r = 0.12$, $p = 0.25$). In the Altruistic and Cooperative/Competitive treatments, however, in which financial rewards are contingent on one's partner's play, the correlation between partners increases to 0.36 ($p < 0.01$) and 0.22 ($p = 0.01$), respectively.

In addition to these simple correlations, a number of other interesting patterns of concordance were generated by the social and financial incentives of the treatment arms. Column (1) of Table 5 displays results from a linear probability regression examining the probability that an individual completes zero exercises as a function of their treatment group, binary variables indicating whether their partner completed zero exercises that day or the previous day, and treatment interacted with the binary variables. Column (2) presents similar results with binary variables for completing at least 30 exercises. Both the current day and lagged interaction terms are strongly positive and significant for the Altruistic condition indicating that individuals in this condition were more likely than individuals in the Control group to complete zero (30 or more exercises) if their partner did the same on either the current day or the previous day. Of further interest is the fact that, for the Altruistic treatment, the point estimate for lagged positive reciprocity is substantially larger, although not statistically distinguishable from, negative reciprocity. Negative reciprocity may be mitigated by the fact that the exercises are intended to promote health, encouraging engagement even in the absence of financial remuneration.

To further examine these spillovers and their evolution over time, we regress the number of exercises completed by the individual on their partner's exercise completion that day and the previous three days as well as treatment assignment in a fully interacted model. (See online Appendix A for regression, Table A1. Fig. 5 summarizes the results from this regression.) The point estimates of all contemporaneous and lagged effects are positive and most are significantly different from zero. Initially (contemporaneous effects and one lag), reciprocity effects are greatest in the Altruistic condition followed by the Cooperative/Competitive condition. By two periods (days) back, however, the effects are small and indistinguishable across conditions despite remaining positive.

Building on this analysis, we investigate these reciprocity effects over time in the study. Fig. 6, which displays the between-partner correlation in daily exercises by study week, shows that these reciprocity effects grew stronger over the course of the six week intervention period in the Altruistic and Cooperative/Competitive conditions in which payoffs were interdependent. In contrast, the correlation between partners' play declined over time in the Control condition and remained fairly stable, but low, in the Atomistic treatment condition.

3.2. Performance on cognitive exercises

Participants in all experimental treatments significantly improved their performance on ten of the eleven cognitive exercises included in the software (see Table 6, Panel A). Even in the

Control group, improvements in performance were substantial in magnitude, typically between 3/4 and 1 standard deviation. The doubling of exercises completed by individuals in the treatment groups generated an additional marginal improvement of roughly 1/4 to 1/2 standard deviations on approximately half of the 11 exercises. The differential gains were largest in exercises focusing on executive function, speed/reaction time, and spatial orientation (Table 6 also indicates which exercises, numbered from 1 to 11, target each of the cognitive domains. Exercise 2 is co-categorized in both Reaction Time and Spatial Reasoning. Fig. 7 presents these changes in performance by cognitive domain). Although these estimates suggest decreasing marginal returns to additional exercises, the differential gains still represent substantial improvements on these exercises for treated individuals.

The improvements in scores on the exercises are mediated by the increase in the number of exercises completed (see Table 6, Panel B). Each additional 100 exercises is associated with a gain of approximately 0.05 to 0.2 standard deviations. However, congruent with the results presented in Panel A, the negative coefficients on the squared terms indicate diminishing marginal returns.

Given that the number of exercises (i.e. quantity) is incentivized rather than the scores on the exercises (i.e. "quality"), it is possible the design of the incentives could encourage participants to strategically substitute quantity of engagement for quality of engagement in order to maximize their rewards. If this substitution occurred, it would limit the potential cognitive benefits of training.

Table 6 Panel B allows us to examine whether this occurred by testing whether receiving financial incentives impacts scores on the exercises, conditional on the number of exercises completed. To be explicit, because improvements in scores are a function of both practice (the number of exercises completed) and "quality" or concentration per exercise, if treated individuals exerted less cognitive effort per exercise we would expect treated individuals to obtain lower scores conditional on the amount of practice (number of exercises). Hence, if substitution from quality to quantity occurs we would expect that the regression coefficients on the Treatment indicator to be negative.

As can be seen in Table 6 Panel B, nine of the eleven coefficients on the Treated variable are insignificant, suggesting no or minimal substitution toward quantity over "quality" of engagement among those exercises. Two coefficients [columns (9) and (10)] are, however, statistically significant and negative. These significant coefficients occur in exercises in which the duration of the exercise increases substantially with improved performance.

Specifically, while the majority of exercises were of fixed duration, a small number of exercises increased in duration as performance improved (e.g. a certain number of mistakes are granted before the game ends, so as performance improves and the fraction of rounds with a mistake declines, the duration of the game increases). The games in Columns (9) and (10) exhibited this feature and ranged in duration from roughly 2 to 10 min per exercise, roughly 1 to 5 times the duration of a "typical" exercise. Hence, the incentive to shift from quality to quantity on these exercises was higher given the additional time costs of quality improvement. Correspondingly, there is greater substitution away from quality on these two exercises. For these 2 exercises, the magnitude of the performance decline driven by incentivizing quantity is approximately equivalent to the expected decline in performance corresponding to completing 9 to 10 fewer exercises per day[9]. In short, in circumstances in which the exercises become much more taxing as participants improve, there is evidence of substitution toward quantity over quality; however, this substitution appears to have been minimal overall.

3.3. Performance on cognitive testing battery

Although individuals in the treatment groups typically had greater improvement on scores on the training exercises, individuals in the incentive conditions did not show greater improvement on scores on the cognitive testing battery over the course of the six-week study as compared with the Control group (see Table 7 Panel A).

There are universal improvements, defined as the difference between exit score and baseline score, across all experimental groups in the cognitive testing battery[10]. However, as can be seen in Table 7 Panel B, these improvements may be at least partially due to a test-retest effect. While Processing Speed is significantly correlated with the number of exercises completed even after a Bonferroni correction, there is no significant relationship between the number of exercises completed and improvements on the cognitive testing battery for the overall cognitive score or three of the four cognitive domains[11].

An alternative explanation consistent with these results is that even the lower levels of training done by the Control group can be highly efficacious in increasing scores on this testing battery. However, the improvement of those individuals in the bottom decile of exercises per day (approximately 4 or fewer exercises per day, or fewer than one exercise per day in each domain) is statistically indistinguishable from that of individuals in the top decile of exercises per day (more than 31 exercises per day). Hence, the improvements from the training would need to be highly non-linear (i.e. all of the benefits accrue from the completing the first exercise or two) for this explanation to hold, suggesting that a test-retest effect is the more likely explanation driving these results.

Finally, it is also possible that this particular cognitive assessment failed to capture changes generated by the training or that additional training is necessary to detect effects on this test. However, the validation of the testing battery, as described in Section 2.3, suggests this is also unlikely to fully explain these results. Hence, despite the fact that the incentives were effective in generating high levels of sustained engagement and substantial gains on the trained exercises, these cognitive testing results are consistent with a large number of other studies which point to limited or no improvement on general cognitive tasks which are not specifically trained (Jaeggi et al., 2008).

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[9]For example, in column (9) each additional 100 exercises completed over the course of the study increases average performance on the task by 0.05 standard deviations (the coefficient on "Total exercises," the coefficient on the quadratic term is small enough not to exert substantial influence). Being treated with any incentives decreases performance by −0.21 standard deviations (the coefficient on "Treated"). So, being treated is roughly equivalent to completing 400 fewer games over the 6 week study, or completing about 9.5 fewer games per day.

[10]Section 2.3 provides additional details regarding this cognitive testing battery.

[11]Results of a two stage least squares regression using treatment as an instrument for the number of exercises completed provide similar results.

3.4. Time trends

One of the most significant challenges in changing health-related behaviors is to maintain the behavior changes over time. During the six weeks of the active study period there was a small but statistically significant decline in the number of exercises completed in the Control, Atomistic, and Altruistic conditions. The effect amounted to a decline of approximately 3.3 exercises per day over the course of six weeks, in a fairly linear trend of approximately 0.5 exercise per week. There was no decline in engagement in the Cooperative/Competitive treatment (see Fig. 8).

At the conclusion of the six-week experimental period, participants were given continued access to the software; however the monetary rewards and daily information about their own and their partner's engagement with the software ceased. In contrast to the moderate decline in engagement with the software during the six-week experimental period (except in the Cooperative/Competitive treatment), there was a large and immediate decline in all experimental conditions at the conclusion of the study. In fact, the average total number of exercises completed per participant in the five months following the completion of the study was only 84, or approximately 0.5 exercise per day. This low level of engagement is in sharp contrast to the previous overall average of 21.6 exercises per day during the active experimental period.

However, a post-hoc analysis comparing the average number of exercises between socially oriented and individually oriented treatments reveals that individuals in the socially oriented incentive conditions completed nearly twice as many exercises (103 in Cooperative/Competitive and 98 in Altruistic) as individuals in the individually oriented conditions (58 in Control and 57 in Atomistic). The difference between the Cooperative/Competitive and Altruistic treatments and the Atomistic and Control treatments is marginally significant ($p = 0.06$) during the first month, but becomes insignificant as the treatments converge over time (see Fig. 9).

The large standard errors on these estimates are due to substantial variation in the level of software utilization after the end of the active experimental period. The fraction of individuals who never log onto the software again after the active experimental period ended is relatively constant across experimental conditions, ranging from 39 percent to 42 percent. However, approximately 7 percent of individuals continue to engage at meaningful levels (>5 exercises per day on average) for at least a month, and 77 percent of these individuals are in the Cooperative/Competitive and Altruistic treatments, a pattern of difference that persists, albeit more weakly, after the first month. Hence, these results suggest that the more socially oriented treatments enhance intrinsic motivation more (or detract from it less) than more individually oriented treatments, at least for a subset of the population.

4. Discussion

In this experiment, all three types of monetary incentives, whether direct or socially motivated, approximately doubled engagement with the cognitive training exercises. Strikingly, the altruistically motivated incentives and the Cooperative/Competitive incentives (both of which had much lower average marginal benefit per exercise to the individual engaging in the exercise) generated gains in the number of exercises completed that are statistically indistinguishable from the direct monetary incentives in the Atomistic condition. The dramatic increase in the average number of exercises completed each day was the result of gains on both the extensive and intensive margins, with individuals in the treatments logging in on a larger fraction of the days and completing more exercises conditional on logging in.

Despite the fact that the gains in utilization of the software were statistically indistinguishable across the incentivized treatments, the patterns of engagement with the software among paired participants were strikingly different across the experimental treatments. While pairs of participants in the Control and Atomistic treatments exhibited modest correlations in exercises completed each day, suggesting the existence of spillovers purely from the information provided about the partner's use of the software, the correlation between partners in the Altruistic and Cooperative/Competitive conditions was both much higher and increased over time.

The consistent and high levels of utilization of the software led to meaningful improvements on the majority of the incentivized exercises; these gains were typically 0.75 to 1 standard deviation in the Control group and 1 to 1.5 standard deviations in the Treatment groups. Although there were also substantial gains on a cognitive testing battery administered at enrollment and again at week six, the gains did not differ substantially between Control and Treatment groups or those in the top and bottom decile of exercise completion, suggesting that the effects may be driven primarily by a test–retest effect. This finding, which is suggestive of limited gen-eralizability of cognitive changes, is consistent with a wide range of previous studies examining the impact of'brain exercises' on generalized cognitive function despite the high levels of engagement over the six-week training period in our study (Jaeggi et al, 2008).

Following the conclusion of the experimental period, utilization of the software declined dramatically across all experimental groups. However, the decline was attenuated slightly in the Altruistic and Cooperative/Competitive conditions. Individuals in these groups completed nearly twice as many exercises in the first month following the cessation of the intervention as individuals in the Control or Atomistic treatments. This result points to the possibility that the social forces generated by those treatments led to less crowding out, or more crowding in, of intrinsic motivation. These differences between conditions in post-incentive engagement, however, disappeared by the end of the second month following the removal of incentives. Hence, although social forces may promote intrinsic motivation to engage with training, more work is needed to understand how to amplify these effects and increase their longevity.

Although the sample of 312 participants was moderate, the high levels of utilization of the cognitive training software during the study were striking and quite clearly robust. It is possible, with a larger sample, that significant differences might have emerged between treatment groups, but our sample size was chosen to be large enough that clinically meaningful differences would be likely to emerge. Indeed some differences, e.g., in relationships of engagement between partners as well as differences in persistence once incentives were removed, did emerge, and were significant.

While the population studied was likely to be particularly motivated, a fact demonstrated by the substantial utilization even among individuals in the Control group, financial and social incentives still resulted in large increases in the number of exercises completed. The high initial motivation of the participants may moderate generalizability of the magnitude of the effects; if these incentive conditions were implemented in a population that was not intrinsically motivated to do cognitive training, it is possible that the impact of the incentives would be more modest. However, the opposite is also possible, since control participants in such an implementation would also be less motivated.

Additionally, the relatively high levels of education of the study population may also have influenced the participants' reactions to incentives. However, the direction of this effect is also ambiguous. It is possible that more educated individuals may either be more attentive to or better understand the incentives or place a higher value on maintaining strong cognitive skills, leading them to react more strongly. On the other hand, it is also possible that people with greater education would believe there is less need to engage in cognitive training, or that the high correlation between education and lifetime income would moderate the impact of the modest monetary rewards. Although this effect is ambiguous, the fact that incentives improved engagement from already high levels suggests that these types of socially oriented monetary incentives do have the potential to promote engagement both with further studies of alternative cognitive training methods and in those of other health behaviors.

The scalability of the online platform complements the scope of the socially oriented interventions, both in terms of facilitating further research and in terms of possible use in wellness programs or other contexts in which healthy behavior changes are promoted. From the perspective of study participants or individuals considering whether or not to join a wellness program, web-based platforms have the potential to greatly reduce costs and promote active engagement.

Further, in terms of future research, the online platform, and in particular the cognitive training exercises, offer a unique opportunity to gather accurate high frequency data with minimal experimental demand. This feature is important for two key reasons. First, although results of this training regimen did not generalize substantially over the period studied, research to determine how to forestall cognitive decline is still of paramount importance. Alzheimer's disease is not only the sixth most common cause of death, but accounts for an estimated direct costs of care of approximately $150 billion per year in the United States (Mebane-Sims, 2009). Mild cognitive impairment and other less severe forms of cognitive decline further add to this enormous cost and loss of healthy years of life. This burden will only increase with an aging population. The total costs of dementia in the United States are expected to climb to between 300 billion and 615 billion by 2040 (Hurd et al, 2013). Hence, while few cognitive training programs to date have proven successful, further study of creative programs design to forestall these declines remains essential. This platform and similar incentives may serve as an ideal venue for further study in this area by promoting substantially higher rates of sustained engagement with alternative training regimens.

Second, and more broadly, although prior research examining the impact of monetary incentives on other health-related behaviors has yielded a number of interesting findings, this research has often been stymied by poor measures of incentivized behaviors. For example, in studies examining monetary incentives for gym attendance, attendance has been measured by card-swipes (e.g., Acland and Levy, 2015; Charness and Gneezy, 2009). However, it is unclear whether the individual actually completed any exercise or simply swiped the card to receive the promised rewards. A variety of other health behaviors such as medication adherence face similar challenges. Some studies have addressed behaviors with more directly verifiable outcomes such as weight loss or smoking cessation, but it is difficult to measure these behaviors with high frequency and accuracy in many settings, limitations that likely diminish the effectiveness of incentives. Online cognitive training addresses these concerns by accurately capturing exactly how much exercise was completed and by providing high frequency data that can be used to provide rapid accurate feedback and incentives.

Although the positive, and generally comparable, effects of the different incentive schemes on participant engagement might seem to suggest that all that matters is whether engagement is incentivized, the different patterns of engagement produced by the various incentive schemes suggest that the incentive designs may be more or less appropriate for different health related behaviors. For example, in activities where individuals can “fall off the bandwagon” easily, altruistic designs may provide discouraging results because when one team member fails and is unable to get back on track there are likely to be negative spillovers to the other team member. The same is true of the Cooperative/Competitive condition. The higher correlation in behaviors between pairs in the two conditions involving social incentives is, thus, a double-edged sword. On the one hand, each of these conditions may have been successful in channeling powerful social motives to the goal of motivating people to engage in cognitive exercises. On the other hand, the same connectedness between the players also introduces hazards in terms of likely non-engagement if one of the players drops out. This could happen for reasons that have nothing to do with lack of motivation, such as vacations, work, or lack of internet access but nevertheless effectively demotivate the other member of a pair. These are important factors to take into account when deciding what types of incentives to introduce in a particular setting.

In sum, although the diverse incentive schemes examined in this study were successful in substantially increasing older adults’ engagement with online cognitive exercises, and this engagement produced significant improvements in performance on the exercises themselves, these improvements did not appear to generalize beyond the incentivized exercises. While these results are disappointing given the urgent need for strategies to forestall cognitive decline in aging populations, the research does provide empirical support for the efficacy of financial and social incentives in motivating engagement in health-promoting behaviors. If online cognitive training regimens that confer generalized benefits are developed in the future, the ability to promote sustained and intensive engagement with them will be crucial to realizing their full benefits.

Appendix A

Table A1

Table A1

Mean daily exercises as a function of partner's lagged exercises.

Atomistic	10.62** (3.82)
Altruistic	2.64 (4.38)
Cooperative/Competitive	8.73* (3.56)
Partner's exercises today (p_t)	0.01 (0.05)
Atomistic × p_t	0.03 (0.07)
Altruistic × p_t	0.13* (0.06)
Cooperative/Competitive × p_t	0.06 (0.06)
Partner's exercises $t-1$ (p_{t-1})	0.06 (0.03)
Atomistic × p_{t-1}	−0.05 (0.05)
Altruistic × p_{t-1}	0.10 (0.06)
Cooperative/Competitive × p_{t-1}	0.05 (0.04)
Partner's exercises $t-2$ (p_{t-2})	0.06* (0.03)
Atomistic × p_{t-2}	0.003 (0.05)
Altruistic × p_{t-2}	0.02 (0.05)
Cooperative/Competitive × p_{t-2}	0.008 (0.04)
Partner's exercises $t-3$ (p_{t-3})	0.091* (0.04)
Atomistic × p_{t-3}	−0.06 (0.05)
Altruistic × p_{t-3}	0.00 (0.05)
Cooperative/Competitive × p_{t-3}	−0.03 (0.05)
Constant	9.01*** (1.68)
R^2	0.19
N	12,168

Notes: This table examines how an individual's exercise completion relates to the current and previous exercise completion of their partner (other pair in the Cooperative/Competitive treatment). The table reports results of an OLS regression of exercises completed on indicators for experimental condition, the number of exercises completed by the individual's partner on the current day and three previous days, and interactions between the treatments and the lagged exercise completion. The unit of observation is the participant-day. Standard errors clustered at the level of the pair for all experimental groups except Cooperative/Competitive which is clustered at the level of the group.

*** Significant at the 1 percent level.

** Significant at the 5 percent level.

* Significant at the 10 percent level.

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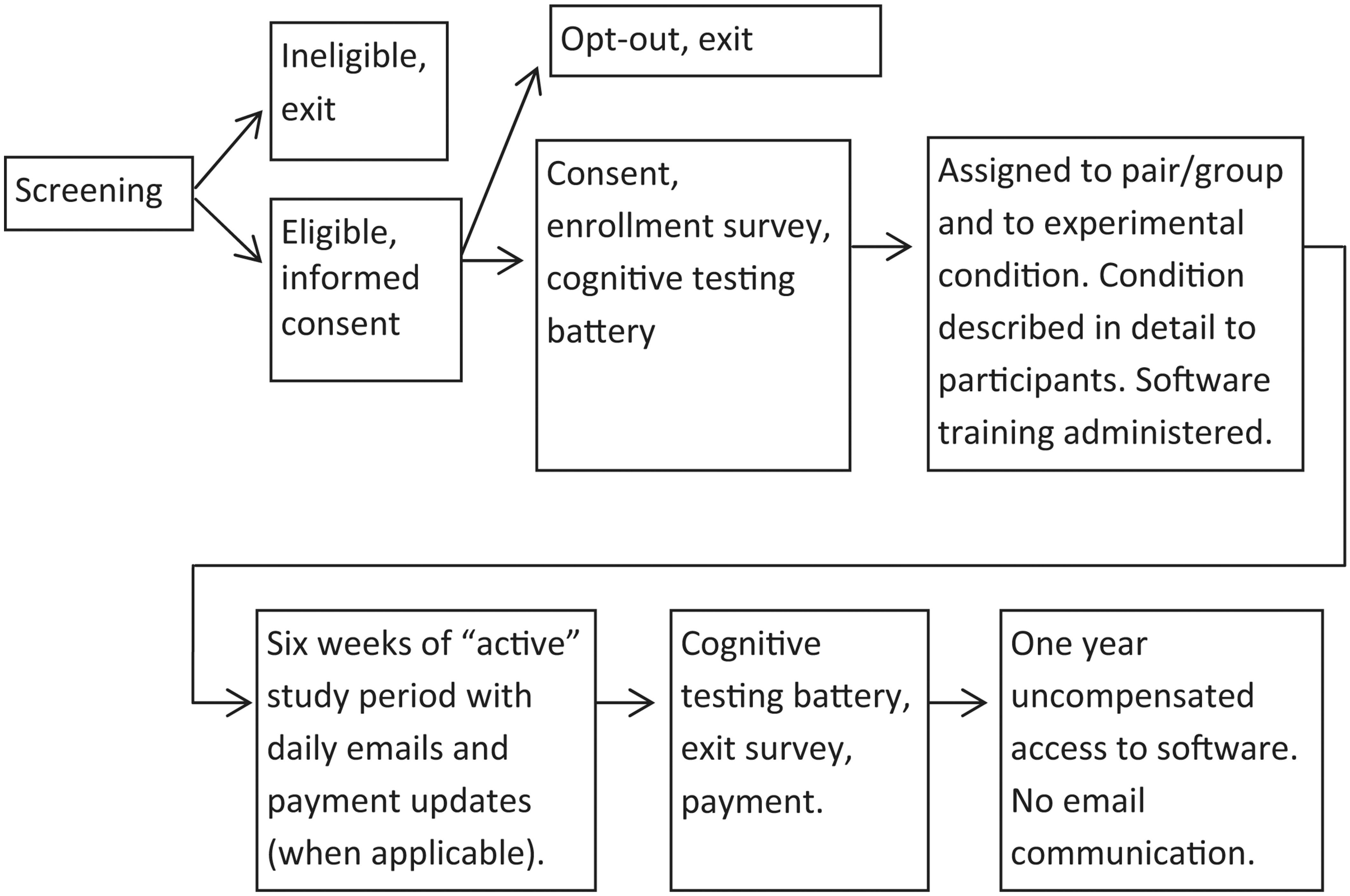

Fig. 1.
Participant timeline.

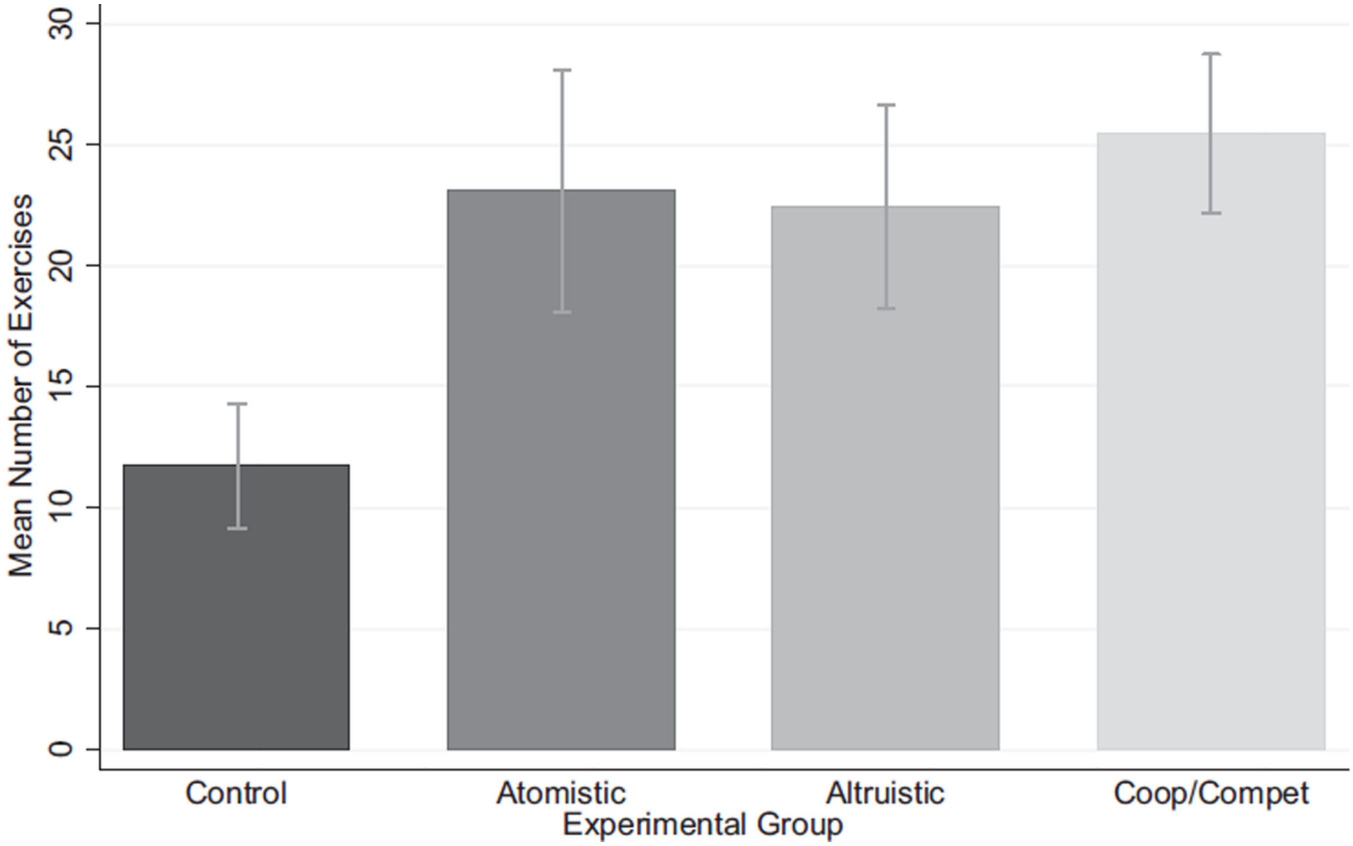

Fig. 2.
Mean number of cognitive exercises per day.

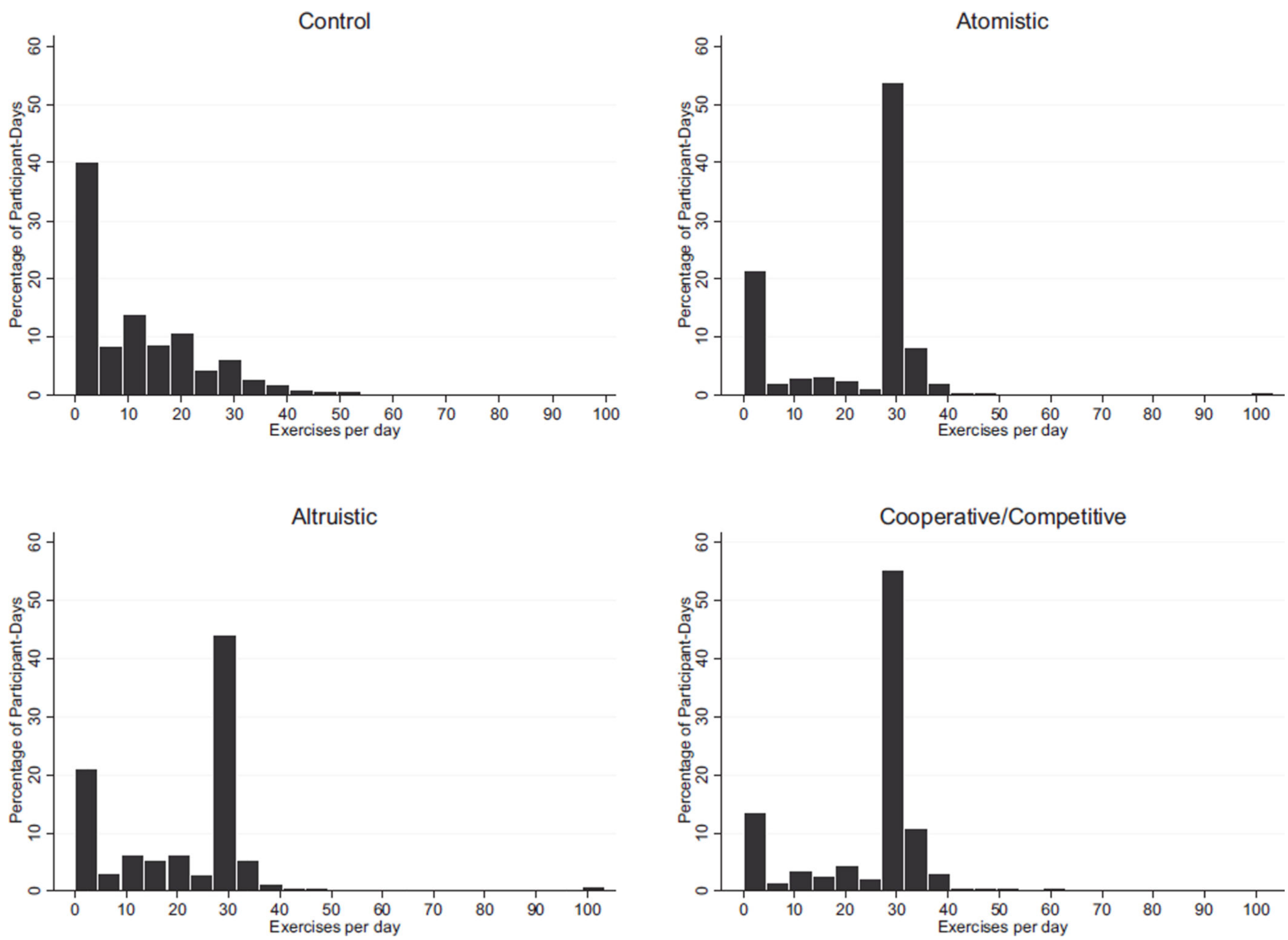

Fig. 3.
Cognitive exercises per day by experimental condition.

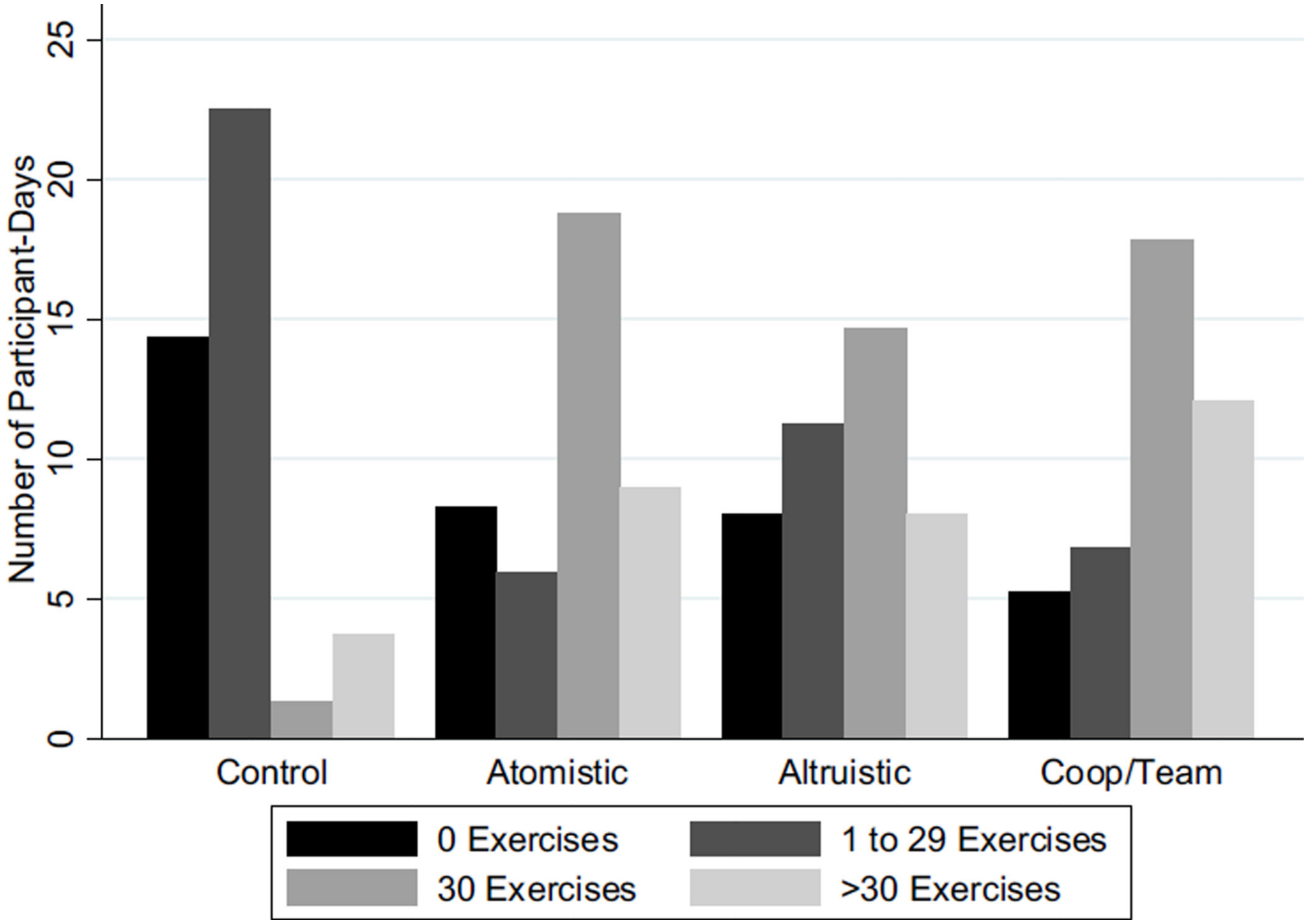

Fig. 4.
Mean number of days completing *N* exercises.

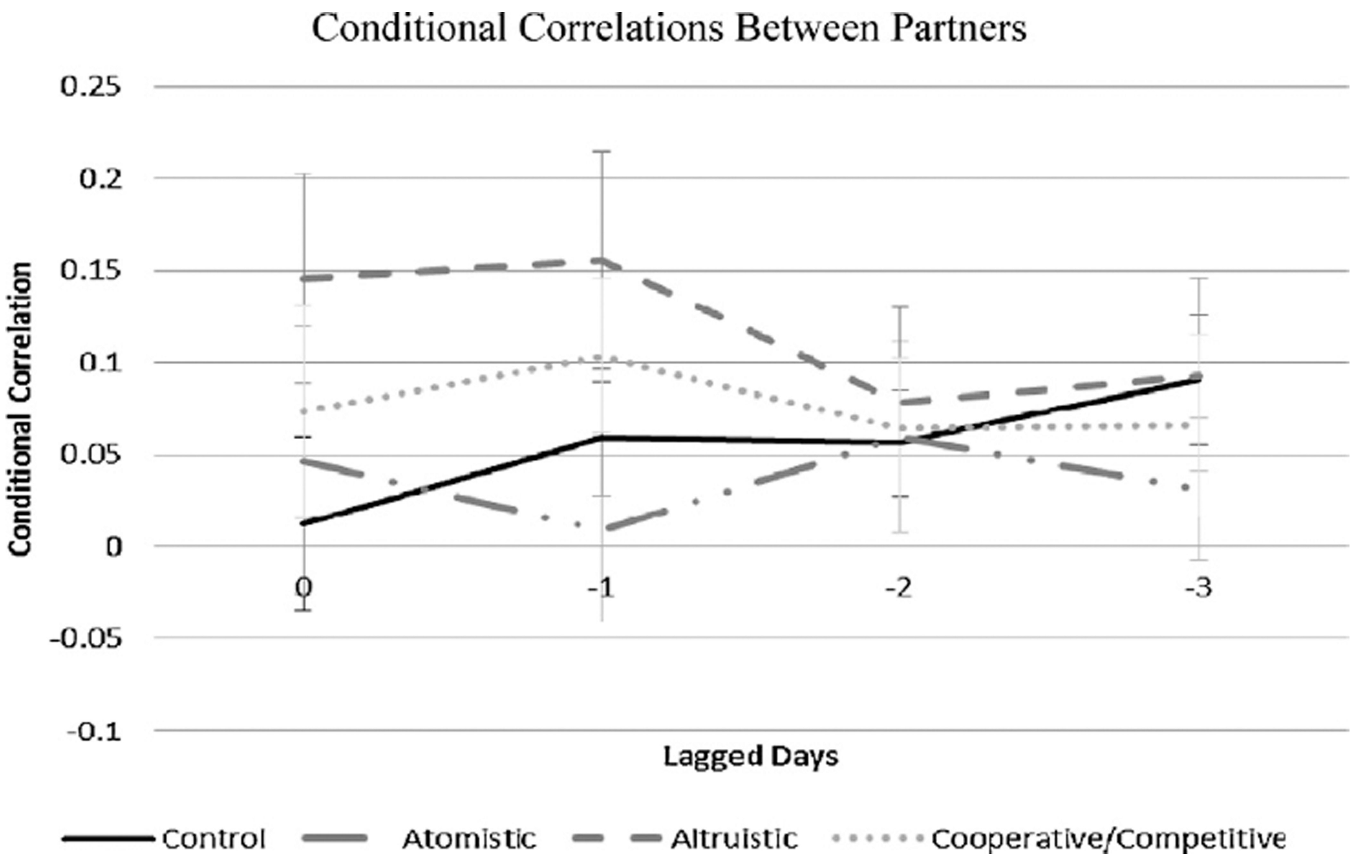

Fig. 5.
Conditional correlations between partners.

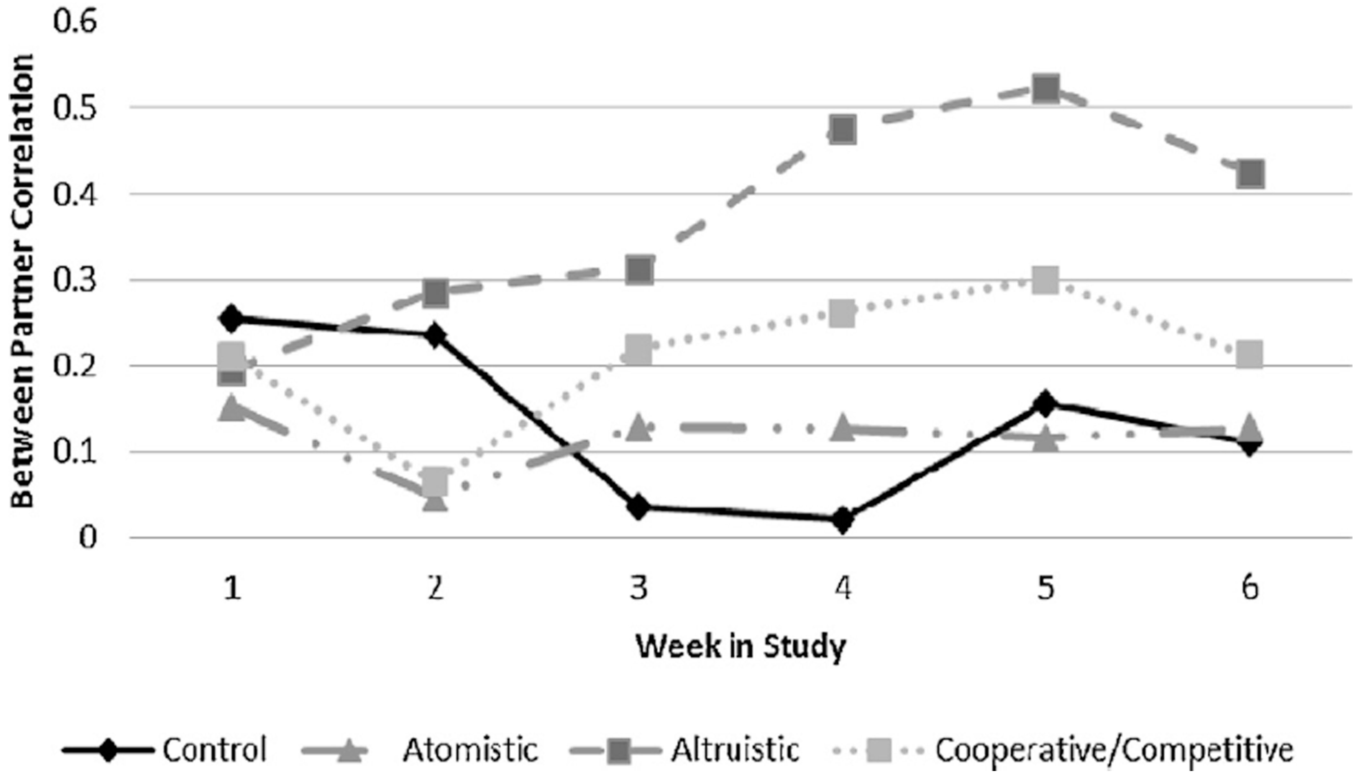

Fig. 6.
Between partner correlation in exercises completed.

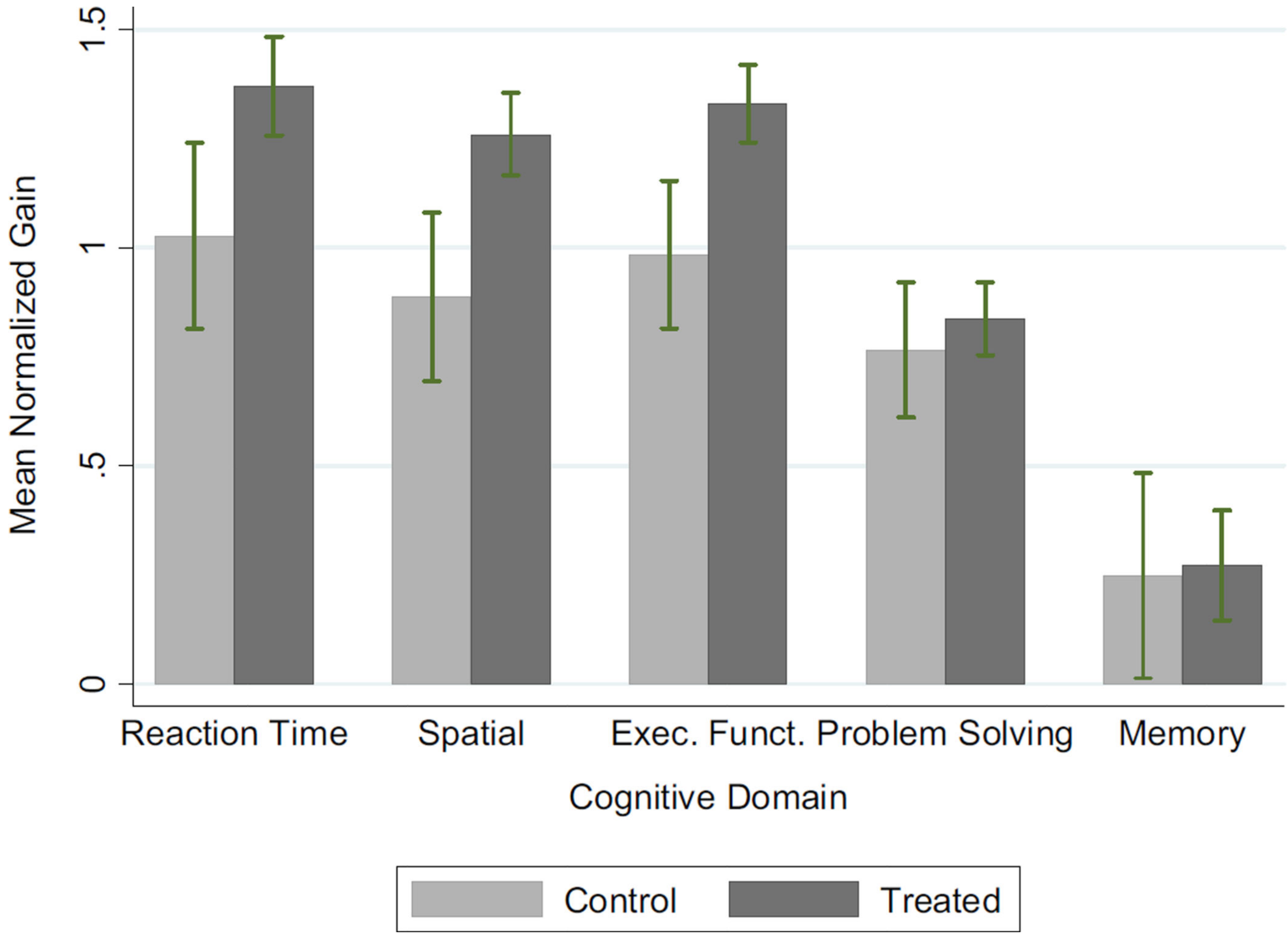

Fig. 7.
Mean normalized gains in exercise scores by cognitive domain.

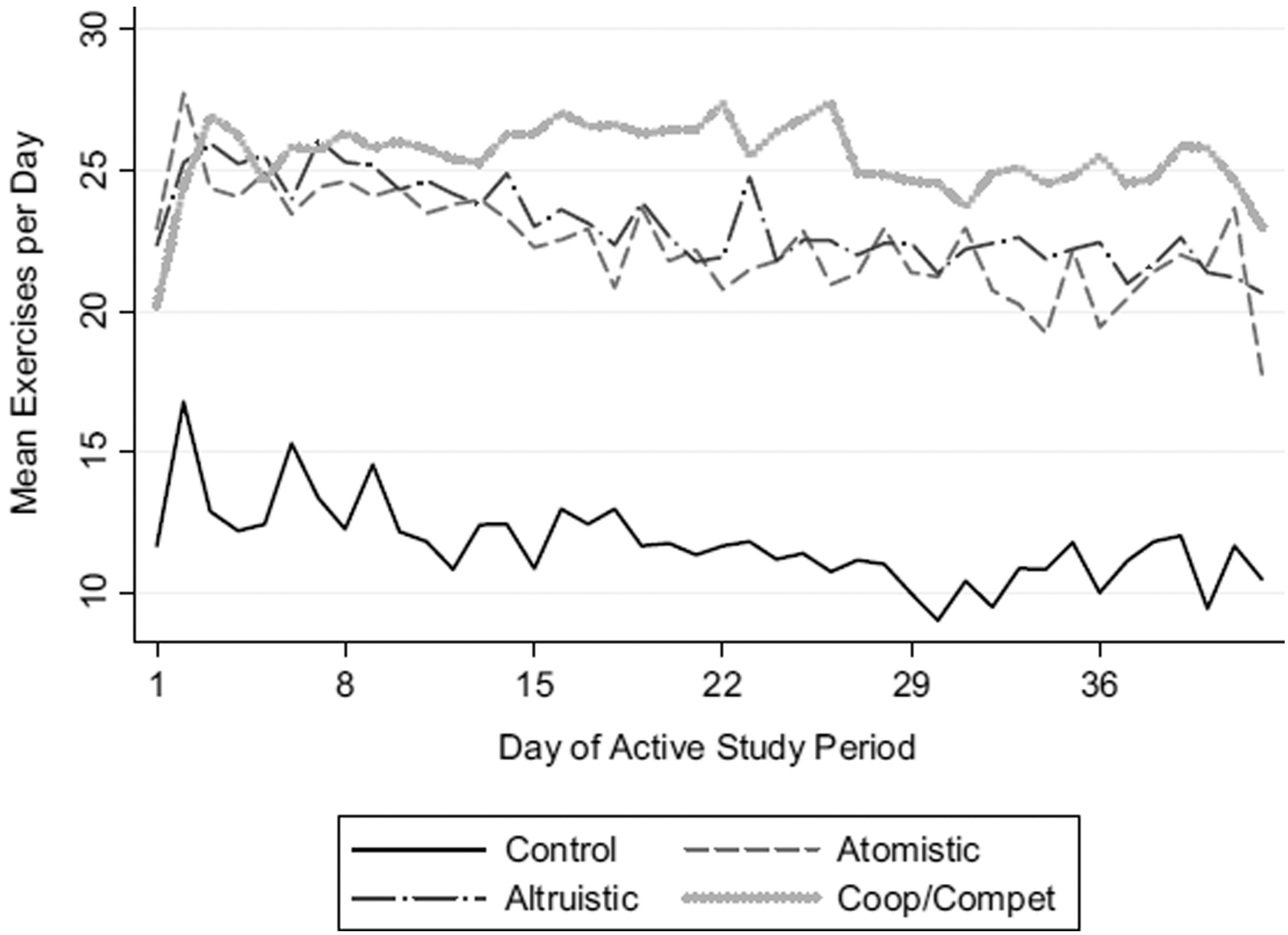

Fig. 8.
Mean exercises per day by treatment group.

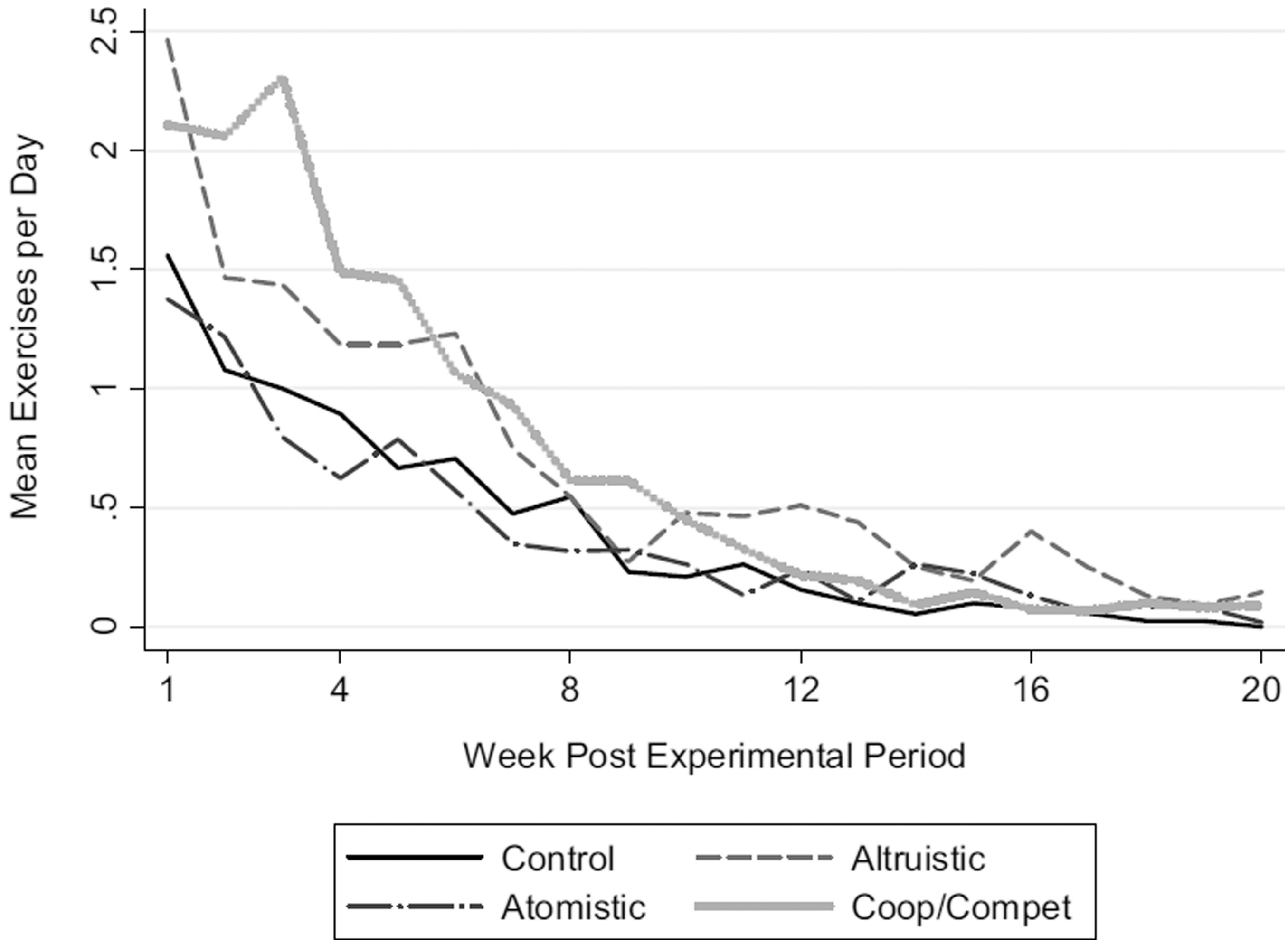

Fig. 9.
Post experimental period exercises.

Table 1

Baseline participant characteristics.

	All	Control	Atomistic	Altruistic	Cooperative/ Competitive	Current Population Survey (CPS)(2015)
Age	64.76 (6.40)	65.11 (6.74)	64.85 (6.98)	64.88 (6.16)	64.48 (6.10)	67
Female	0.70 (0.46)	0.68 (0.47)	0.73 (0.45)	0.75 (0.44)	0.68 (0.47)	0.55
Married	0.61 (0.49)	0.61 (0.49)	0.56 (0.50)	0.52 (0.50)	0.69 (0.47)	0.62
Left handed	0.12 (0.33)	0.06 (0.25)	0.13 (0.34)	0.20** (0.41)	0.10 (0.31)	Not available
Not born in US	0.05 (0.21)	0.05 (0.22)	0.03 (0.18)	0.03 (0.18)	0.06 (0.25)	0.12
Retired	0.61 (0.49)	0.61 (0.49)	0.63 (0.49)	0.66 (0.48)	0.58 (0.50)	0.60
White/Caucasian	0.93 (0.26)	0.89 (0.32)	0.92 (0.27)	0.92 (0.27)	0.95 (0.22)	0.85
Family member has/had dementia	0.62 (0.70)	0.58 (0.74)	0.65 (0.70)	0.67 (0.71)	0.60 (0.67)	Not available
Normalized cognitive test score at enrollment	107.32 (7.03)	106.81 (7.45)	107.49 (6.30)	107.47 (7.48)	107.41 (7.00)	Not available
Education						
Less than BA	0.14	0.15	0.19	0.17	0.10	0.68
BA	0.32	0.35	0.26	0.30	0.35	0.15
More than BA	0.48	0.48	0.47	0.45	0.51	0.10
Other	0.05	0.02	0.08	0.08	0.05	Not available
Median household income range (USD)	50,000–74,999	50,000–74,999	35,000–49,999	50,000–74,999	50,000–74,999	46,080
N	312	62	62	64	124	

Notes: This table contains the mean and standard deviation of participant characteristics as reported at enrollment. Current Population Survey (CPS) data is approximate based upon the most relevant information available. Not being born in the US was proxied by being a naturalized citizen or not being a citizen. Being retired was proxied by not being in the labor force but also not being unemployed.

*** Significant at the 1 percent level.

** Significant at the 5 percent level.

* Significant at the 10 percent level.

Table 2

Experimental conditions and payments.

Experimental condition	Description	Payment formula
Control	No payment	$P_1 = 0$ $P_2 = 0$
Atomistic	Flat rate of $0.17 per exercise completed	$P_1 = E_1/6$ $P_2 = E_2/6$
Altruistic	Flat rate of $0.17 paid to partner for each exercise completed	$P_1 = E_2/6$ $P_2 = E_1/6$
Cooperative/Competitive	Marginal payments vary as a function of exercises by both teams. Team members earn the same amount.	$P_1 = P_2 = [(\text{Max}[(E_1 + E_2), (E_3 + E_4)]/6) ((E_1 + E_2)/(E_1 + E_2 + E_3 + E_4))]$
		$P_3 = P_4 = [(\text{Max}[(E_1 + E_2), (E_3 + E_4)]/6) ((E_3 + E_4)/(E_1 + E_2 + E_3 + E_4))]$

Notes: E_X = exercises completed by partner x, P_X = payment to partner x.

Table 3

Exercises per day.

Atomistic	11.39*** (2.15)
Altruistic	10.70*** (2.55)
Cooperative/Competitive	13.76*** (1.68)
Constant	11.72*** (1.32)
R-squared	0.11
N	13,104

Notes: This table reports the OLS regression of the number of exercises completed on indicator variables for each experimental condition. The unit of observation is the participant-day. Standard errors are clustered at the level of the pair for all experimental groups except Cooperative/Competitive which is clustered at the level of the group.

*** Significant at the 1 percent level.

** Significant at the 5 percent level.

* Significant at the 10 percent level.

Table 4

Summary statistics of daily completion of exercises.

	Control	Atomistic	Altruistic	Cooperative/Competitive
Percentile				
10th	0	0	0	0
25th	0	10	10	21
50th	9	30	30	30
75th	20	30	30	31
90th	30	32	32	33
95th	35	35	37	37
99th	50	56	94	60
Mean	11.72	23.12	22.43	25.48
SD	12.67	15.03	17.65	12.86
Correlation with partner	0.15	0.12	0.36	0.22
Mean percent of days logging on	65.78	80.30	80.92	87.50
Mean exercises if exercises >0	17.82	28.79	27.72	29.14

Table 5

Probability of completing zero/more than thirty exercises.

	Column 1 **0 exercises**		**Column 2** **≥ 30 exercises**
Atomistic	−0.17 * (0.07)	Atomistic	0.46 *** (0.11)
Altruistic	−0.24 *** (0.07)	Altruistic	0.04 (0.05)
Cooperative/Competitive	−0.26 *** (0.06)	Cooperative/Competitive	0.34 *** (0.09)
$\text{Partner}_t = 0$ (binary)	−0.06 (0.05)	$\text{Partner}_t \geq 30$ (binary)	0.08 (0.04)
Atomistic × $\text{Partner}_t = 0$	0.05 (0.09)	Atomistic × $\text{Partner}_t \geq 30$	0.00 (0.08)
Altruistic × $\text{Partner}_t = 0$	0.28 *** (0.08)	Altruistic × $\text{Partner}_t \geq 30$	0.30 *** (0.06)
Cooperative/Competitive × $\text{Partner}_t = 0$	0.18 * (0.07)	Cooperative/Competitive × $\text{Partner}_t \geq 30$	0.11 (0.07)
$\text{Partner}_{t-1} = 0$ (binary)	−0.00 (0.05)	$\text{Partner}_{t-1} \geq 30$ (binary)	0.03 (0.06)
Atomistic × $\text{Partner}_{t-1} = 0$	0.05 (0.10)	Atomistic × $\text{Partner}_{t-1} \geq 30$	0.03 (0.10)
Altruistic × $\text{Partner}_{t-1} = 0$	0.17 * (0.08)	Altruistic × $\text{Partner}_{t-1} \geq 30$	0.32 *** (0.07)
Cooperative/Competitive × $\text{Partner}_{t-1} = 0$	0.08 (0.07)	Cooperative/Competitive × $\text{Partner}_{t-1} \geq 30$	0.15 (0.08)
Constant (Control)	0.36 *** (0.06)	Constant (Control)	0.11 *** (0.03)
N	13,104	N	13,104
R^2	0.07	R^2	0.33

Notes: This table examines positive and negative reciprocity between partners (pairs in the Cooperative/Competitive condition) in each of the experimental conditions. Column (1) reports the results of a linear probability model regressing an indicator for whether an individual completes zero exercises on indicators for experimental condition, an indicator for whether their partner completed zero exercises that day and whether their partner completed zero exercises the previous day, and those indicators interacted with each experimental treatment. Column (2) has the same general design but presents the probability of completing at least 30 exercises. The unit of observation is the participant-day. Standard errors clustered at the level of the pair for all experimental groups except Cooperative/Competitive which is clustered at the level of the group.

*** Significant at the 1 percent level.

** Significant at the 5 percent level.

* Significant at the 10 percent level.

Table 6

Changes in normalized scores on cognitive exercises.

Cognitive domain	Spatial			Executive function			Memory		Problem solving		
		Reaction time									
Exercise number	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
Panel A											
Treated	0.26* (0.14)	0.45*** (0.12)	0.31** (0.13)	0.39*** (0.13)	0.37*** (0.14)	0.30*** (0.10)	0.07 (0.14)	−0.02 (0.16)	−0.04 (0.09)	−0.02 (0.12)	0.28* (0.14)
Constant (Control)	1.08*** (0.12)	0.96*** (0.10)	0.81*** (0.11)	1.06*** (0.12)	1.13*** (0.12)	0.74*** (0.07)	0.07 (0.11)	0.42*** (0.14)	0.75*** (0.07)	0.75*** (0.11)	0.79*** (0.12)
N	294	293	294	294	293	294	293	293	293	294	292
R^2	0.01	0.04	0.02	0.03	0.02	0.02	0	0	0	0	0.01
Panel B											
Treated	−0.02 (0.15)	0.06 (0.12)	−0.08 (0.13)	−0.03 (0.13)	−0.12 (0.14)	0.00 (0.10)	−0.05 (0.17)	−0.13 (0.19)	−0.21** (0.09)	−0.26** (0.13)	−0.11 (0.14)
Total Exercises (00s)	0.09*** (0.02)	0.12*** (0.02)	0.12*** (0.02)	0.13*** (0.02)	0.17*** (0.02)	0.10*** (0.02)	0.06** (0.02)	0.08*** (0.03)	0.05** (0.02)	0.06*** (0.02)	0.11*** (0.03)
Total Exercises (00s) Squared	−0.002*** (0.001)	−0.003*** (0.001)	−0.003** (.001)	−0.003*** (0.001)	−0.004*** (0.001)	−0.002*** (0.001)	−0.002*** (0.001)	−0.003*** (0.001)	0.001 (0.001)	−0.001** (0.001)	0.002 (0.001)
Constant (Control)	0.71*** (0.15)	0.44*** (0.12)	0.29*** (0.11)	0.50*** (0.12)	0.44*** (0.12)	0.34*** (0.10)	−0.15 (0.14)	0.16 (0.17)	0.54*** (0.10)	0.46*** (0.11)	0.28*** (0.14)
N	294	293	294	294	293	294	293	293	293	294	292
R^2	0.06	0.15	0.13	0.16	0.21	0.11	0.02	0.02	0.03	0.04	0.12

Notes: Panel A reports results of OLS regressions of changes in scores on each cognitive exercise, as defined below, on an indicator for “Treatment” which includes all individuals in the Atomistic, Altruistic, and Cooperative/Competitive conditions. Panel B contains the results of OLS regressions of the same dependent variable on an indicator for treatment, the total exercises completed by each participant over the experimental period, and the square of that total. Scores for each exercise are normalized to a mean of zero and standard deviation of one. Changes are defined as the last score-first score, conditional on having completed an exercise at least twice during the experimental period. Results are qualitatively similar using averages of the last three scores-first three scores. Results are also similar examining indicators for each treatment rather than grouping all treatments together. The unit of observation is the participant. Although some exercises train multiple domains simultaneously, exercises are categorized into primary cognitive domains as indicated by Lumosity, the company providing the software. Exercise number 2 has strong spatial reasoning and reaction time components and hence is included in both categories. Standard errors clustered at the level of the pair for all experimental groups except Cooperative/Competitive which is clustered at the level of the group.

*** Significant at the 1 percent level.

** Significant at the 5 percent level.

* Significant at the 10 percent level.

Table 7

Changes in NeuroTrax cognitive testing scores by domain.

Cognitive domain	Global	Memory	Executive function	Attention	Processing speed
Panel A					
Treated	0.03 (0.76)	−0.38 (0.95)	0.13 (1.38)	0.02 (0.99)	0.31 (1.35)
Constant (Control)	4.29*** (0.70)	2.38*** (0.83)	2.80** (1.24)	2.73*** (0.91)	9.22*** (1.22)
N	310	310	310	310	308
R^2	0.00	0.00	0.00	0.00	0.00
Panel B					
Total exercises (00s)	0.06 (0.05)	−0.01 (0.08)	0.01 (0.09)	−0.01 (0.08)	0.25*** (0.10)
Constant	3.81*** (0.62)	2.16*** (0.81)	2.78*** (1.02)	2.81*** (0.82)	7.16*** (1.01)
N	310	310	310	310	308
R^2	0.00	0.00	0.00	0.00	0.02

Notes: This table reports on changes in the cognitive testing scores from enrollment to the end of the active experimental period. Each column in Panel A is an OLS regression of the change in score within the cognitive domain indicated at the top of each column on an indicator (Treated) for belonging to Atomistic, Altruistic, or Cooperative/Competitive condition. The change in score is defined as the normalized score at the end of the active experimental period score minus the normalized enrollment score. Panel B includes OLS regressions of the change in score on the total number of exercises completed by the participant during the active experimental period. The testing battery used in this study is a validated battery with high reliability. The battery, produced by NeuroTrax, is based on nine cognitive tests focused on memory, executive function, attention, and processing speed. These underlying tests are used to produce aggregate performance metrics within a domain, as well as an overall “global” score which averages across the domains being tested. While reaction time is not considered a distinct domain in the NeuroTrax testing, it is used as an underlying metric in processing speed and attention tests. Due to time constraints during testing, tests explicitly targeting problem solving and spatial reasoning were omitted from the battery. Additional information on the testing battery is provided in Section 2.3 of the text. Standard errors are clustered at the level of the pair for all experimental groups except Cooperative/Competitive which is clustered at the level of the group.

*** Significant at the 1 percent level,

** Significant at the 5 percent level.

* Significant at the 10 percent level.