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. 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 designs 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 but not on an independent cognitive testing battery.

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I. Introduction

Faced with a variety of challenges to public health arising from unhealthy behaviors, such as smoking, poor diet, sedentary lifestyles, and low rates of medication adherence, employers, health insurers, and government agencies have been dramatically expanding the use of monetary incentives to motivate healthy behavior change. Most of the programs that have been implemented in the field as well as most of the incentives tested by researchers (e.g., Cawley and Price 2009; Charness and Gneezy 2009; Perez et al. 2009) employ individual incentives. There are many reasons, however, to suspect that socially oriented incentives that play on motives such as competition and reciprocity, might have beneficial effects.

First, social motives can sometimes provide 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 Harre 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 2012). By playing on such non-pecuniary motives, social incentives have, at least in theory, the potential to produce more substantial behavioral changes at lower cost than individualistic incentives.

Second, by associating the desired behaviors with social cues rather than purely financial or economic cues, socially oriented incentives are less likely to be subject to the crowding out of intrinsic motivation that are a potential concern with the provision of financial incentives (Gneezy and Rustichini 2000; Benabou and Tirole 2003; Heyman and Ariely, 2004). Further, despite the predominant focus on individual-level incentives, social incentive schemes may be of particular interest in this domain because many health behaviors (e.g. eating, and some forms of exercise) have strong social elements, suggesting that the use of social forces may substantially augment the effectiveness of such programs both directly and indirectly.

Finally, 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, Kremer, and Mullainathan 2010, 2011; Bandiera, Barankay, and Rasul 2010; Duflo and Saez 2003). 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 paid 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 2012). 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.

This paper provides a test of the comparative effectiveness of individualistic and socially oriented monetary incentives in motivating health-promoting behaviors via a randomized controlled trial among 312 elderly individuals who receive no monetary incentives, individualistic incentives, altruistic incentives, or team-based cooperative/competitive incentives for daily completion of cognitive training exercises. In all conditions, including the Control, individuals were randomly paired and provided with daily information about the number of exercises completed (and, if relevant, the earnings) by themselves and by their partner. While participants in the Control condition did not receive monetary incentives for completing cognitive training exercises, the magnitude of the incentives provided in the three treatment conditions were designed to be as similar to one-another as possible, so as to provide a clean test of their relative effectiveness in motivating engagement.

The use of online cognitive training exercises as an outcome serves a variety of purposes. First, given the 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 has become the sixth most prevalent cause of death in the United States, and accounts for an estimated direct costs 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, Small, and Wahlin 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).

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, disappointing effects may stem in part from low rates of adherence to training programs and the lack of cost-effective approaches to improving adherence to these regimens. For example, the most comprehensive test of cognitive exercises, the ACTIVE study, had an overall budget of $15 million for 2,802 enrolled participants, or approximately $5,000 per participant over 24 months (Ball et al. 2002).

In addition to examining an important domain of health, use of a web-based cognitive training task also 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. The use of an on-line platform also provides the potential for scalability, since replicating a web-based intervention is much easier than one which involves physical facilities and/or personnel. These technologies have the potential to reach individuals and promote healthy habits on a daily basis at low cost and in an automated fashion.

Finally, the online platform also provides an opportunity to examine the long run impacts of the provision of incentives with minimal experimental demand effects. In this study, 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.

During the six-week active study period, individuals in all experimental groups, including the Control, were paired with another participant in the study and received free access to the training software and information about their own and their partner's completion of exercises. Participants in the incentive groups, but not the Control group, were additionally eligible to receive financial compensation during this period. In the individual incentives condition, referred to as the Atomistic treatment, participants were provided with a flat payment of approximately $0.17 per exercise up to 30 exercises per day. In the Altruistic treatment, the level of compensation was the same; however individuals were paid as a function of the number of exercises completed by their partner rather than as a function of their own exercise completion. In the Cooperative/Competitive treatment, teams, each consisting of a pair of individuals, 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 total exercises completed by the opposing team. Further details regarding the exact payment structures are given below.

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 treatments (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. Despite similar gains in exercises completion across incentivized treatments, we did observe very different patterns of engagement in pairs of participants across the experimental treatments. We also found that while utilization of the software led to substantial improvements on scores in the majority of the incentivized exercises, the gains did not typically generalize to improvements in measures cognitive function more broadly. Finally, examining utilization of the 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.

II. Experimental Design

II.A. 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. Baseline participant characteristics are presented in Table I. 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.

[Table I here]

II.B. 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 minute baseline battery of computer based cognitive tests utilizing the Mindstreams software developed by Neurotrax.[2] Following the cognitive testing, participants were randomly paired and/or grouped and assigned to an experimental condition. Participants also completed an in-person training session to familiarize them with the cognitive exercise software, including the exercises themselves, the website's messaging features which allowed them to communicate directly with their partner(s), and 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, 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

[2] The testing battery has also been used in over 50 published peer reviewed studies and allows for measurement of cognitive function in a variety of domains such as reaction time, attention, and memory. Over 17,000 patients have completed this testing battery. More information is available at http://www.neurotrax.com.

regarding their own and their partner's/group's engagement (and earnings, when relevant). In addition, all participants, including those in the Control group, could access, via the website at any time, information regarding their own use of the software as well as their partner's use of the software. This information was updated in real time. At the completion of the study period, participants completed an alternate version of the cognitive testing battery they had completed at intake, and an exit survey.[3] 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. Figure I details the participant timeline.

[Figure I here]

II.C. Cognitive Training Software

The cognitive training software consisted of eleven exercises targeting five cognitive domains, including spatial orientation, problem solving, memory, executive function, and reaction time. The exercises used in the training software were provided by Lumosity,[4] a firm that provides online cognitive training exercises. The average exercise took approximately two to three minutes to complete, however the range in duration was approximately one to ten minutes 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.

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[3] 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).

[4] Lumosity is a commercial developer of cognitive training exercises. The firm collaborates with cognitive science researchers from a variety of institutions such as Stanford and UCSF in developing their training exercises. More information is available at www.lumosity.com.

II.D. Experimental Treatments

Payment formulas for all experimental conditions are presented in Table II. As noted, individuals in all conditions, including the Control, were paired and provided with access to information about their partner's participation (and payments, if relevant), and could also communicate with their partner via a messaging feature of the website.

Individuals assigned to the Control group were provided with free access to the cognitive training software, messaging service, and emails, but were not given any monetary incentives to utilize the software. Participants in the Atomistic treatment were provided with a flat rate monetary incentive of approximately $0.17 per exercise up to 30 exercises for their own participation, resulting in maximum daily earnings of $5. 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 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 varies significantly and ranges from less than $0.01 to $0.17 per partner[5] based on the performance of both teams. 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).

[Table II here]

[5] 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 towards the low engagement team is small. Despite the variability in the marginal payments, the median payment per exercise in this condition was $0.17 and the average payment per exercise was $0.23.

III. Results

III.A. 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 minutes 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 III and Figure II)[6]. The increase in engagement in the treatment groups is statistically indistinguishable across the three treatment arms, with an average of 22.4, 23.1, and 25.5 exercises per day for the Altruistic, Atomistic, and Cooperative/Competitive groups respectively. This result is particularly striking given that participants in the Altruistic condition receive no direct monetary benefit from completing exercises and that the marginal payment for completing an exercise in the Atomistic treatment weakly dominates the payment for completing an exercise in the Cooperative/Competitive condition. Further, 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 ($0.23) was quite similar and the median payment per exercise ($0.17) was nearly identical to the other compensated treatments.

[Table III here]

[Figure II here]

[6] 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 Competitive/Cooperative condition.

This dramatic increase in engagement with the exercises in the treatment groups is 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 IV). 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 (Altruistic), 28.8 (Atomistic), 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.

[Table IV here]

As shown in Figures IIIa-IIId and Figure IV, 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 also lead significantly more individuals to complete more than the monetarily incentivized number of activities. Specifically, averaging across participant-days, 19.2 percent, 21.4 percent, and 28.7 percent of the Altruistic, Atomistic, and Cooperative/Competitive groups engaged in more than 30 activities per day.

[Figures IIIa-IIId here]

[Figure IV here]

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 with the exercises. 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 peer effects resulting purely from the daily emails regarding how many exercises that individual and their partner completed. 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, 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.

The simple correlations, while informative, hide other differences in patterns of concordance across treatments. Column (1) of Table V 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 positive reciprocity is substantially larger, although not statistically distinguishable from, negative reciprocity. Negative reciprocity may be mitigated in these circumstances by the fact that the exercises are intended to promote health, so even if the absence of financial remuneration for engagement individuals are likely to engage for the health benefits.

[Table V here]

To examine this potential avenue of influence between partners and the evolution of the spillovers 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 and treatment assignment in a fully interacted model (see online appendix for regression table AI. Figure V summarizes the results from this regression). From the figure it can be seen that 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 and second greatest in the cooperative/competitive condition. By two periods (days) back, however, the effects, while positive, are small and indistinguishable across conditions.

[Figure V here]

Figure VI, 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.

[Figure VI here]

III.B. Performance on Cognitive Exercises

Participants in all experimental treatments significantly improved their performance on all but one of the eleven cognitive exercises included in the software. These improvements were substantial in magnitude, typically between ¾ and 1 standard deviation. The doubling of exercises completed by individuals in the treatment groups also led to differential improvement in those groups relative to the Control group on approximately half of the 11 exercises (See Table VI Panel A for changes in performance on each of the 11 exercises and Figure VII for changes in performance when grouping exercises by cognitive domain. Table VI 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). In particular, the differential gains were largest in exercises focusing on executive function, speed/reaction time, and spatial orientation, on which participants in the incentive treatment groups improved approximately ¼ to ½ of a standard deviation beyond the improvements in the control group on average. Although these estimates suggest decreasing marginal returns to additional exercises, the differential gains still represent substantial improvements on these exercises.

[Table VI here]

[Figure VII here]

The improvements in scores on the exercises appear to be mediated by the increase in the number of exercises completed (See Table VI, 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 indicated 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 crowd out the "quality" of the engagement and encourage participants to hurry through with little thought. Table VI 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 motivational crowd out in the quality of cognitive effort occurs we would expect that the regression coefficients on the Treatment indicator to be negative.

However, as can be seen in Table VI Panel B, nine of the eleven coefficients on the Treated variable are insignificant. Interestingly, the two coefficients (columns (9) and (10)) that are statistically significant are in exercises in which the duration of the exercise increases significantly with improved performance with a range of approximately three to ten minutes. Hence, in circumstances in which the exercises become much more taxing as participants improve, there is some slight evidence of "quality" crowdout, however, quality crowdout appears to have been minimal overall.

III.C. 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 VII Panel A).

There are universal improvements, defined below as the difference between exit score and baseline score, across all experimental groups in the cognitive testing battery.[7] However, these improvements may be at least partially due to a test-retest effect. As can be seen in Table VII Panel B, 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[8].

Alternatively, it is possible that the large positive constants in these regressions suggest 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 less 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

[7] The Neurotrax Mindstreams software generates normalized scores for each of four domains as well as an overall "global" score based on a series of underlying tests such as Stroop, Go/No-go, and delayed recall tests.

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

two) for this explanation to hold, suggesting that a test-retest effect is the more likely explanation of the majority of the results in this table.

While these 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), 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.

[Table VII here]

III.D. 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 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 similar decline in engagement in the Cooperative/Competitive treatment (See Figure VIII).

[Figure VIII here]

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 five months following the completion of the study was only 84, or approximately ½ 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 Figure IX).

[Figure IX here]

The large standard errors on these estimates are due to substantial variation in the level of software utilization during this period. The fraction of individuals who never log onto the software again after the end of the experimental period 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, as compared with more individualistically oriented treatments, enhance intrinsic motivation, at least for some subset of the population.

IV. 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 increasing over time.

Utilization of the software led to substantial 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 appear likely to be driven primarily by a test-retest effect and did not differ between control and treatment groups, despite substantial differences in the numbers of exercises completed. This finding, which is suggestive of limited generalizability of cognitive changes, is consistent with a wide range of previous studies examining the impact of ‘brain exercises’ on generalized cognitive function (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 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, pointing 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.

The high levels of utilization of the cognitive training software during this study were striking. While the population was likely to be particularly motivated, a fact demonstrated by the substantial utilization even among the control group, financial and social incentives still resulted in large increases in the number of exercises completed. Although the high initial motivation of the participants may reduce generalizability of the magnitude of the effects, the fact that incentives improved engagement from already high levels suggests that these types of socially oriented monetary incentives could potentially have broad applicability.

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.

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 because, 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 2010; 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 usually difficult to measure these behaviors with high frequency and accuracy in many settings, both limitations that likely diminish the effectiveness of incentives. Online cognitive training address these concerns by accurately capturing exactly how much exercise was completed and providing high frequency data that can be used to provide rapid accurate feedback and incentives.

Although the platform offers the benefits of scalability in a wide variety of domains, the differential effects on patterns of engagement suggest that the various 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 spillovers to the other team member. The same is true of the competitive/cooperative condition. The higher correlation in behaviors between pairs in the two conditions involving social incentives is, thus, a kind of 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 the pair. These are important factors to take into account when deciding what types of incentives to introduce in a particular setting.

The title of a recent important paper on motivational crowding out was “pay enough or don’t pay at all.” While not contradicting the findings of that paper, since our study focused on different issues and involved fairly substantial payments, the equivalent title for this paper could have been “pay enough, and it doesn’t matter who or how.”

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DEPARTMENT OF SOCIAL AND DECISION SCIENCES, CARNEGIE MELLON UNIVERSITY

APPENDIX

Table AI

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	12168

Notes:

1. 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.
2. The unit of observation is the participant-day.
3. 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.
4. *** Significant at the 1 percent level, ** Significant at the 5 percent level, * Significant at the 10 percent level.

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TABLES

Table I
Baseline Participant Characteristics

	All	Control	Atomistic	Altruistic	Cooperative/ Competitive
Age	64.76	65.11	64.85	64.88	64.48
	(6.40)	(6.74)	(6.98)	(6.16)	(6.10)
Female	0.70	0.68	0.73	0.75	0.68
	(0.46)	(0.47)	(0.45)	(0.44)	(0.47)
Married	0.61	0.61	0.56	0.52	0.69
	(0.49)	(0.49)	(0.50)	(0.50)	(0.47)
Left handed	0.12	0.06	0.13	0.20**	0.10
	(0.33)	(0.25)	(0.34)	(0.41)	(0.31)
Not born in US	0.05	0.05	0.03	0.03	0.06
	(0.21)	(0.22)	(0.18)	(0.18)	(0.25)
Retired	0.61	0.61	0.63	0.66	0.58
	(0.49)	(0.49)	(0.49)	(0.48)	(0.50)
White/Caucasian	0.93	0.89	0.92	0.92	0.95
	(0.26)	(0.32)	(0.27)	(0.27)	(0.22)
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)
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)
Education					
Less than BA	0.14	0.15	0.19	0.17	0.10
BA	0.32	0.35	0.26	0.30	0.35
More than BA	0.48	0.48	0.47	0.45	0.51
Other	0.05	0.02	0.08	0.08	0.05
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
N	312	62	62	64	124

Notes:
1. This table contains the mean and standard deviation of participant characteristics as reported at enrollment.
2. *** Significant at the 1 percent level, ** Significant at the 5 percent level, * Significant at the 10 percent level.

Table II

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	$P_1 = \frac{E_1}{6}$ $P_2 = \frac{E_2}{6}$
Altruistic	Flat rate of \$0.17 paid to partner for each exercise completed	$P_1 = \frac{E_2}{6}$ $P_2 = \frac{E_1}{6}$
Cooperative/ Competitive	Marginal payments vary as a function of exercises by both teams. Team members earn the same amount.	$P_1 = P_2 = \frac{\text{Max}[(E_1 + E_2),(E_3 + E_4)]}{6} \quad \frac{(E_1+E_2)}{(E_1 + E_2 + E_3 + E_4)}$ $P_3 = P_4 = \frac{\text{Max}[(E_1 + E_2),(E_3 + E_4)]}{6} \quad \frac{(E_3 + E_4)}{(E_1 + E_2 + E_3 + E_4)}$

Notes:

1. E_x = Exercises completed by partner x, P_x = Payment to partner x.

Table III
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:
1. This table reports the OLS regression of the number of exercises completed on indicator variables for each experimental condition.
2. The unit of observation is the participant-day.
3. 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.
4.*** Significant at the 1 percent level, ** Significant at the 5 percent level, * Significant at the 10 percent level.

Table IV
Summary Statistics Of Daily Completion of Exercises

Percentile	Control	Atomistic	Altruistic	Cooperative/ Competitive
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	87.5
Mean exercises if exercises > 0	17.82	28.79	27.72	29.14

Table V

Probability Of Completing Zero/More Than Thirty Exercises

	Column 1 0 exercises		Column 2 ≥30 exercises
Atomistic	-0.17*	Atomistic	0.46***
	(0.07)		(0.11)
Altruistic	-0.24***	Altruistic	0.04
	(0.07)		(0.05)
Cooperative/ Competitive	-0.26*** (0.06)	Cooperative/ Competitive	0.34*** (0.09)
$\text{Partner}_t = 0$ (binary)	-0.06	$\text{Partner}_t \geq 30$ (binary)	0.08
	(0.05)		(0.04)
$\text{Atomistic*Partner}_t = 0$	0.05	$\text{Atomistic*Partner}_t \geq 30$	0.00
	(0.09)		(0.08)
$\text{Altruistic*Partner}_t = 0$	0.28***	$\text{Altruistic*Partner}_t \geq 30$	0.30***
	(0.08)		(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	$\text{Partner}_{t-1} \geq 30$ (binary)	0.03
	(0.05)		(0.06)
$\text{Atomistic*Partner}_{t-1} = 0$	0.05	$\text{Atomistic*Partner}_{t-1} \geq 30$	0.03
	(0.10)		(0.10)
$\text{Altruistic*Partner}_{t-1} = 0$	0.17*	$\text{Altruistic*Partner}_{t-1} \geq 30$	0.32***
	(0.08)		(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	13104	N	13104
R^2	0.07	R^2	0.33

Notes:

1. 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 studies the probability of completing at least 30 exercises.
2. The unit of observation is the participant-day.
3. 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.
4. *** Significant at the 1 percent level, ** Significant at the 5 percent level, * Significant at the 10 percent level

Table VI
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*	0.45***	0.31**	0.39***	0.37***	0.30***	0.07	-0.02	-0.04	-0.02	0.28*
		(0.14)	(0.12)	(0.13)	(0.13)	(0.14)	(0.10)	(0.14)	(0.16)	(0.09)	(0.12)	(0.14)
	Constant (Control)	1.08***	0.96***	0.81***	1.06***	1.13***	0.74***	0.07	0.42***	0.75***	0.75***	0.79***
		(0.12)	(0.10)	(0.11)	(0.12)	(0.12)	(0.07)	(0.11)	(0.14)	(0.07)	(0.11)	(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	0.06	-0.08	-0.03	-0.12	0.00	-0.05	-0.13	-0.21**	-0.26**	-0.11
		(0.15)	(0.12)	(0.13)	(0.13)	(0.14)	(0.10)	(0.17)	(0.19)	(0.09)	(0.13)	(0.14)
	Total Exercises (00s)	0.09***	0.12***	0.12***	0.13***	0.17***	0.10***	0.06**	0.08***	0.05**	0.06***	0.11***
		(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.03)	(0.02)	(0.02)	(0.03)
	Total Exercises (00s) Squared	-0.002***	-0.003***	-0.003**	-0.003***	-0.004***	-0.002***	-0.002***	-0.003***	0.001	-0.001**	0.002
		(0.001)	(0.001)	(.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
	Constant (Control)	0.71***	0.44***	0.29***	0.50***	0.44***	0.34***	-0.15	0.16	0.54***	0.46***	0.28***
		(0.15)	(0.12)	(0.11)	(0.12)	(0.12)	(0.10)	(0.14)	(0.17)	(0.10)	(0.11)	(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:

1. 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.
2. 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 qualitative 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.
3. The unit of observation is the participant-day.
4. Exercises are categorized into cognitive domains as indicated by Lumosity, the company providing the software. Exercise number 2 has both spatial

reasoning and reaction time components and hence is included in both of those categories.
5. 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.
6. *** Significant at the 1 percent level, ** Significant at the 5 percent level, * Significant at the 10 percent level.

Table VII

Changes in Mindstreams Cognitive Testing Scores By Domain

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

Notes:

1. 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 Competitive/Cooperative 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.
2. The aggregate domain scores are calculated by the Mindstreams test from underlying tests (e.g. Stroop, Go/No-go) in each area of cognitive function. The "Global" score aggregates across all domains tested. More information on the tests used and the scores is available on the Mindstreams website: http://www.neurotrax.com.
3. 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.
4. *** Significant at the 1 percent level, ** Significant at the 5 percent level, * Significant at the 10 percent level.

FIGURES

Figure I
Participant Timeline

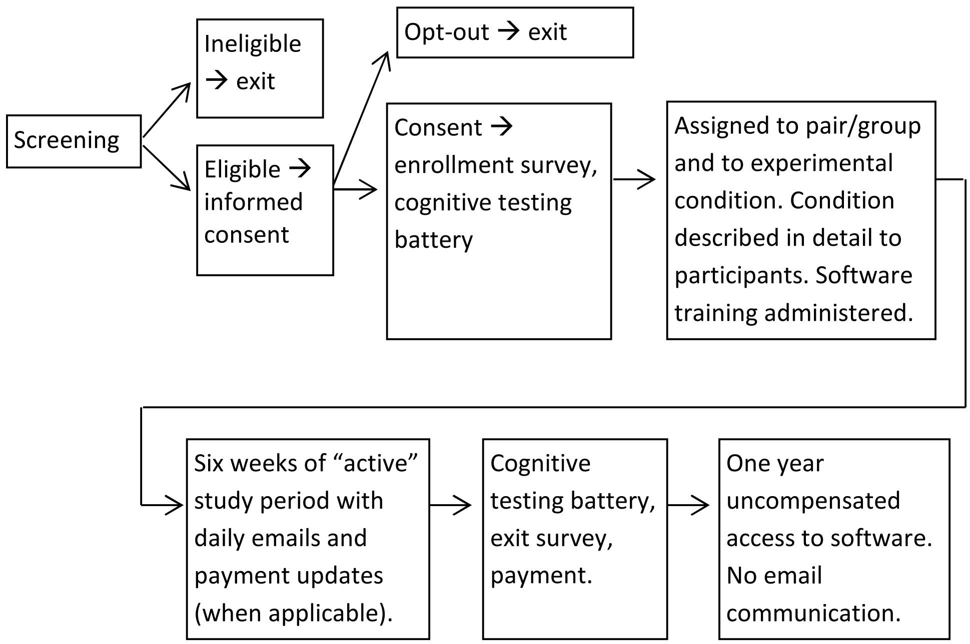

Figure II
Mean Number of Cognitive Exercises Per Day

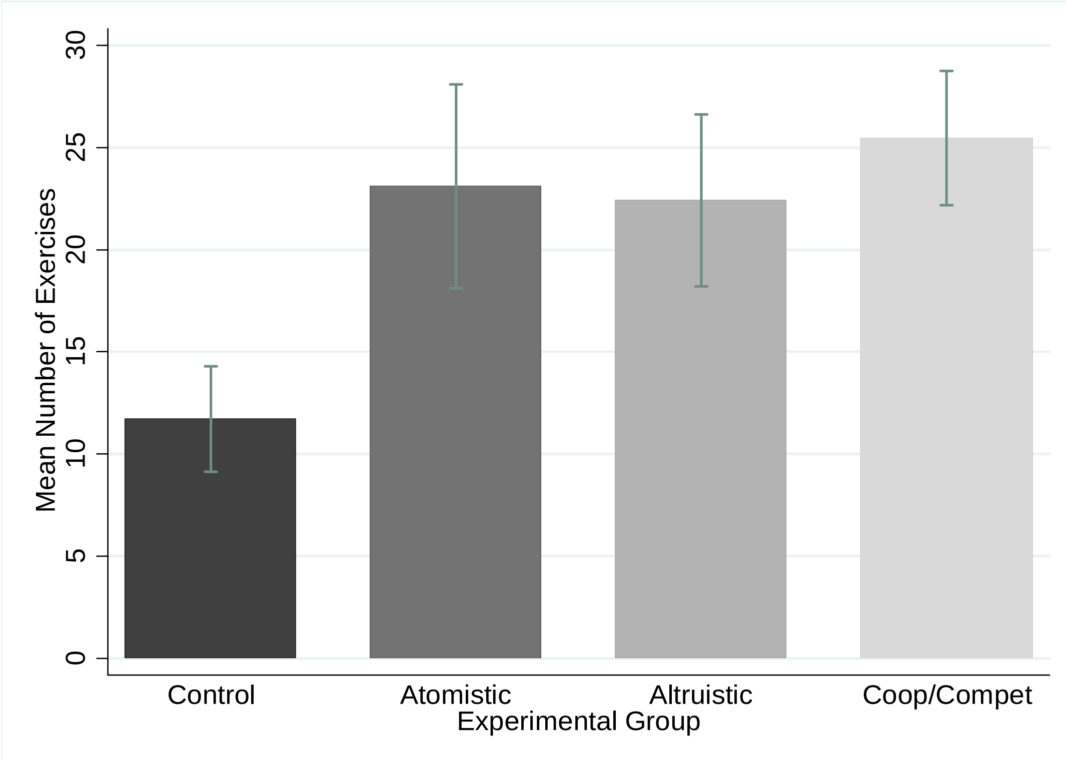

Figure III
Cognitive Exercises Per Day By Experimental Condition

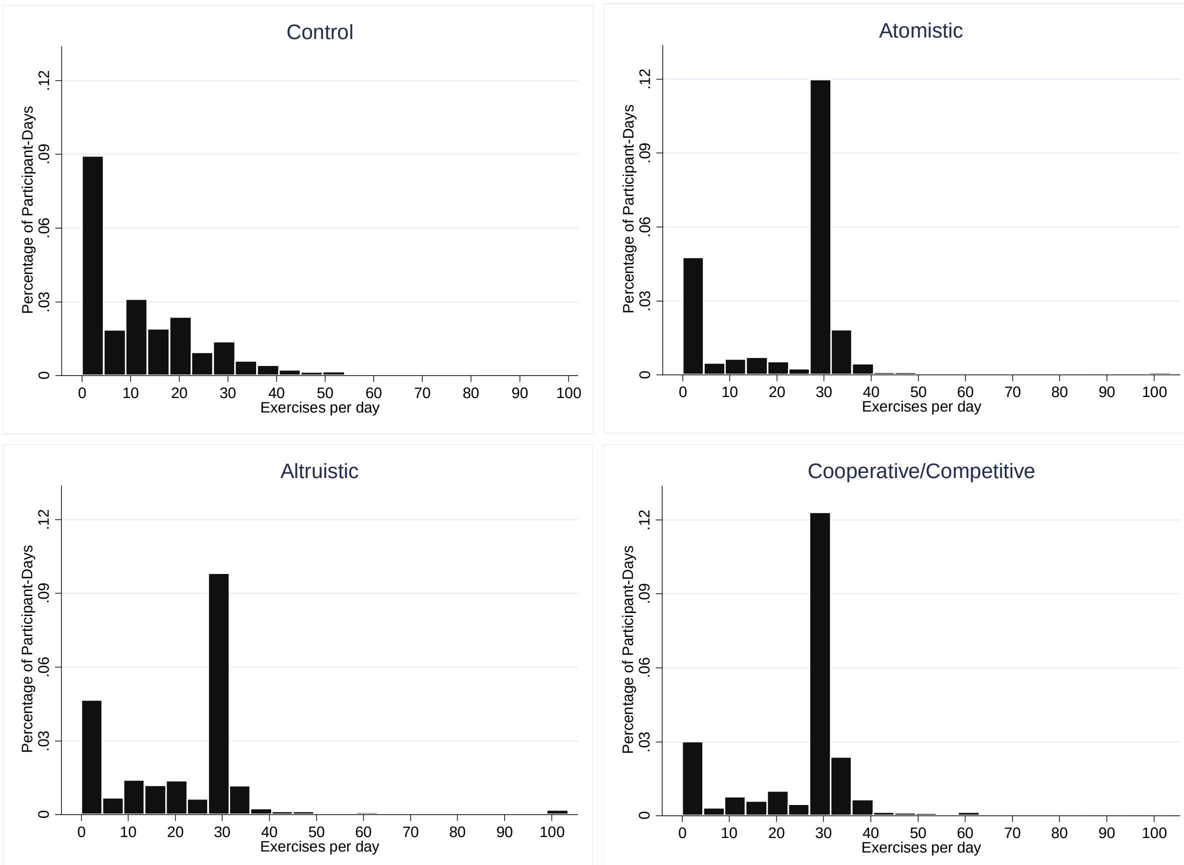

Figure IV
Mean Number of Days Completing N Exercises

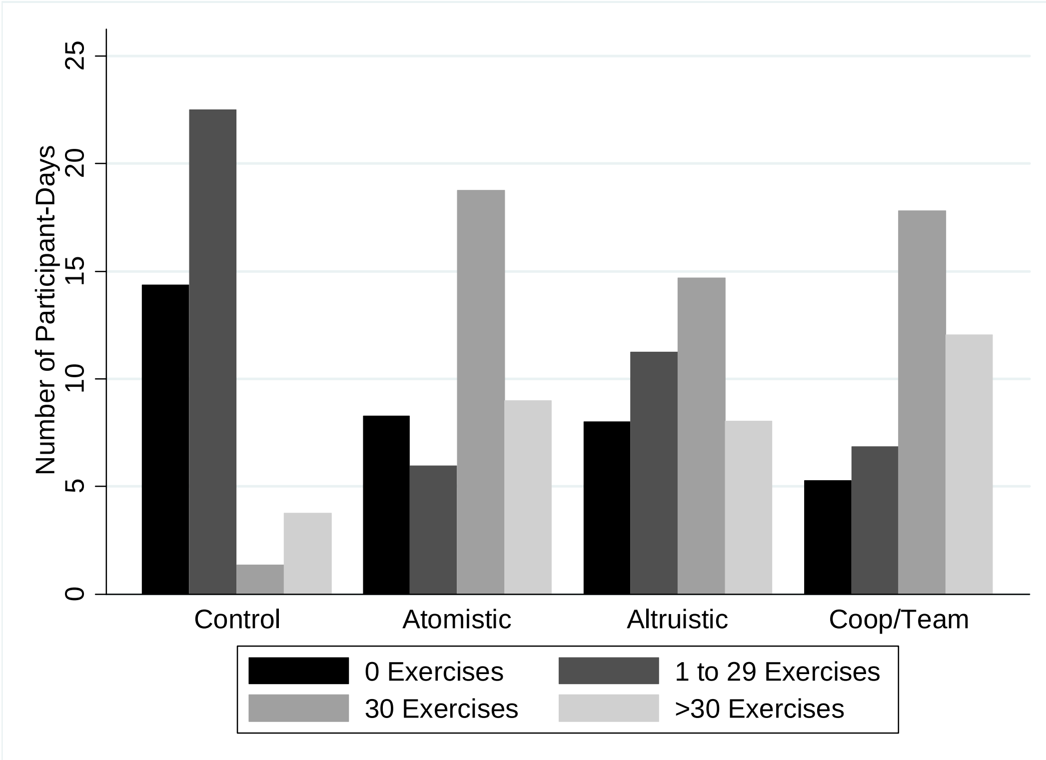

Figure V
Conditional Correlations Between Partners

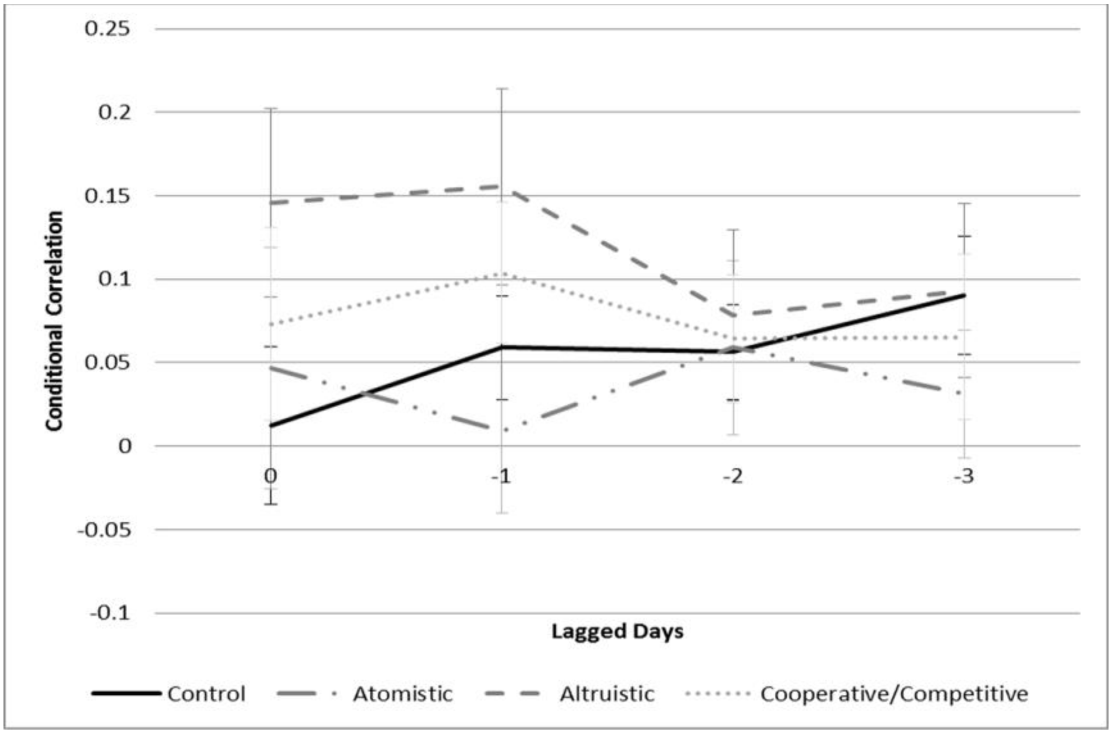

Figure VI
Between Partner Correlation in Exercises Completed

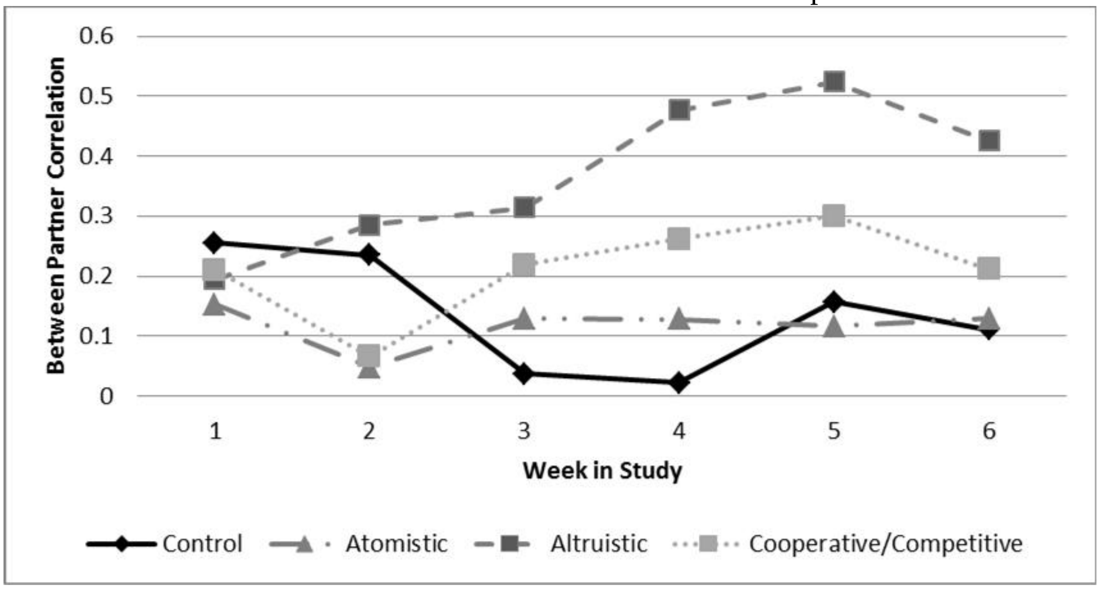

Figure VII

Mean Normalized Gains In Exercise Scores By Cognitive Domain

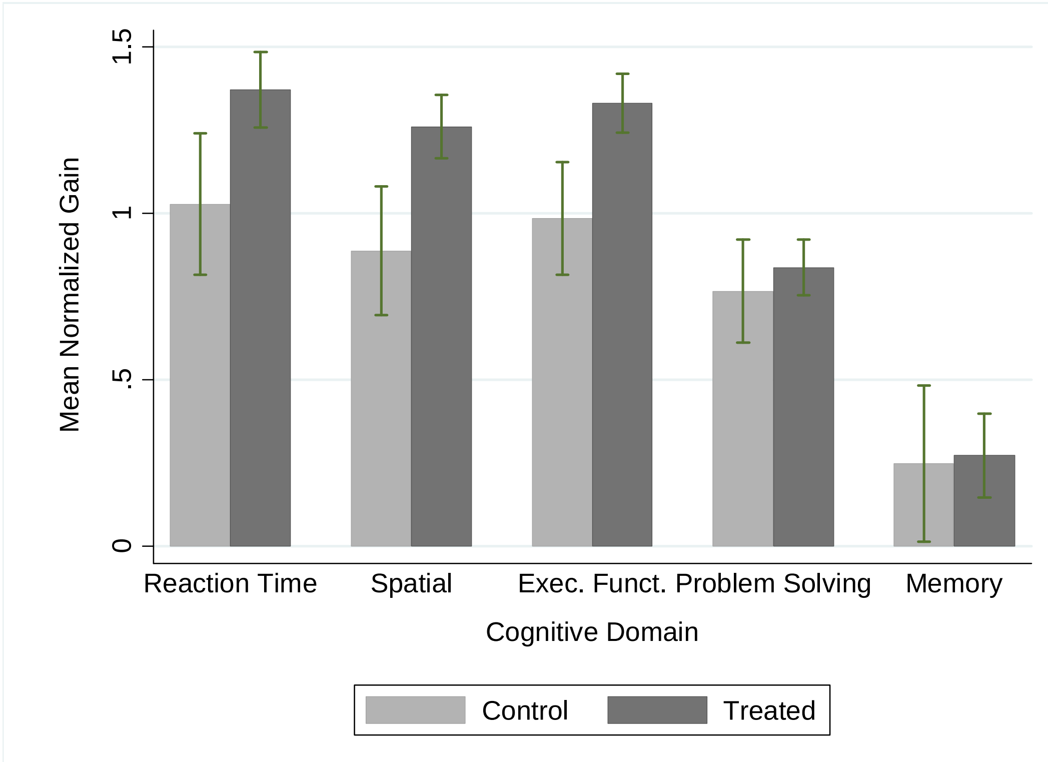

Figure VIII
Mean Exercises Per Day By Treatment Group

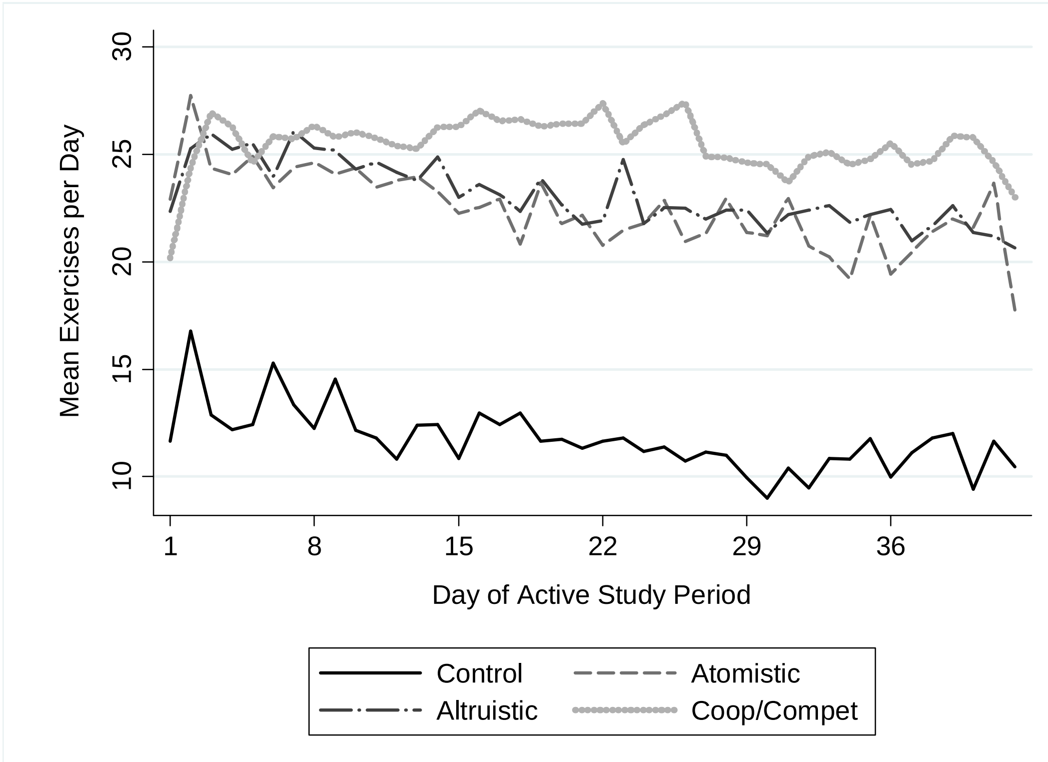

Figure IX
Post Experimental Period Exercises