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Abstract

Telecommuting policies have been increasingly adopted by employers. The benefits of telecommuting from the employer's perspective include direct cost-saving from not having to house employees in an office and indirect cost-saving through reduced turnover associated with increased employee satisfaction. The downside is the perceived opportunity for shirking outside of the traditional workplace, a problem which is potentially exacerbated if employees are placed into telecommuting teams. Using a controlled experiment which randomly assigned subjects to participate in the laboratory (non-telecommuters) or to participate online in a location of their choice (telecommuters), we directly test whether telecommuters are more likely to free ride when in teams and whether or not the locational composition of the team influences this outcome. We find no evidence of free-riding in teams for either telecommuters or non-telecommuters. We also find that variation in output when a worker is paired in a traditional team versus a telecommuting team can be attributed to the beliefs subjects have about their teammates productivity. The last result leads directly to policy implications for managers.

JEL Codes: J21 J24 J28 C90

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1 Introduction

Many workers have or will have the opportunity to work in a location other than the traditional office. Matthews and Williams (2005) estimated that ap-

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proximately 53 million people could potentially take advantage of the benefits from telecommuting, or 40% of the work force for the United States in 2005. Though the potential number of workers who could telecommute is substantial, the 2008 National Study of Employers found that only 3% of employers offered paid work at home for the majority of employees. In 2004, this translated to approximately 13.7 million salaried employees working from home at least once a week.[1] The discrepancy between the potential and observed numbers of telecommuters poses a puzzle given the many known benefits stemming from such policies. Telecommuting policies represent an opportunity for employers to directly lower costs through reduced overhead expenditures associated with housing employees in a traditional office (Piskurich, 1996). They also provide an opportunity to increase employee satisfaction which attracts a higher quality, more diverse workforce, and leads to cost savings by reducing turnover.

Yet despite these benefits, a large number of employers are hesitant to adopt telecommuting policies for all employees because of strong beliefs that telecommuting will lead to shirking outside of the office - a problem which is potentially exacerbated by the widespread use of teams in the workplace. The National Study of Employers included open-ended questions for why workplace flexibility was implemented and the primary reason given by employers is overall retention of employees (37%), with a small group of respondents (4%) citing increased productivity.[2] The primary factors associated negatively with implementing workplace flexibility were costs (30%) followed by expectations of productivity loss (11%). What is notable is the contrast in opinions on productivity. Some employers believe that workplace flexibility will decrease productivity, while others feel it will increase productivity.

In light of the above, it is perhaps not surprising that our current understanding of how the telecommuting environment affects worker productivity is not well understood (Bailey and Kurland, 2002, Menezes and Kelliher, 2011). Two recent studies by Dutcher (2012) and Bloom et al. (2012) help shed light on individual productivity differences for telecommuters, but to our knowledge there exists no direct empirical evidence for the impact of telecommuting policies on team productivity. Arguably, the examination of telecommuting policies on team productivity should be of utmost importance given the prevalence of team usage in the workplace (Milliken and Martins, 1996) and the well-known incentives for shirking under team production (Alchian and Demsetz, 1972; Holmström, 1982). Part of the gap in our understanding is likely due to the difficulties involved in gathering accurate measures of productivity in a field setting where team output is not cleanly separable into individual parts. To circumvent these problems, we utilize an experimental design which allows us to carefully control the variables of interest and isolate, in a causal manner, what may be driving behavior in this complex setting.

The primary purpose of this paper is to determine if worker productivity falls within a team environment when individuals are allowed to telecommute

[1] As estimated by the U.S. Bureau of Labor Statistics.

[2] In addition to telecommuting, workplace flexibility includes care giving leaves and dependent care initiatives.

and to determine to what extent any changes in a worker's productivity within a team is influenced by the number of teammates who are telecommuting. To accomplish these goals, we randomly assigned subjects to participate in a team production experiment in either a traditional structured office-type location (the experimental laboratory) or in an unstructured location of their choice. Production involved a paid real-effort typing task where to receive payment subjects had to correctly decode a string of 6 letters into a set of 6 numbers.

Regardless of their location, all subjects participated initially on their own where they were paid a piece-rate based on how many typing tasks were correctly completed in a period of 8 minutes. Following the individual stage, participants were then informed that they would be randomly matched with two other participants to participate in a series of team stages that mimicked the individual stage in all aspects except that payment was now based on average team output rather than their individual output. Thus, the marginal payment in the team stages was 1/3 of the marginal payment in the individual stage. Each subject participated in three team rounds that varied the locational composition of the members.

To examine a worker's response to the locational composition of team, we elicited beliefs for both the individual and team rounds. By eliciting these beliefs for all types of participants we obtain an overall picture of worker beliefs on telecommuting productivity which allows us to control for differences in team production arising not because of location, but because of beliefs over the relative productivity of partners.

We find that productivity does not decrease when subjects are in a team versus when they are not. We also find a pronounced increase in productivity when subjects have fewer telecommuters in their team. Underlying this result, there exists a strong relationship between a subject's effort and their beliefs about the output of their teammates which suggests that subjects are behaving as conditional cooperators. Surprisingly, telecommuters are not affected by the presence of other telecommuters or non-telecommuters on their team.

Our findings have direct consequences for managers choosing to implement telecommuting policies. First, managers should continue to play an active role in selecting and maintaining a telecommuting team since individual characteristics such as gender matter. Our results also indicate that managers need not worry as much about the productivity of their telecommuters but should pay more attention to the productivity of their office-based workers. Finally, to encourage high productivity, managers should engage in activities which update and maintain a worker's perception (beliefs) that all members of the team are contributing high effort.

2 Related Literature

While conclusive empirical evidence on the productivity consequences of telecommuting is slim, a number of inroads on the broad topic of telecommuting have been made in the business literature. Bailey and Kurland (2002) provide a summary of this literature and point out the many benefits associated with firms implementing telecommuting policies. These advantages suggest a happier, more satisfied workforce, higher profitability for companies, and positive spillovers to society.

Positive spillovers of telecommuting policies for society include reduced air pollution, reduced energy consumption and reduced traffic congestion (Piskurich, 1996 and Cascio, 2000).[3] Moreover, benefits to employees include decreased transportation costs, increased control over their work environments, and increased flexibility; all of which allows the worker to work when they are the most productive (Niles, 1975; Mokhtarian, 1991). Piskurich also states other benefits directly realized by the company. The most notable is saving as much as $8,000 per worker annually in office space. Additionally, firms can expect increased employee retention and increased productivity if they allow their workforce to telecommute.

Though these are important elements to consider, we will focus on one of the more controversial claims, which is that employees who telecommute are more productive (Bailyn, 1988; Belanger, 1999; Hill et al., 1998). The almost universal finding that telecommuters are more productive is often scrutinized because of the methodology employed to make this claim. The typical study uses a survey method which asks the telecommuters directly if they are more productive in their telecommuting environment or in the office environment. In most instances, the telecommuters chose to be in this environment and would like to continue to do so and so they may unintentionally or intentionally bias their responses. Even when looking at a non-survey study (DuBrin, 1991), comparing the productivity of the workers a manager allowed to telecommute with those whom she did not does not give a clear indication of the environmental factors. This is due to the fact that those workers who are allowed to telecommute have likely built up the trust of a manager through their work ethic.

To overcome these difficulties, there are two studies which use random assignment of people to a location in order to isolate the environmental factors on individual productivity. The first is Dutcher (2012) who designed an experiment around creative and dull tasks which randomly assigned subjects to the laboratory or a location of their choice to perform the tasks in an effort to understand how telecommuting affects individual productivity. The main finding of this paper is that productivity of the subjects performing the experiment outside of the laboratory (telecommuting) decreased for the dull task, but actually increased for the creative task. This environmental influence was found to be strongest for males as females were not as affected by their environment. The second by Bloom et al. (2012) took advantage of a company seeking to implement a telecommuting environment in China to perform a randomized field experiment. The authors find that the performance of those working from home exceeds that of those working in the office. While useful for the measurement of individual productivity under telecommuting policies, neither addresses work

[3] Cascio (2000) suggests that if 20,000 federal employees work from home at least one day a week, they would save over 2 million commuting miles, 102,000 gallons of gasoline and 81,600 pounds of carbon dioxide emissions per week.

performed in teams.

In addition to the literature on telecommuting, our paper also contributes to the experimental literature on team production. In the examination of the incentives for free-riding under a team revenue-sharing scheme our study relates to the study by Nalbantian and Schotter (1997), who found high levels of free-riding in an abstract effort choice setting. Frequently, team production is modeled through the use of public goods games (Dickinson and Isaac, 1998; Croson, 2000). Closest in spirit to our set-up is the examination of individual and team productivity using a real effort public good framework by van Dijk et al. (2001). The task utilized was a difficult two-variable optimization problem. They find no significant differences in effort levels between the individual and team stages, a result which occurs because while some free-riding is observed in teams in other instances individuals increased their effort between individual stage and team stage.

Our task design is most similar to Kuhn and Villeval (2011) who examine gender selection into team-based payment or individual payment. Similar to our design, Kuhn and Villeval also use a decoding task with broader outside options such as internet search and reading magazines. One of their team-based payment treatments involved equal revenue sharing between partners (teams of two). Their primary result is that women select into team-based payment schemes more often than men, except in situations where an efficiency advantage is added to the team payment, however, it is a secondary result that is of more relevance to our paper. In line with our results, they find no evidence of free-riding when individuals move from individual based payment schemes to revenue sharing teams. Furthermore, they find evidence of an increase in productivity as subjects move from the individual stage to the team.

3 Design of Experiments

The goal of the experimental design is to measure changes in productivity within a team setting with varying numbers of telecommuters. To accomplish this we had two types of subjects. The first type, non-telecommuters, were individuals recruited to participate in the laboratory at a pre-specified time. The second type, telecommuters, were individuals recruited to participate online at a place of their choosing anytime within a 24 hour block of time.[4] To avoid self-selection issues, the assignment of location was random and subjects in both locations were recruited in exactly the same manner.[5]

Each subject, regardless of type, participated in a series of four 8-minute rounds that gave them the option to spend their time on a paid typing task, unpaid games of tic-tac-toe, or some combination of both tasks. The typing

[4] We did place one restriction on the telecommuting subjects. We asked that they participate in any location except the SOWI computer laboratory where the laboratory experiment was taking place to ensure true location differences.

[5] The show-up, or participation rate was similar for subjects recruited to both locations thus ensuring that the assignment to location was truly random.

task required subjects to decode a series of 6 random letters into a series of 6 numbers using a code that changed with each combination of letters.[6] All subjects received the same random sequence of letters and code in each round. Across all four rounds the typing task was always paid while tic-tac-toe was never paid. Prior to the set of paid rounds, all subjects participated in an unpaid and virtually unlimited practice period of the typing task and tic-tac-toe.[7] Neither of the tasks required practice for mastery, but including this round familiarized subjects with the interface used during the paid rounds.[8]

The first paid 8-minute round was always played as an individual, regardless of location. The individual round paid 8 euro-cents for each correctly coded set of 6 letters and serves as our baseline measure of individual productivity. Following the individual stage, all subjects then entered into a series of three team rounds which varied the telecommuting composition of the team. In each team round, subjects were randomly placed into teams of three so the location composition varied between 0, 1, 2, and 3 telecommuters. In order to isolate the environmental effects, our teams were purposefully minimalistic with no interaction or feedback, and were teams only in the sense that team output was the determinant of pay rather than individual output.[9] Subjects' anonymity was preserved through the use of a random number for identification and payment.

The team stage itself was identical to the individual stage in that each subject had the option of using the entire 8 minutes on the paid typing task or unpaid tic-tac-toe, or some combination of both. However, in the team rounds the payment for the typing task was now equal to 8 euro-cents multiplied by the average correct output of the team so that effort exerted in the paid task was exerted for the team. In other words, we implemented a team pay scheme that involved equal revenue sharing between the partners. Note that this reduced marginal payment for each correctly coded word by 2/3.

Prior to each team round, we primed the subjects with their location and the location of their partners, which changed in each round. To guarantee that subjects were fully aware of the location of their teammates, we also included prominent location information at the top of the screen where the subjects performed the tasks. Our primary treatments are defined by the number of telecommuters in a team.

Team Treatments:

1. **Zero Telecommuter Team (LLL)** - in the *zero telecommuter team* treatment, each randomly matched team of three had only participants in the laboratory (zero telecommuters).

[6] We used a revolving code to minimize learning effects.

[7] Note that tic-tac-toe was included in order to ensure that our result is not overestimated. This task gives subjects, especially those in the lab, an outside option and thus their effort in the task is not simply due to boredom from the task.

[8] The program had 100 random codes for the subject to practice with before the codes would repeat and unlimited games of tic-tac-toe. On average, subjects correctly coded 14 words in the coding task and played 5 games of tic-tac-toe in the practice round.

[9] Subjects were told that no one in their team would ever observe any of their decisions or outcomes.

Order	Lab (# of Subjects)	Telecommuter (# of Subjects)
1	LLL, LTT, LLT (17)	TTT, LLT, LTT (18)
2	LLL, LLT, LTT (19)	TTT, LTT, LLT (16)
3	LTT, LLT, LLL (18)	LLT, LTT, TTT (17)
4	LLT, LTT, LLL (16)	LTT, LLT, TTT (14)

Table 1: Treatment order and number of subjects in each session

2. **One Telecommuter Team (LLT) -** in the *one telecommuter team* treatment, the team consisted of two participants in the laboratory and one telecommuter, playing in a location of their choice.

3. **Two Telecommuter Team (LTT)-** in the *two telecommuter team* treatment, the team consisted of one participant in the laboratory and two telecommuters playing in a location of their choice.

4. **Three Telecommuter Team (TTT)** - in the *three telecommuter team* treatment, each randomly matched team of three had only telecommuting participants, playing in a location of their choice (zero participants from the lab).

Recognizing that this type of task may result in fatigue or learning over subsequent rounds, leading to the possibility of order effects, we ran four orders of the above treatments for each location type of subject. This resulted in 8 total sessions summarized in table 1. We use *Lab* (L) to denote non-telecommuters who participated in the laboratory and *Telecommuter* (T) to denote subjects participating in a location of their choice. We ensured that subjects were matched in a round with others primed with the same group composition. For example, subjects participating in LTT for the first team round in the laboratory were matched with telecommuting subjects also participating in LLT for the first round.[10]

At the end of the four rounds, we elicited beliefs regarding the performance of their co-participants. Six questions were asked regarding co-participant outcomes for the individual round and the three team rounds. Each question was incentivized according to Palfrey and Wang (2009) using the payoff equation:

$$question\ earnings = 100 - (Actual\ Outcome - Guess)^2$$

[10] For the two telecommuter team treatment, the instructions for the lab participants specified that they would be placed into a team with two individuals participating in a location of their choice, while the instructions for the telecommuting subjects stated that they would be paired with one partner in the laboratory and one partner also participating in a location of their choice. Priming for the other treatments was conducted in a similar fashion, taking into account differences in a subject's perception of the location of partners based on their own location.

All answers were paid in euro-cents with a correct answer resulting in payment of 1 Euro. The use of the quadratic rule implied that incorrect answers were also paid, but as the distance between the respondent's answer and the correct answer increased, earnings decreased rapidly, providing strong incentives to answer with accurate beliefs. Incorrect answers that would lead to negative earnings were capped at zero.

For individual round beliefs, subjects were asked to guess the average performance of those who participated in the lab and the average performance of telecommuters. In teams, subjects were asked to guess the performance of their teammates. When their teammates were both from the same location (for example, as in the LLL), the subjects were asked to guess the average of both teammates, while if their teammates were in different locations (for example, as in LLT), subjects were asked to guess the absolute performance of each teammate.

After beliefs, we also elicited risk preferences using a mechanism adapted from Eckel and Grossman (2008). Subjects were offered a choice between five binary 50/50 gambles where both expected value and risk are increasing in the order of gambles. Choosing a lower gamble corresponds to higher risk aversion. The experiment ended with subjects filling out a survey which asked about their demographic characteristics, simple questions over workplace preferences, and the location they participated in for the experiment.

The experimental design was programmed using Z-tree (Fischbacher, 2007) and subjects were recruited through ORSEE (Greiner, 2004). We ensured that the recruitment procedure did not reveal that some of the subjects would be asked to participate online. After the initial recruitment, subjects that would participate in the laboratory were instructed of the time and place to participate via e-mail. Telecommuting subjects were sent an e-mail that directed them to a website with a link that contained an installer for the client-side of Z-tree (zleaf) which would connect to the university server for these subjects to participate online. The telecommuting subjects were instructed to participate in a location of the choice and informed that they had 24 hours to complete the experiment.

The nature of the experiment required that payment was delayed for all subjects. This has the added benefit that the payment for subjects in both locations is held constant. Each subject received an e-mail within 3 days of their participation that their payment was ready and that they should bring their unique subject ID with them to collect payment. The average subject payment was €13.87 which does not include a show-up fee.

4 Hypotheses

Our first hypothesis is derived from the simple realization that the marginal payment for a correctly coded word decreases by 2/3 when an individual joins a team. This reduction in pay should lead to a reduction in effort, or at a minimum, no increase for a money-maximizing agent.

Hypothesis 1: The productivity of a subject in a team will not be higher when compared to an individual baseline.

The stronger form of this hypothesis would state that productivity should decline, but because we do not know the true value of the outside option for this real-effort task, we will maintain the safer assumption of no increase in productivity.

The second hypothesis will examine what happens between our treatments in the team setting. Specifically, we want to examine if and how productivity changes as a result of the location of a subject's teammates. Several studies (Alchian and Demsetz, 1972; Dickinson and Isaac, 1998) point out that work done in teams has many of the features of a public good, and evidence also exists that in the public goods setting many subjects are conditional cooperators (Keser and Van Winden, 2000; Fischbacher et al. 2001) which implies that subjects in a team will only work harder if they think others are also working hard.

Hypothesis 2: Subjects' productivity while in a team will positively correlate with their beliefs about their team members' productivity.

Hypothesis 2 requires two things. First, it requires us to know what subjects' beliefs are about their teammates, which we gather after the last round. Second, it requires us to examine if these beliefs influence behavior. Specifically, we will examine how subjects' beliefs vary with the location of their teammates and how this influences their own behavior. In our setting, this suggests that if subjects have varying beliefs on the productivity of their team members based on location, their contributions while in a team will reflect these beliefs. The most obvious implication of this hypothesis is if subjects think that telecommuters are less productive. If an individual, regardless of location, believes that telecommuters are less productive, then hypothesis 2 predicts lower resulting effort as the number of telecommuters on a team increases.

5 Results

We begin our results with an overview of the data. Figure 1 summarizes the average correct output in the coding task by period. Period 1 was always the individual round while periods 2 to 4 were team rounds where the treatment order was varied. For each location, we ran four different orders summarized previously in Table 1. The clear observation from figure 1 is that for both subjects in the laboratory and telecommuters, output increased between the individual round and team rounds. The increase in output from the individual stage to the team stage is surprising given that the marginal wage earned for each correctly coded sequence of letters decreased by 2/3 and according to Hypothesis 1, the implementation of a revenue sharing pay scheme between team members is predicted to result in no productivity increase. Nevertheless, we observe

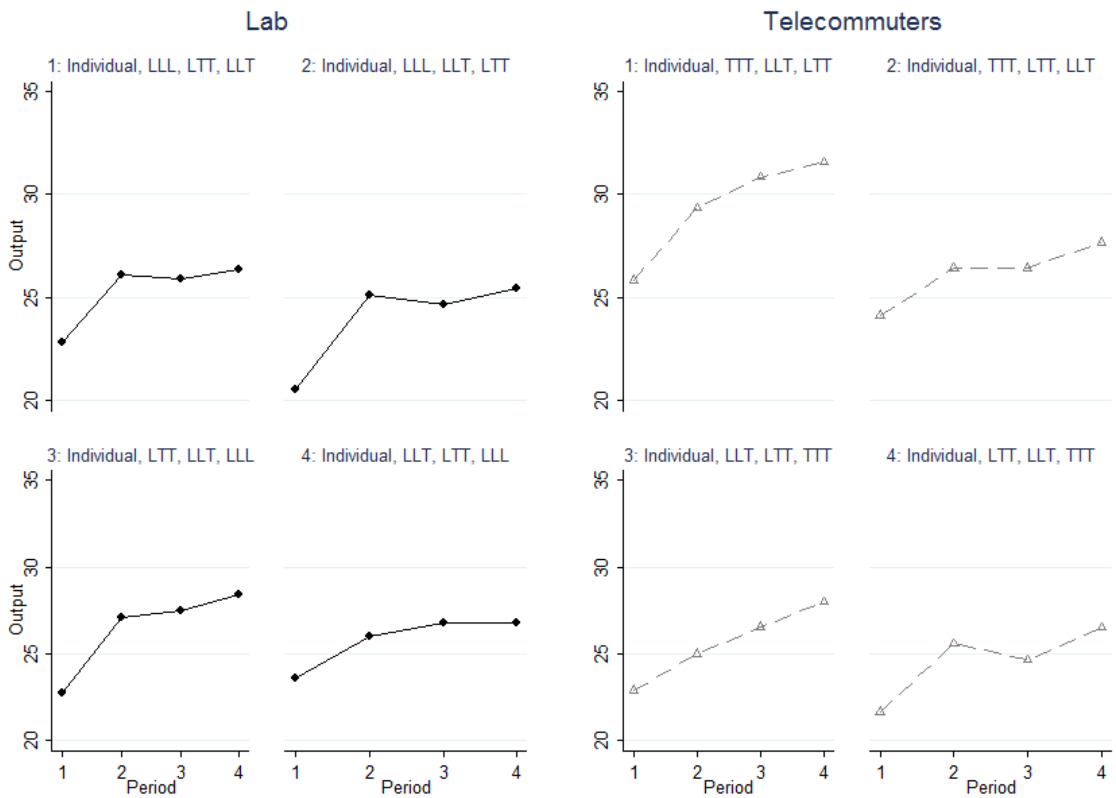

Figure 1: Average output in each period across orders

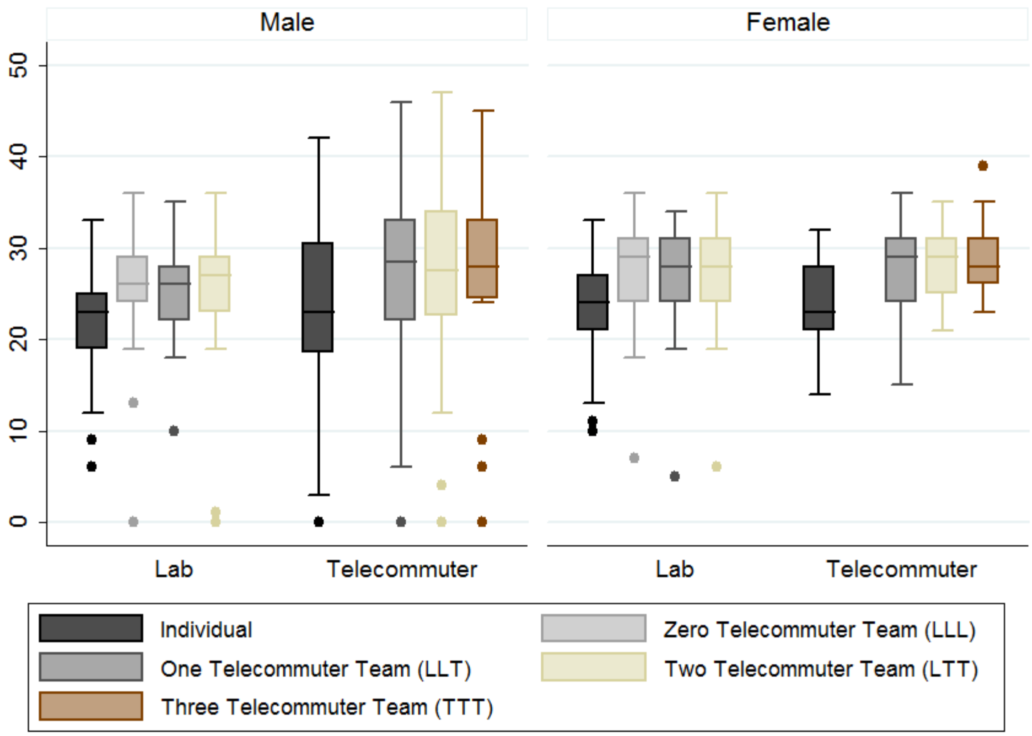

Figure 2: Boxplot of output by gender

significant increases in productivity for the coding task between the individual baseline and team rounds. This result mirrors what was found by Kuhn and Villeval (2011) under a similar set-up using a decoding task when individuals moved from an individual piece rate to revenue sharing two-person teams.[11]

Figure 1 also suggests that the data possess a slight time trend which needs to be controlled for, but no obvious order effects appear.[12]

Regularity 1: Average productivity increased for both telecommuters and non-telecommuters when subjects move from the individual stage to team stages.

Figure 2 is a boxplot diagram which allows a cleaner understanding of variance based on the treatment and gender. The box shows the interquartile range

[11] T-tests of the individual output to the output of any of the team treatments for either location type show significant differences. While we are intrigued by the productivity increase from individual to team output, the reason for this increase is beyond the scope of the current paper.

[12] Kruskal-Wallis tests by location type across orders indicate significant differences between orders, however this result is driven by ability and gender effects rather than order effects. The Appendix contains a more detailed discussion of these results.

(25-75) with the median highlighted, while the whisker extends from the box to the most extreme data value within 1.5 times the interquartile range. The remaining points represent outliers beyond that range. We see in Figure 2 that medians across the team treatments do not vary greatly, but it is immediately evident that for males who telecommute there is a large variation in output suggesting strong gender effects.

To determine the overall effect of telecommuting teams, we must carefully control for individual effects and time trends. To differentiate the impact of the treatments on behavior from individual characteristics, we present a series of random effects panel regressions on output of correctly coded letter sequences, seen in Table 2.[13]

The outcome variable is correctly coded sequences while the main explanatory variables of interest are how many telecommuters are in a team. The variables $Zero$, One, Two, and $Three\ Telecommuters$ implies teams where there are zero, one, two and three telecommuters in the team, respectively, while the individual treatment serves as the baseline. These treatment variables are then interacted with the location dummy, $Home$, to account for differences in the effect of subjects participating in the lab versus telecommuters.[14] Notice that there are only two such interactions, $One\ Telecommuter \times Home$ and $Two\ Telecommuters \times Home$, because teams of zero telecommuters only exist for the subjects in the laboratory and teams of three telecommuters exist only for telecommuting subjects. Thus, these six variables test if the increase (or decrease) in output from the individual treatment to the respective team treatments is statistically different than zero after controlling for other factors.

We also include a control variable for gender, represented by $Female$. The variable $Tic - Tac - Toe$ defines the number of games played in each round while the variable $Risk\ Measure$ is our use of the gamble chosen in the Eckel-Grossman mechanism as a measure of risk attitude where lower numbers correspond to higher risk aversion. Finally, $Log\ Period$ represents the logged period of play, and an interaction of $Log\ Period \times Home$ accounts for potential differences in learning by location. $Log\ Period$ is used to account for the decrease in learning over time, a characteristic which is typical in these types of tasks and is seen in Figure 1.

In the interest of space, we have suppressed control variables for individual productivity and orders to focus on the variables of interest. Specifically, all regressions in Table 2 include decile rank dummy variables, an interaction of the decile rank with $Home$, and dummy controls for the specific order a subject participated in to account for potential order effects.[15]

[13] All regressions include 135 subjects, participating over 4 rounds, giving 540 total observations. The numbers reported in parentheses are clustered standard errors at the individual level to control for potential dependence of error terms. Three (***), two (**), and one (*) stars indicate statistical significance at the 1%, 5%, and 10% respectively. Regressions exclude the practice round.

[14] Our use of the term "home" to denote telecommuting subjects breaks with our previous convention. However, this is done in a effort to reduce confusion on treatments named by the number of telecommuters interacted with the location of the subject.

[15] Full regressions are available from the authors upon request. All order effects are insignif-

Output	**Model 1** Pooled	**Model 2** Female Only	**Model 3** Male Only
Constant	15.667*** (0.884)	14.736*** (0.598)	15.730*** (1.718)
Home (telecommuter)	−4.004*** (1.528)	−0.177 (1.419)	−6.918*** (2.415)
Zero Telecommuter Team	2.228*** (0.541)	1.446** (0.570)	3.047*** (0.870)
One Telecommuter Team	1.598*** (0.560)	0.900 (0.616)	2.407*** (0.911)
One Telecommuter Team × Home	−1.074 (1.096)	−0.825 (1.447)	−1.650 (1.642)
Two Telecommuter Team	1.664*** (0.423)	1.282* (0.694)	2.214*** (0.585)
Two Telecommuter Team × Home	−0.424 (0.850)	−0.155 (1.131)	−1.267 (1.426)
Three Telecommuter Team	1.167* (0.704)	1.488* (0.857)	0.242 (1.335)
Female	−0.090 (0.426)		
Tic-Tac-Toe	−0.414*** (0.035)	−0.371*** (0.069)	−0.382*** (0.046)
Risk Measure (1-5)	−0.162 (0.148)	−0.170* (0.103)	−0.165 (0.306)
Log Period	1.858** (0.754)	3.119*** (0.622)	0.692 (1.232)
Log Period×Home	1.967 (1.237)	1.408 (1.369)	2.727 (2.168)
# of Observations	540	296	244
# of Clusters	135	74	61
$R-squared$	0.817	0.854	0.835

Table 2: Random effects panel regressions on correctly coded output, robust standard errors clustered at the individual level.

Model 1 demonstrates that when lab subjects move from the individual baseline to any of the team stages there is a significant increase in productivity. This effect is strongly significant for Zero, One and Two Telecommuter Teams. The largest impact on behavior appears to be when there are no telecommuters in the team, though this effect can only be confirmed when comparing the coefficients of teams of zero versus one telecommuter (Wald test, $p < 0.01$), giving a statistical indication that the number of telecommuters in a subject's team matters.

The story is quite different for the telecommuters. Looking first at the three telecommuter team case, it is shown that the increase in productivity from the individual stage to teams made up of three telecommuters is not significant at the 5% level. For the telecommuters, it is also confirmed that the there is no increase in productivity when there is one telecommuter on a team ($p = 0.581$) or two telecommuters on a team ($p = 0.099$). Thus, the results show that the non-telecommuters are affected by the team treatment much more than the telecommuters.

Turning to gender effects, figure 2 provided evidence that males had a much larger variance in productivity than females when allowed to telecommute. In order to more cleanly account for these gender differences, Model 1 was rerun using only Females (Model 2) and only Males (Model 3).

From Model 2, we can see that the only strongly significant effect for females is the increase in output for subjects in the lab going from the individual stage to teams made of entirely other lab subjects (zero telecommuter team treatment). No other increases in productivity can be confirmed for lab subjects or telecommuters at acceptable levels. Turning to males, in Model 3 we immediately see a stronger team effect for males in the lab who increase their output when going from the individual rounds to team rounds. Telecommuting males do not increase their productivity regardless of the team composition, mirroring what was previously observed for telecommuting females in Model 2 ($p > 0.05$ for the total effect in both instances).

Result 1: Subjects increased their productivity when going from the individual treatment to the team treatments. This effect is largely driven by non-telecommuting males, and is strongest for teams composed of the fewest telecommuters.

Having established that the number of telecommuters in a team and the location of the subject impacts the contributions of current teammates, we will now address the underlying reason for these differences, namely subjects' beliefs about their teammates. Our starting point for this analysis begins with hypothesis 2, which states that a subject may contribute more effort to a team if they think their teammates are also contributing more, and will contribute less if they think their teammates are contributing less. To obtain a precise understanding

icant at conventional levels, and all decile ranks and interactions of decile rank with location are significant at the 1% level.

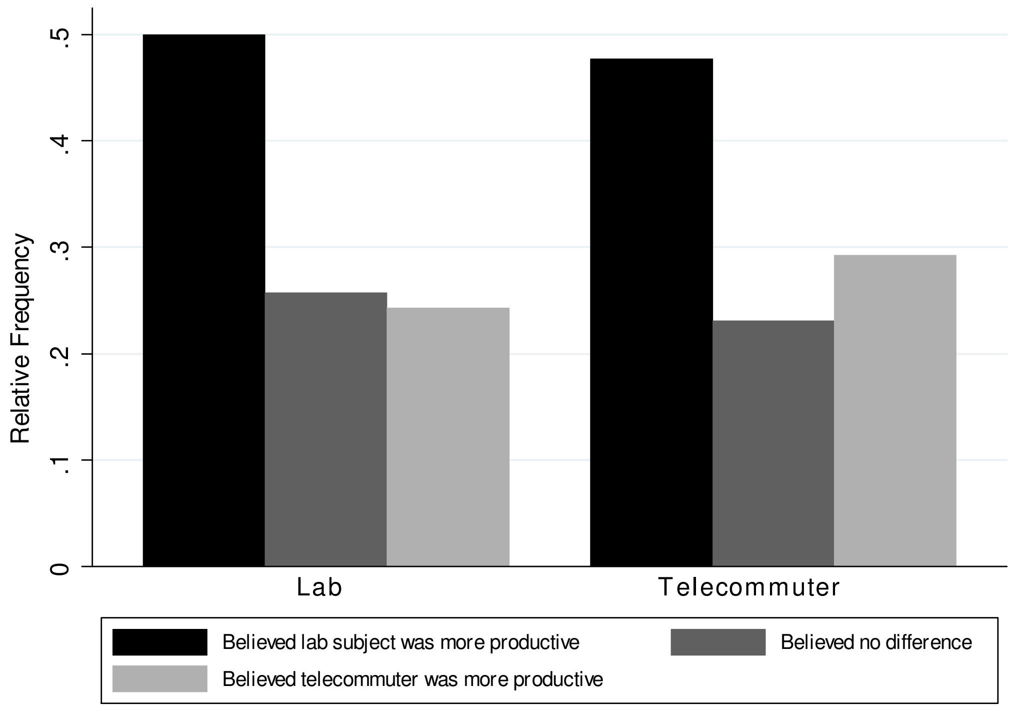

Figure 3: Relative frequency of beliefs regarding telecommuting productivity.

of beliefs, we examine the differences in beliefs when subjects were asked to predict output of telecommuters and lab subjects within the same treatment. Our design facilitates this analysis as all subjects, regardless of whether or not they were lab-based or a telecommuter, participated in one treatment where they were paired in a team with one lab subject and one telecommuter.

Figure 3 breaks down this data by examining the frequency of subjects who thought those based in the lab were more productive than, as productive as, or less productive than telecommuters. It is evident that many more subjects believed that lab subjects were more productive than believed they were less productive or equally productive. A McNemar's test confirms that the number of subjects who thought those in the lab were more productive is greater than those who thought there was no difference ($p < 0.01$) or who thought telecommuters were more productive ($p < 0.01$) The same result can also be found when looking at beliefs over productivity in the individual treatment where subjects were also asked to compare the productivity of subjects in each location. In the individual treatment, 47% believed those in the lab were more productive, while 26% thought there was no difference and 27% believed telecommuters were more

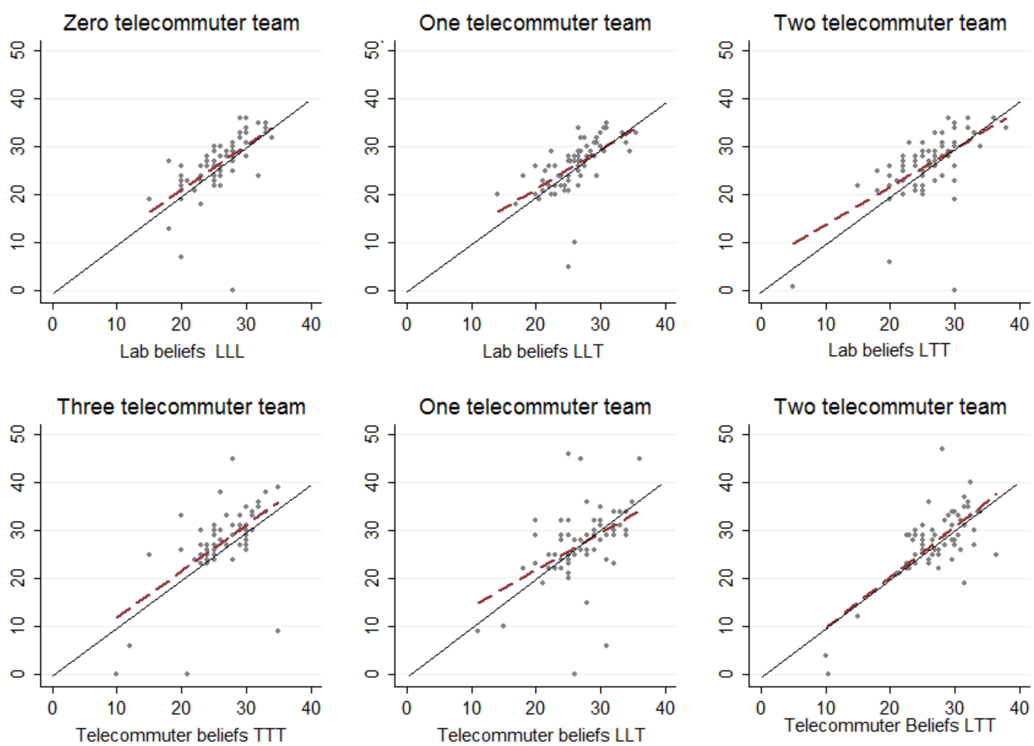

Figure 4: Scatterplot of average beliefs over partner productivity (x-axis) versus output (y-axis)

productive.

Regularity 2: Both telecommuters and non-telecommuters believed that telecommuting would have a detrimental effect on productivity.

To begin the examination of how these beliefs correlate with effort decisions in the treatments, testing hypothesis 2, figure 4 provides a scatterplot of output in relation to beliefs about teammates' output for each treatment. Included in each of the belief graphs is a dashed line representing the simple regression and how this correlation relates to a 45 degree line. From this figure, it is easy to see the positive correlation between output and beliefs, though some heterogeneity is obviously present.

To go beyond the simple correlations, Figure 5 illustrates how beliefs influence relative increases (or decreases) in output when subjects hold differing beliefs about their teammates' productivity when paired with two telecommuters versus when they were paired with two lab subjects. Comparing when an individual was paired with two telecommuters versus when they were paired with

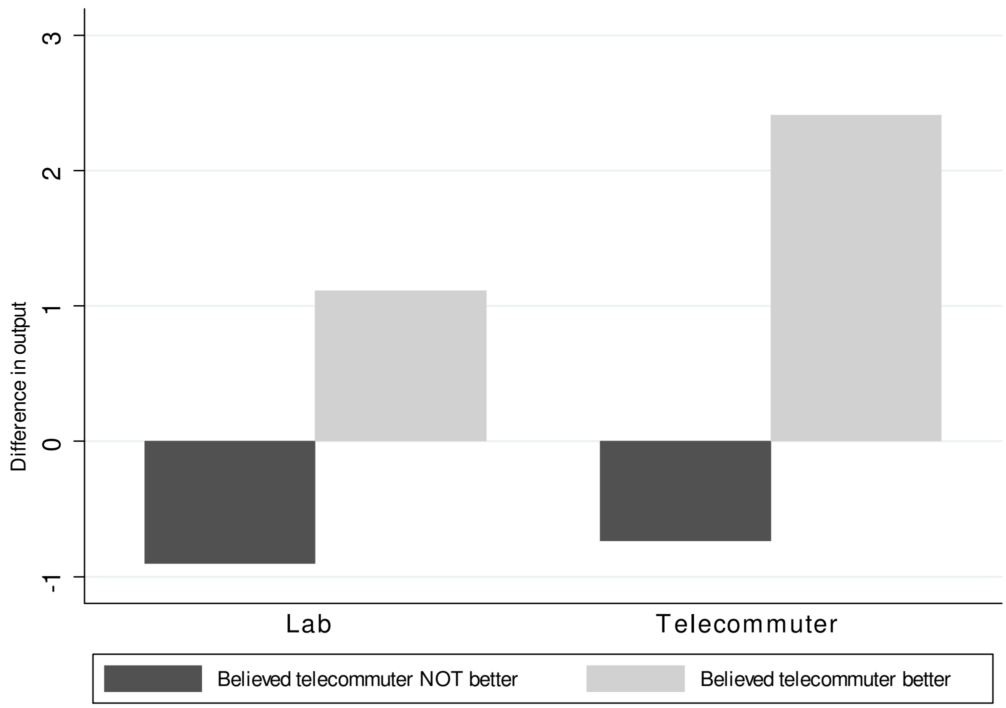

Figure 5: Correlation of beliefs with an increase in productivity when subjects are paired with telecommuting teammates versus when they are paired with lab-based subjects.

Difference in Output	**Model 4**	**Model 5** Female Only	**Model 6** Male Only
Constant	−3.345 (3.377)	−1.264 (5.317)	−4.843 (4.359)
Beliefs of Lab Teammates	−0.472*** (0.179)	−0.051 (0.266)	−0.915*** (0.2422)
Beliefs of Lab Teammates×Home	0.285 (0.232)	−0.204 (0.323)	0.781** (0.335)
Beliefs of Home Teammates	0.521*** (0.122)	0.067 (0.172)	1.062*** (0.178)
Beliefs of Home Teammates×Home	−0.007 (0.185)	0.753*** (0.281)	−0.590** (0.270)
Female	0.226 (0.627)		
Home (telecommuter)	−3.471 (4.375)	−11.160 (7.249)	−3.265 (2.582)
Difference in Tic-Tac-Toe	−0.340** (0.139)	−0.244 (0.182)	−0.236 (0.220)
Risk Measure (1-5)	−0.011 (0.209)	−0.061 (0.263)	0.216 (0.328)
# of Observations	135	74	61
$R-squared$	0.267	0.145	0.459

Table 3: Regressions on the difference in correctly coded output when a subject was paired with two other subjects who were at home versus when they were paired with two other subjects who were in the lab.

two lab-based subjects provides the best contrast for how subjects will behave in the two extreme situations. The vertical axis represents the difference in a subject's output when paired with two telecommuting subjects versus when they are paired with two lab subjects. Values above zero indicate that the subject produced more when paired with two telecommuters than when paired with two lab workers while values below zero imply the opposite. The graph shows that subjects who believe that telecommuters are better than their lab counterparts increase their output when paired with two telecommuters over what they produced when they were paired with two lab subjects. The reverse is true when subjects think that telecommuters are *not* better. If a subject held beliefs that telecommuters were not more productive than those in the lab, output was below their productivity when they were paired with teammates from the lab. Notice that these results hold regardless of the location of the subject.

We again turn to regression analysis, seen in Table 3, for a more formal understanding of beliefs.[16] The dependent variable in the regressions presented is the difference in output when a subject was paired with two home subjects versus when they are paired with two lab subjects, following what was previously shown in Figure 5. The model is similar to the one used in Table 2 except now the main explanatory variables are the beliefs a subject holds about the productivity of their lab teammates, their telecommuting teammates and these

[16] As in the previous regressions, Three (***), two (**), and one (*) stars indicate statistical significance at the 1%, 5%, and 10% respectively.

two variables interacted with *Home* to account for locational differences. Looking at these beliefs separately will inform us if the effect is stronger for beliefs about telecommuters or lab-based subjects. Notice that since the dependent variable is the output of a subject when paired with two telecommuters minus output when paired with two lab-based teammates, according to Figure 4 there should be a negative correlation on the beliefs of other lab subjects and a positive correlation on the beliefs of telecommuters. In other words, the difference in output should become more negative as beliefs of the lab subjects becomes more positive since there is a positive relationship between beliefs and effort. Similarly for the beliefs of the telecommuters. As before, we will run regressions on the full sample (Model 4), then break the sample into only females (model 5) and only males (model 6).

Focusing first on the subjects in the lab, Model 4 confirms that there is a strong correlation between effort and beliefs about a subject's teammates regardless of their location. This can be seen in the significant negative effect on the coefficient *Beliefs of Lab Teammates* and the significant positive effect seen on the coefficient *Beliefs of Home Teammates*. For telecommuters, the same negative effect of beliefs about a subject's lab teammates cannot be confirmed ($p = 0.196$) while the positive effect of beliefs about other telecommuting teammates' productivity is confirmed ($p < 0.01$).

Returning once again to gender differences, Model 5 shows that females, regardless of location, are not influenced by their beliefs of the output of their teammates in the lab (for telecommuting females, $p = 0.161$) but telecommuting females are influenced by their beliefs of their teammates who are also telecommuting ($p < 0.01$) while the same cannot be said for the beliefs of females in the lab.

For males in the lab, Model 6 confirms the negative effect of beliefs about their teammates in the lab and the positive effect of their beliefs about their telecommuting teammates. For telecommuting males, Model 6 does not confirm that a subject's beliefs about their teammates in the lab influenced their relative effort choices ($p = 0.556$), but it does confirm the positive, but smaller, effect of a subject's beliefs of their teammates who were also telecommuting ($p = 0.027$).

Result 2: Subjects' effort choices are positively related to their beliefs about their teammates' output. This result is strongest for non-telecommuting males and both male and female telecommuter's beliefs about other telecommuters.

6 Conclusion

In this paper we set out to address a very fundamental question on the minds of many managers: How does telecommuting influence output of teams? Answering this question is vital since managers still have reservations about allowing their employees to work outside the office even though the evidence is mounting in favor of doing so. The apprehension is understandable, however. The additional free-riding incentives present in teams compounds the fears that the telecommuting environment fosters shirking behavior (Mokhtarian and Salomon, 1997). In order to provide more relevant policy recommendations, we also set out to answer, not just if, but why productivity may vary when someone moves from being matched in a traditional team to a telecommuting team.

We used a novel experimental design which randomly assigned subjects to participate in either the laboratory or online in a location of their choice. They were asked to perform a real-effort task individually or in teams with varying numbers of telecommuters. Surprisingly, when comparing the output in the individual rounds to the team rounds, we found no evidence of free-riding in teams. At the individual level, we find that as in Dutcher (2012), the main effects come from males. The output of male telecommuters is more variable and there is a (slight) increase in output of the lab subjects when they are paired with fewer telecommuters. Our teams were minimalistic in form as we allowed no communication, no joint decision making, and all three members retained complete anonymity. The use of random matching of anonymous partners and no feedback likely helped support no free-riding, a conjecture forwarded by Andreoni (1988) who found that stranger matching led to higher contributions and less free-riding in a public goods framework.

Nevertheless, the non-decrease in productivity moving from the individual stage to the team stages is surprising, especially given the boring nature of the task and 2/3 marginal payoff decline moving from a piece-rate pay scheme to revenue sharing. This result extends the previous experimental results found in Kuhn and Villeval (2011) who used a similar task and provides laboratory robustness for the field evidence of more productive teams observed in Hamilton, Nickerson, and Owan (2003).

Examining why this effect exists, Kandel and Lazear (1992) argue that increases in team productivity can be due to increased peer-pressure. Despite the fact that subjects would never observe the efforts of their partners and vice versa, their effort directly impacted the payoffs of others in their team. If they felt internal pressure (guilt), they would be more reluctant to free-ride in teams. This effect is amplified if the subjects believed everyone else in their team would choose a high effort level.

This leads naturally to the idea that subjects in our setting were responding as if they were conditional cooperators (Keser and Van Winden, 2000; Fischbacher et al. 2001). In our setting, conditional cooperators would be defined as individuals who contribute more effort to the paid task if they believe their teammates also contributed more effort to the paid task.

Evidence of the above two conjectures is supported by our findings that differences in output when a subject is paired with two lab-based workers versus when they are paired with two telecommuters is strongly tied to their beliefs about their teammates productivity. Specifically, we find a positive correlation between a subject's chosen effort and their beliefs about the effort of their teammates which provides an explanation as to why a subject may be less productive when they are in a telecommuting team.

This paper has three main implications for managers considering implementation of a telecommuting policy. The first is that the main finding should help alleviate managers' fears that employees will shirk more outside of a manager's direct supervision when the work to be performed is in teams. The second point, more subtle in nature, is that managers should continue to play an active role in selecting who they allow to telecommute given the substantial role played by individual heterogeneity in productivity. The third, and most important implication of our findings is that even if there is a negative consequence due to some team members telecommuting, reinforcement that all team members are contributing a high effort level will keep productivity high since effort choice is positively correlated to beliefs about their teammates' productivity.

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8 Appendix

8.1 Examination of order effects and treatment averages

Our objective in running the selected four treatment orders for each location type was to test the strongest cases for order effects. For the lab subjects, the orders were defined by having the zero telecommuter treatment (LLL) placed at the front and back-end of the team rounds. Correspondingly, the orders for the telecommuters alternated the three telecommuter treatment (TTT) between the front and back-end of the team rounds. For individuals participating in the lab, Kruskal-Wallis tests indicate no significant differences between orders for output (zero telecommuter team, LLL, $p = 0.250$; one telecommuter team, LLT, $p = 0.646$; two telecommuter team, LTT, $p = 0.583$). For individuals participating as telecommuters, there are no significant effects between orders for the

Coding Task	Individual	0 Telecommuter Team	1 Telecommuter Team	2 Telecommuter Team	3 Telecommuter Team
Lab (n=70)	22.35 (5.90)	26.58 (6.14)	26.18 (5.33)	26.20 (6.69)	–
Telecommuter (n=65)	23.73 (6.84)	–	27.09 (7.89)	27.8 (7.13)	27.66 (7.56)
$p - value$	0.210		0.432	0.181	

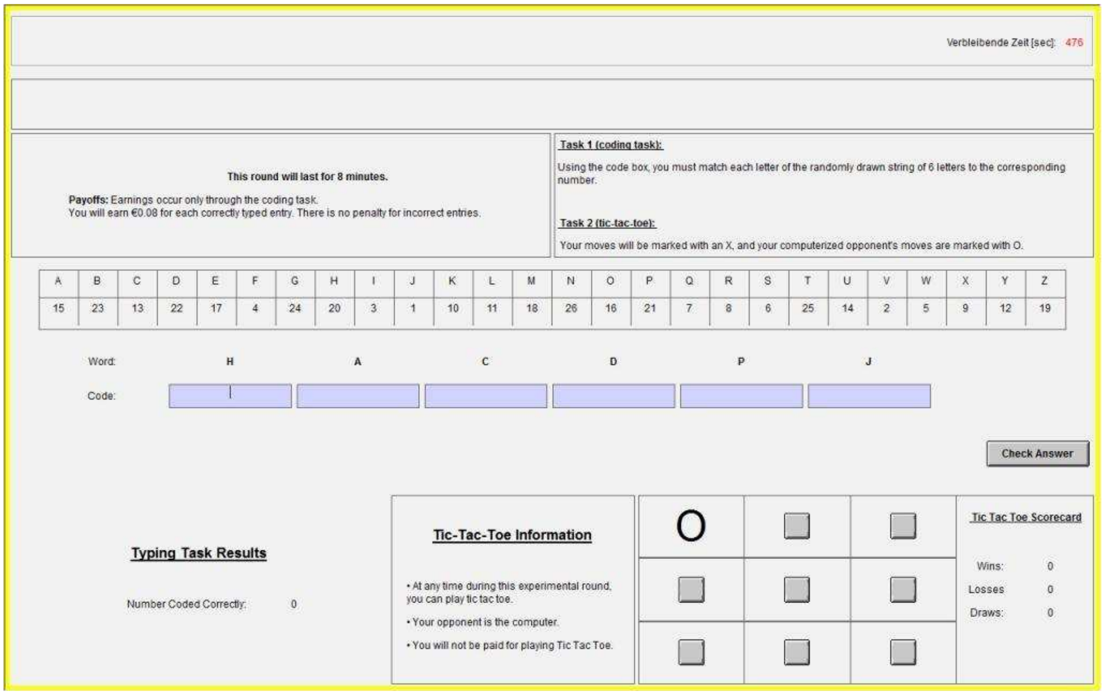
Table 4: Average output of coding task, by location type. Standard deviation in parentheses. Reported p-values represent results from two-sided t-tests for differences in means.

three telecommuter team treatment, TTT ($p = 0.550$). However, significant differences are found for the two telecommuter team, LTT, and one telecommuter team, LLT ($p = 0.048$ and $p = 0.014$, respectively).

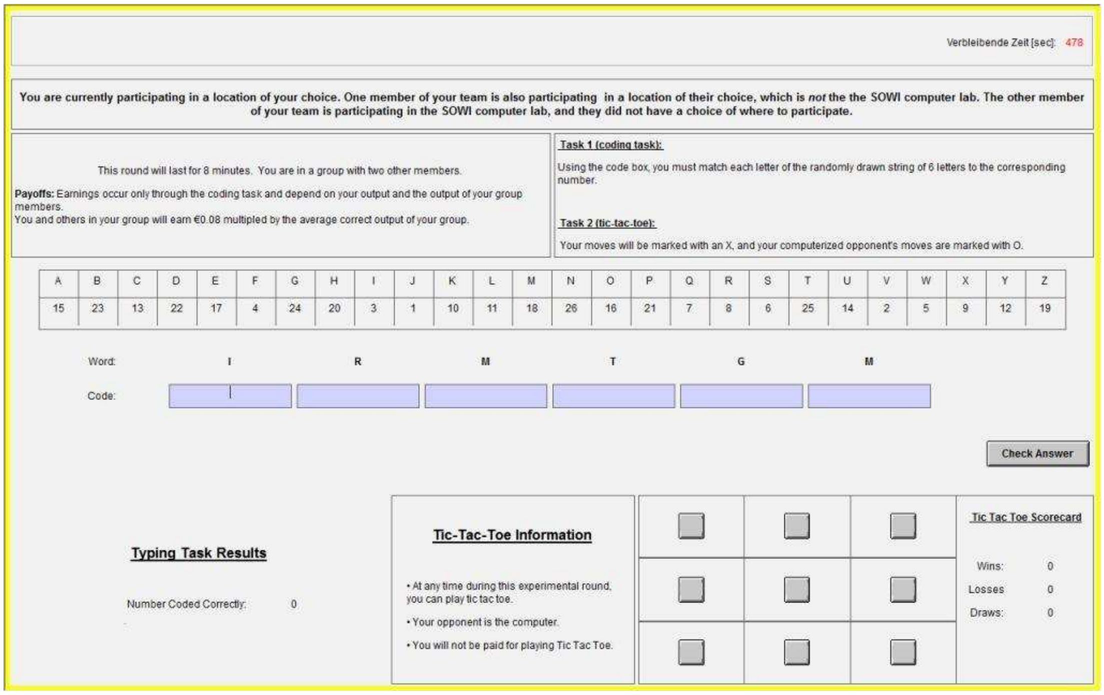
Breaking down the two telecommuter team treatment by gender for the telecommuters, we eliminate the significant differences between orders (females in the two telecommuter team treatment, $p = 0.109$; males in the two telecommuter team treatment, $p = 0.279$). Likewise for the one telecommuter team treatment, between orders there are no significant differences for females outside of the lab ($p = 0.121$), yet significant differences remain for males outside of the lab, but these can be attributed to ability effects as removing the top 10% of performers in overall productivity results in insignificant differences ($p = 0.380$). We have also run these same tests using the parametric version of the Kruskal-Wallis test (ANOVA) and find the same results.

Table 4 provides averages, by treatment and location type. Note that these overall means are largely misleading given the individual effects and the time trends observed, but we include these here for the interested reader. Again, the previously observed increase from the individual stage to any of the team stages remains. In terms of raw average output, a t-test picks up no statistical difference between the average output of lab subjects and telecommuters when they both have the same number of telecommuters in their team. The difference in output when there are three telecommuter teams versus when there are zero telecommuter teams is also found to be insignificant ($p = 0.37$). While these averages support no productivity loss due to the number of telecommuters on a team, they must be interpreted carefully as a significant amount of variation in the data exists due to gender and ability. Moreover, these averages do not address the idiosyncratic response to the number of telecommuters in a team.

8.2 Screenshots



Individual Round



Team Round

8.3 Experimental Instructions

Introduction:

Thank you for participating in today's experiment. These instructions explain the nature of today's experiment as well as how to work the computer interface you will be using.

These instructions are complex, please make sure you read through them carefully. The instructions and stages of the experiment are self-paced, so when you have finished and a "Continue" button is available, please press it.

General Description:

This is an experiment on the economics of decision making where you will have the chance to earn money based on the decisions made by you and others. You should be able to complete the entire experiment on your own without any external assistance of any kind.

You will have the opportunity to make money during today's experiment, which consists of four, 8-minute rounds. Because of the nature of the experiment, your payment cannot be immediately calculated. More detailed instructions for how you can pick up your cash payment for participation today will be given at the end of the experiment.

All payments are confidential; no other participant will be told the amount you make.

Tasks:

In each round, you will be able to choose between two tasks. You can split your time among the tasks however you choose. Meaning you can spend all of your time on task I and none on task II, all of your time on task II and none on task I, or some combination of task I and task II, or neither.

Please press "Continue" to see an example of the tasks you will be presented with in each round.

Task 1:

For task I, a string of 6 random letters is displayed below a code bar. The code bar will link a series of letters with a corresponding number. Your task is to find the corresponding number associated with the letters and type it in the space provided. Once you are satisfied with your answer, you will hit the "check answer" button to submit your answer. For each correctly coded string, you will receive €0.08.

The example below shows you the layout of the game. After you submit a code correctly, the code bar will change and a new set of random letters will appear

In this example, the correct code would be 10 17 12 11 22 17. You would get credit for this answer by typing each number in the box below each letter which corresponds to this number in the code bar. However, because this is an example, the "Check Answer" button is non-functioning. During the actual experiment, you would submit your answer with the "Check Answer" button.

Please press Continue to see an example of the second task you will be presented with in each round.

Task 2:

In task II, you will be playing a game against the computer. The game is commonly known as tic-tac-toe. There are nine spaces in which to either put an X or an O. The X represents your choice, while the O represents the computer's choice. You will win the game when you have three X's in a row.

You will be able to track your wins and losses against the computer. You will not be paid for playing tic-tac-toe.

Practice:

To familiarize yourself with the tasks and computer interface, you will be taken to a practice round. You will not be paid for this round, it is only for practice purposes. Please press continue to enter into the practice round.

When you have finished practicing the two tasks, you may continue whenever you are ready by clicking Continue.

Below, you will see an example screen of the screen you would see during a round. You will always have the ability to play both tasks in a round.

In the actual experiment, the left box will contain detailed information about how you will be paid while the right box will contain the summary instructions for both tasks.

Payoffs:

As explained previously, you will be presented with two tasks: the coding task and tic-tac-toe. For each correctly coded string in the coding task, you will receive €0.08. Incorrectly coded strings carry no penalty of payment. Tic-tac-toe is unpaid. Let's go through an example of how payoffs work.

Payment Example:

Assume in this round you correctly coded 35 strings of random characters in the allotted time. Since you will get €0.08 for each correctly typed entry, you would receive €2.80 for this round.

If on the other hand you correctly coded 30 strings of random characters in the allotted time, you would receive €2.40 for this round.

Timing:

The time remaining in each round will be displayed in the upper right corner of your screen. When the time limit of 8 minutes has expired, you will automatically be taken to a new screen with instructions on how to proceed. When you are ready, please click continue to enter into round 1.

New Instructions:

The tasks and time limit (8 minutes) in this round are the same as the previous round. However, there is an important change. The difference between this round and the previous round you played is that instead of playing as an individual, you will now be playing in a group of two others and your pay will now depend on your choices and the choices of two others. The others in your group will either perform the task in the SOWI Computer lab or in a location of their choice. More on the locations in a moment.

You will be randomly and anonymously matched with the others in your group. The other members of the group will be given the same two tasks that you are, and as before, the coding task is the only task paid, however, the way that the coding task is paid has changed.

New Payoffs:

In this round, you and the other 2 members of your group will accumulate group earnings equal to €0.08 for each correctly coded string your group solves, together. These group earnings will then be equally divided between you and the other two members of your group. In equation form, your payoff = [€0.08 * (your output + member 1's output +member 2's output)]/3

To understand how the team payment scheme differs from the individual payment scheme, please click "Continue" to see examples.

Group Payment Examples:

Suppose for example you solve 30 coding problems correctly (recall that tic-tac-toe is still unpaid) and the other two group members each solved 20 . You and the other two members of your group would now receive [€0.08 * (30+20+20)]/3 = €1.87, which is less than the payoff example previously given for the individual payment scheme where you contributed 30.

If, on the other hand, you solve 30 problems and the other two group members each solved 40, you and the other two members of your group would now receive [€0.08 * (30+40+40)]/3 = €2.94, which is more than the example of the individual payment scheme where you contributed 30.

As another example, suppose that you correctly solved 28 and the other two group members each solved 30. You and the other two members of your group receive [€0.08 * (28+30+30)]/3 = €2.35, which is less than in the example for the individual payment scheme where you contributed 30.

As a final example, suppose that you and the other two group members each solved 30 coding task problems correctly. You and the other two members of your group receive [€0.08 * (30+30+30)]/3 = €2.40, which is the same as in the example for the individual payment scheme where you contributed 30.

Group Member Information:

All choices are anonymous. The other members in your group will **never** be told your specific output, nor will they be told the amount that you played tic-tac-toe. Likewise, you will never be told the specific output of your group members or how much they played tic-tac-toe.

The only information you will be given about the other members of your group is where they will be participating. Similarly, the other members of your group will only know that you are participating in "the SOWI computer lab (“a location of your choice"). The members of your group are not necessarily participating today.

You are about to begin the next round, but before you begin, we will give you information about the location of the members of your group.

Location of the members of your Group:

You are currently participating in “the SOWI computer lab" ("a location of your choice"). The other members of your group are also participating in “the SOWI computer lab." (“a location of their choice, which is not the SOWI computer lab (for example, they may be participating from home on their personal computer).

When you are ready, please click continue to enter into the next round.