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Using the Slider Task**

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ABSTRACT

Measuring Costly Effort Using the Slider Task*

Using real effort to implement costly activities increases the likelihood that the motivations that drive effort provision in real life carry over to the laboratory. However, unobserved differences between subjects in the cost of real effort make quantitative prediction problematic. In this paper we present the slider task, which was designed by us to overcome the drawbacks of real effort tasks. The slider task allows the researcher to collect precise and repeated observations of effort provision from the same subjects in a short time frame. The resulting high-quality panel data allow sophisticated statistical analysis. We illustrate these advantages in two ways. First, we show how to use panel data from the slider task to improve precision by controlling for persistent unobserved heterogeneity. Second, we show how to estimate effort costs at the subject level by exploiting within-subject variation in incentives across repetitions of the slider task. We also provide z-Tree code and practical guidance to help researchers implement the slider task.

JEL Classification: C91, C13

Keywords: experimental methodology, real effort, effort provision, cost of effort, slider task, design of laboratory experiments, unobserved heterogeneity

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1 Introduction

Laboratory experiments are a powerful tool for understanding drivers of agents' behavior and for testing the predictions of economic theories. In particular, laboratory experiments are often used to study how much effort subjects exert in a costly activity. For example, subjects may choose how much effort to exert when competing in a tournament (Bull et al., 1987), when producing output as part of a team (van Dijk et al., 2001), when responding to the wages set by an employer (Fehr et al., 1997), and when earning endowments that form the starting point for a bargaining game (Burrows and Loomes, 1994).

There are two ways of implementing costly activities in a laboratory experiment: via a monetary cost function that mimics effort by specifying output as a function of how much money the subject contributes (e.g., Bull et al., 1987); and using a real effort task. The monetary cost function allows the experimenter full control over the cost of effort.¹ Increasingly, laboratory experiments have featured real effort tasks, such as: (i) solving mazes (Gneezy et al., 2003), mathematical problems (Sutter and Weck-Hannemann, 2003; Niederle and Vesterlund, 2007) or word games (Burrows and Loomes, 1994); (ii) answering general knowledge questions (Hoffman et al., 1994); (iii) counting (Abeler et al., 2011), decoding (Chow, 1983), encrypting (Erkal et al., 2011) or entering (Dickinson, 1999) strings of characters; (iv) performing numerical optimization (van Dijk et al., 2001); and (v) filling envelopes (Konow, 2000), cracking walnuts (Fahr and Irlenbusch, 2000), or other physical tasks.

The main advantage of using a real effort task over a monetary cost function is the greater external validity of the experiment: exerting actual effort makes the environment more realistic and less sterile, increasing the likelihood that the motivations that drive behavior outside the laboratory carry over to the laboratory. Real effort tasks, however, suffer from two critical drawbacks. First, the cost of effort provision varies from subject to subject and is unknown to the experimenter. As Falk and Fehr (2003, p. 404) explain "Since the experimenter does not know the workers' effort cost, it is not possible to derive precise quantitative predictions." Second, since motivation and ability to complete the real effort task vary considerably across subjects, data collected using real effort tasks are noisy and, therefore, statistical analyses of real effort data often lack precision.

In this paper we present the *slider task*, which is a novel and simple computerized real effort task that was designed by us specifically to overcome the drawbacks of real effort tasks. In particular, the slider task provides a finely gradated measure of effort within a short time frame. The slider task thus allows the researcher to collect precise and repeated observations of effort provision by the same subjects. The resulting high-quality panel data on repeated effort choices allow sophisticated statistical analysis of effort provision in the laboratory using panel data methods. We illustrate these advantages in two ways. First, we show how to use panel data from the slider task to improve precision by controlling for persistent unobserved heterogeneity. Second, we show how to estimate effort costs at the subject level by exploiting within-subject variation in incentives across repetitions of the slider task.

¹In particular, the experimenter can control the extent of any convexity in the cost of the activity, and can also determine how the cost varies over individuals and over any repetitions of the task.

The slider task, first developed and used by us in Gill and Prowse (2012) to study disappointment aversion, consists of a single screen containing a number of “sliders” that subjects move to a specified position within an allotted time. One repetition of the slider task takes only 120 seconds and measures effort choices varying from 0 units to over 40 units. The slider task is now well established as a tool for experimental economists. Since its inception, the slider task has been used to study contract law (Depoorter and Tontrup, 2012), tax compliance (Fonseca and Myles, 2012; Doerrenberg et al., 2015), cheating in the workplace (Gill et al., 2013), gender differences in competition (Gill and Prowse, 2014), tax complexity (Abeler and Jäger, 2015), outside options (Goerg et al., 2017), downsizing (Drzensky and Heinz, 2016), social enterprises (Besley and Ghatak, 2017), volunteering (Brown et al., 2013), peer pressure (Georganas et al., 2015), social insurance (Ahlquist et al., 2014), delegation (Feess et al., 2014) and creativity (Bradler et al., 2015), among others.²

This paper describes the properties and advantages of the slider task. In so doing, we provide context for studies that have used the slider task, and we provide direction to experimental economists who are considering how to implement costly activities in their own experiments. In particular, the contribution of this paper is four-fold. First, we explain how the slider task overcomes many of the limitations of real effort tasks. Second, we show that panel data collected from the slider task are of sufficient quality that they can be used to estimate precisely how subjects respond to financial incentives. Third, we demonstrate how repeated observations of effort choices in the slider task can be used to recover information about each subject’s cost of effort function.³ Fourth, we provide some practical guidance for experimental economists who want to use the slider task in their own real effort experiments.

The paper proceeds as follows: Section 2 outlines the design of our slider task; Section 3 details the advantages of the slider task; Section 4 describes the data; Section 5 reports estimates of how effort in the slider task responds to financial incentives; Section 6 shows how data collected from the slider task can be used to estimate effort costs for each subject; Section 7 contains a practical guide for researchers wishing to implement the slider task; and Section 8 concludes. The z-Tree code that accompanies this paper is available online and can be used to create real effort laboratory experiments featuring the slider task.⁴

²The slider task has also been used in other studies including Hetzel (2010), Eacret et al. (2011), Hammermann et al. (2011), Dolan et al. (2012), Kimbrough and Reiss (2012), Monahan (2012), Breuer (2013), Das et al. (2013), Djawadi and Fahr (2013), Fahr and Djawadi (2013), Ibanez and Schaffland (2013), Riener and Wiederhold (2013), Djawadi et al. (2014), Doerrenberg and Duncan (2014a), Doerrenberg and Duncan (2014b), Evdokimov and Rahman (2014), Fan and Zhao (2014), Friedl et al. (2014), Gärtner and Sandberg (2014), Gerhards and Siemer (2014), Khadjavi (2014), Kirchler et al. (2014), Lezzi (2014), Lindner (2014), Schmitz (2014), Straub et al. (2014), Teng et al. (2014), Avram (2015), Bonein and Denant-Boèmont (2015), Zeppenfeld (2015), Cettolin and Riedl (2016), Dorrrough et al. (2016), Imas et al. (2016), Riener and Wiederhold (2016), Smith (2016), Brown et al. (2017), Gee et al. (2017), Meissner and Pfeiffer (2017), Kesternich et al. (2018) and Malik et al. (2018).

³Gill and Prowse (2012) embed heterogeneous effort costs within a more complex structural model, but they do not recover individual-level estimates of the cost of effort.

⁴The code is available from: <http://web.ics.purdue.edu/~vprowse/GillProwseSliderExample.ztt>. The code that we provide comes with no warranty or guarantee. In providing this code, we take no responsibility with regard to the use or modifications of the code.

2 Design of the slider task

Our novel and simple real effort task consists of a single screen displaying a number of “sliders” programmed in z-Tree (Fischbacher, 2007). This screen does not vary across experimental subjects or across repetitions of the task. A schematic representation of a single slider is shown in Figure 1. When the screen containing the effort task is first displayed to the subject all of the sliders are positioned at 0, as shown for a single slider in Figure 1(a). By using the mouse, the subject can position each slider at any integer location between 0 and 100 inclusive. Each slider can be adjusted and readjusted an unlimited number of times, and the current position of each slider is displayed to the right of the slider. The subject’s “points score” in the task, interpreted as effort exerted, is the number of sliders positioned at 50 at the end of the allotted time. Figure 1(b) shows a correctly positioned slider. As the task proceeds, the screen displays the subject’s current points score and the amount of time remaining.

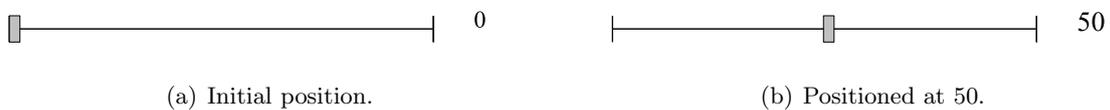
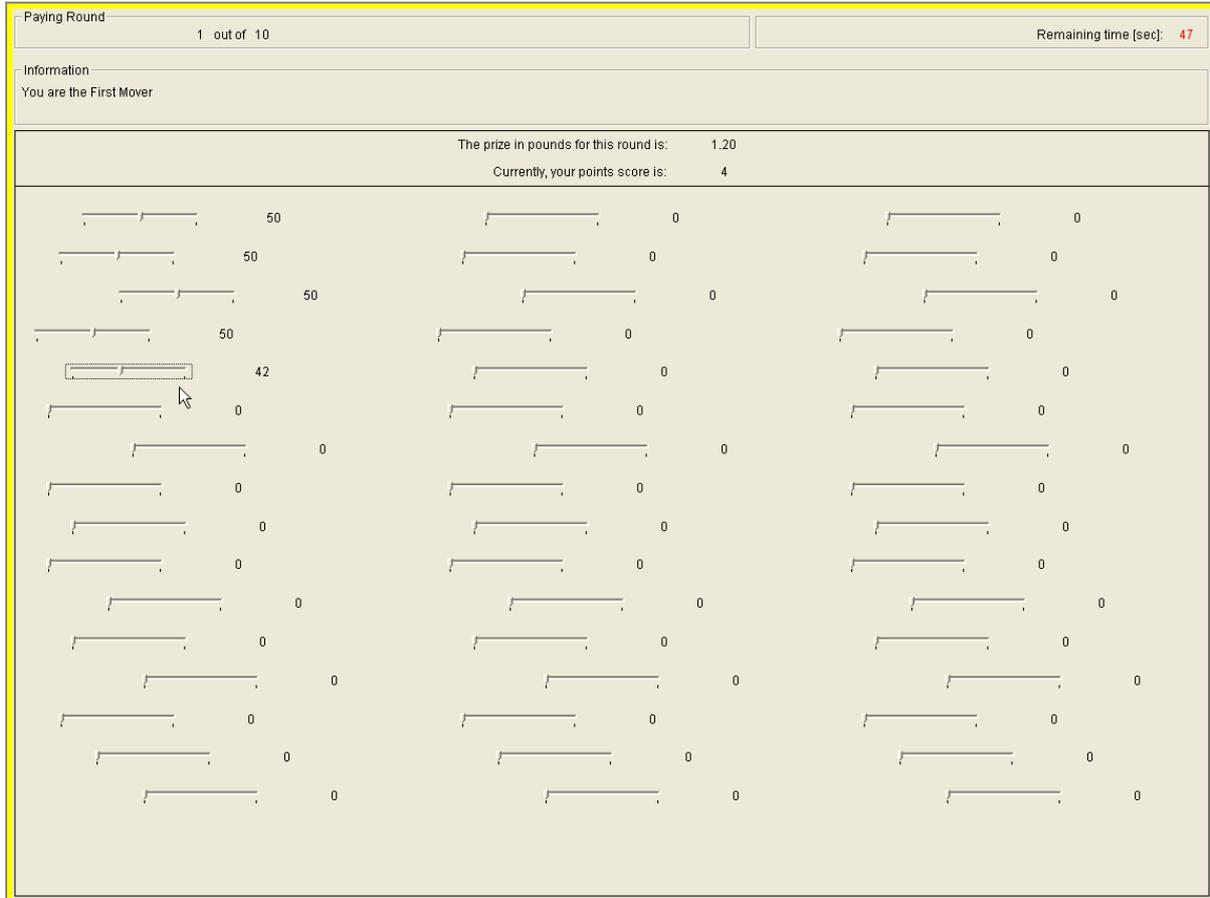


Figure 1: Schematic representation of a slider.

Figure 2 shows a screen containing 48 sliders, as shown to the subject in the laboratory in Gill and Prowse (2012). In this example, the subject has positioned four of the sliders at 50 and a points score of 4 is shown at the top of the screen. A fifth slider is currently positioned at 42 and this slider does not contribute to the subject’s points score as it is not correctly positioned. To ensure that all the sliders are equally difficult to position correctly, the 48 sliders are arranged on the screen such that no two sliders are aligned exactly one under the other. This prevents the subject being able to position the higher slider at 50 and then easily position the lower slider by copying the position of the higher slider. The number of sliders and task length can be chosen by the experimenter.



Note: The screen presented here is slightly squarer than the one seen by our subjects.

Figure 2: Screen showing 48 sliders.

3 Advantages of the slider task

The slider task has a number of desirable attributes. First, the slider task is simple to communicate and to understand, and does not require or test pre-existing knowledge. Second, unlike solving mathematical problems, counting characters, solving anagrams, negotiating mazes or performing numerical optimization, the slider task is identical across repetitions. This feature reduces the noise in measured effort across repetitions of the slider task. Third, the task involves little randomness, and so the number of correctly positioned sliders corresponds closely to the effort exerted by the subject, again reducing noise. Fourth, there is no scope for guessing, which complicates the design and interpretation of some existing tasks such as those based on counting characters or numerical optimization.

These attributes are also shared by the envelope filling task, in which subjects stuff real envelopes with letters. Crucially, and in contrast to stuffing real envelopes, the slider task provides a finely gradated measure of effort within a short time frame. In Section 5 we see that with 48 sliders and an allotted time of 120 seconds, measured effort varies from 0 to over 40. By reducing measurement noise, the finely gradated measure of effort increases statistical precision. The ability to measure effort in a short time frame, meanwhile, makes it feasible for the subjects

to repeat the identical task many times.

The resulting high-quality panel data on repeated effort choices allow sophisticated statistical analysis of effort provision in the laboratory using panel data methods. In Section 5, we show how to use panel data from the slider task to improve precision by controlling for persistent unobserved heterogeneity. In Section 6, we show how to estimate effort costs at the subject level by exploiting within-subject variation in incentives across repetitions of the slider task. The repeated observations of effort from the slider task can also be used to study the dynamics of effort over time: for example, Gill and Prowse (2014) study gender differences in how effort responds to the outcomes of earlier competitions. Furthermore, because the slider task is computerized, it allows flexible real-time subject interactions: Lee (2015) exploits this feature of the slider task to study the effect of real-time relative-performance feedback on effort provision.

4 Description of the data

We used the slider task in six experimental sessions conducted at the Nuffield Centre for Experimental Social Sciences in Oxford. The data were collected to study disappointment aversion (see Gill and Prowse, 2012). The slider task included 48 sliders (as shown in Figure 2) and the task length was 120 seconds.⁵ We use the terms “points score” and “effort” interchangeably to denote the number of sliders correctly positioned by a subject at the end of the 120 seconds.⁶ The experimental instructions can be found in Supplementary Web Appendix I.

Twenty subjects participated in each of the six sessions. At the beginning of every session half the subjects were told that they would be a “First Mover” and the other half told they would be a “Second Mover” for the duration of the session. At the beginning of each round, every First Mover was anonymously paired with a new Second Mover using the no-contagion algorithm of Cooper et al. (1996). A prize for each pair was randomly chosen between £0.10 and £3.90 and revealed to the pair members. The First and Second Movers then completed the slider task sequentially, with the Second Mover discovering the points score of the First Mover she was paired with before starting the task. The prize was then awarded to one pair member based on the relative points scores of the two pair members and some element of chance (see Table SWA.1 in Supplementary Web Appendix I). In particular, a subject’s chance of winning the prize increased by one percentage point with every unit of her own effort and decreased by the same amount for every unit of her opponent’s effort. Furthermore, if the First Mover and her opponent exerted the same effort then each pair member had an equal chance of winning the prize.⁷

⁵The sliders were displayed on 22 inch widescreen monitors with a 1680 by 1050 pixel resolution. To move the sliders, the subjects used 800 dpi USB mice with the scroll wheel disabled.

⁶As is common in the experimental literature on real effort provision, we use the term “effort” to correspond to measurable performance in a work task rather than the cost associated with work effort (see, e.g., Abeler et al., 2011, Gill and Prowse, 2012, and Charness et al., 2014).

⁷In addition to any prizes accumulated during the experiment, all subjects were paid a show-up fee of £4. The subjects also initially played two practice rounds against an automaton for which they were not paid. We do not include the practice rounds in the data analysis.

In total we have data on 60 First Movers and 60 Second Movers, each observed during 10 rounds. For the purposes of analyzing behavior in the slider task, we look only at the behavior of the First Movers (Gill and Prowse, 2012, focus on the behavior of the Second Movers, in particular analyzing how the effort of Second Movers responds to that of the First Movers).

Table 1 summarizes the observed efforts of the First Movers in each of the 10 rounds. We see that the mean points score tended to increase over the 10 rounds, from an average of 22.2 sliders in the first round to 26.3 sliders in the final round. Given that the average prize was constant over rounds, this increase in effort is interpreted as a learning-by-doing effect. The maximum observed effort was 41, and therefore it appears that no subject was able to position correctly all 48 sliders in 120 seconds. We conclude that efforts were not constrained by the upper limit imposed by the design of the task. There are seven observations of 0s. Of these, five correspond to two subjects who appear to have had difficulty positioning sliders at exactly 50 until a few rounds into the session. The remaining two observations of 0 correspond to a further two subjects who chose to exert no effort toward the end of their session in response to low prizes of £0.10 and £0.30.

Round	Subjects	Mean Effort	Median Effort	Minimum Effort	Maximum Effort
1	60	22.20 (6.07)	23	1	33
2	60	22.68 (6.66)	23.5	0	33
3	60	24.80 (6.03)	25.5	0	37
4	60	24.61 (5.90)	25	0	35
5	60	25.18 (6.94)	26	0	38
6	60	24.66 (7.45)	26	1	37
7	60	25.91 (5.81)	26	9	37
8	60	26.88 (5.82)	27	9	41
9	60	25.65 (8.48)	28	0	38
10	60	26.31 (6.72)	27	1	40

Note: Standard deviations in parentheses.

Table 1: Summary of First Movers' efforts by round.

Figure 3 shows the distribution of points scores. This figure was drawn using all 600 subject-round observations of points score from the First Movers in our experiment. We see a substantial amount of variation in effort provision. Specifically, a small cluster of subjects exert zero or very low effort in a particular round, two-thirds of efforts lie between 20 and 30 inclusive, while around 20% of efforts exceed 30. Thus, despite subjects having only 120 seconds to complete the slider task, we see large differences in effort provision. We further explore the heterogeneity in effort provision by decomposing the total variation in effort over the 600 subject-round observations into a component due to between-subject differences in average effort provision in the experiment

(pooling together data from all 10 rounds) and a component due to within-subject fluctuations in effort provision over the 10 rounds of the experiment. We find that 65.4% of the total variation in effort in the experiment is due to between-subject differences in effort provision that persist over the experiment, while the remaining 34.6% of the total variation in effort in the experiment arises from within-subject fluctuations in effort over rounds.

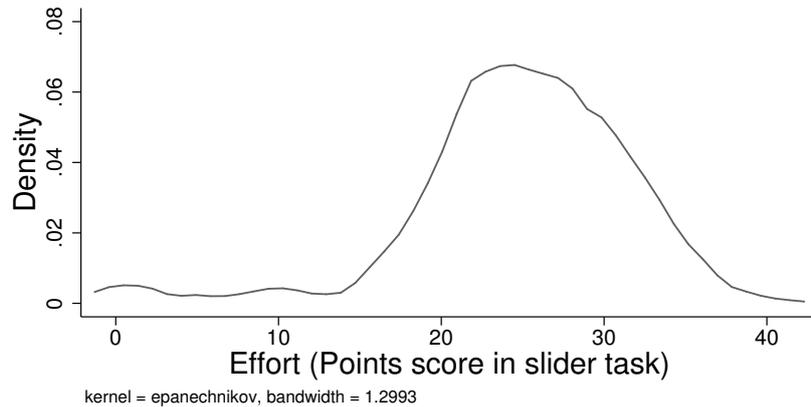


Figure 3: Distribution of First Movers' efforts.

5 Response to incentives in the slider task

In this section we use our panel data on repeated effort choices from the slider task to estimate how effort responds to financial incentives. We show that data generated by the slider task are of sufficient quality to estimate precisely the effect of monetary incentives on effort provision using panel data methods that control for unobserved heterogeneity.

Recall that the prize is announced at the start of each round, and a subject's chance of winning the prize increases with her effort in the round: a subject's financial incentive to exert effort therefore increases with the value of the prize for the round. Figure 4 provides initial evidence that effort provision in the slider task responds positively to financial incentives. The figure shows the results of a Lowess regression of the First Movers' efforts on the prize, estimated using all 600 subject-round observations of the First Movers in our experiment. As the prize increases from its lowest value of £0.10 to its highest value of £3.90, effort rises from about 22 sliders to about 26 sliders.



Figure 4: Response of First Mover's effort to the prize

Table 2 presents the results of a sequence of regressions of First Movers' efforts on the prize and round number. All regressions control for persistent unobserved heterogeneity by including subject fixed effects, which absorb subject-level differences in effort that persist over all 10 rounds of the experiment. Model (1) shows a positive and statistically significant round trend, which captures learning-by-doing. Model (2) includes a full set of round dummies.⁸ Model (3) includes the prize as an additional explanatory variable. We see that the First Movers' efforts increase statistically significantly in the prize, with a £1 increase in the prize causing an increase in effort of 0.7 of a slider.⁹

We explained in Section 3 that the main advantage of the slider task is that it generates high-quality repeated observations of effort in a short time frame. Table 3 explores the statistical precision afforded by the slider task when estimating the effect of monetary incentives on effort provision. Column (1) repeats the fixed effects regression from Model (3) of Table 2. Column (2) shows the results of an OLS regression on the full sample of 600 subject-round observations. Column (3) shows the results of an OLS regression using one randomly selected observation per subject.

The three regressions reported in Table 3 deliver similar estimates of the effect of the prize on effort provision. However, comparing precision in Column (1) to that in Column (2) highlights the importance of being able to apply panel data methods to the high-quality repeated observations of effort generated by the slider task. The OLS regression on the full sample of 600 subject-round observations in Column (2) is inefficient compared to the fixed effects regression in Column (1): reflecting this, the standard error of the prize effect in Column (2) is substantially higher than that in Column (1) (0.240 versus 0.157). The reason for this loss of efficiency is that the OLS regression in Column (2) does not use the repeated observations of effort at the individual level to account for persistent unobserved heterogeneity when obtaining parameter estimates.

⁸The F statistic for the null hypothesis that the round trend is linear is 3.30, which corresponds to a p -value of 0.004. Thus round effects are non-linear. However, we are unable to reject linearity of the round effects starting from round 4: the F statistic for the null hypothesis that the round trend is linear from round 4 onward is 1.61 with a p -value of 0.160.

⁹We investigated the linearity of the prize effect by running a further regression (not reported) that also included the square of the prize. The results show that the square of the prize is not a statistically significant determinant of effort: the two-sided p -value for the coefficient on the square of the prize is 0.121. Effort therefore appears to increase linearly with the prize.

	(1)	(2)	(3)
Prize	-	-	0.671*** (0.157)
Round number	0.434*** (0.084)	-	-
Round 2	-	0.483 (0.557)	0.404 (0.540)
Round 3	-	2.600*** (0.545)	2.498*** (0.565)
Round 4	-	2.417*** (0.562)	2.286*** (0.567)
Round 5	-	2.983*** (0.694)	2.823*** (0.682)
Round 6	-	2.467*** (0.797)	2.481*** (0.766)
Round 7	-	3.717*** (0.540)	3.694*** (0.516)
Round 8	-	4.683*** (0.686)	4.676*** (0.682)
Round 9	-	3.450*** (1.079)	3.482*** (1.044)
Round 10	-	4.117*** (0.754)	4.355*** (0.767)
Intercept	22.504*** (0.620)	22.200*** (0.466)	20.894*** (0.508)
σ_α	5.494	5.494	5.491
σ_ϵ	3.971	3.938	3.873
Subject fixed effects	Yes	Yes	Yes
Subject-round observations	600	600	600
Subjects	60	60	60

Notes: σ_α denotes the standard deviation of the time-invariant subject-specific fixed effects and σ_ϵ is the standard deviation of the time-varying component of the subject-level error terms. Heteroskedasticity-robust standard errors with clustering at the subject level are reported in parentheses. *, ** and *** denote, respectively, significance at the 10%, 5% and 1% levels (two-sided tests).

Table 2: Fixed effects regressions for First Movers' efforts.

	(1)	(2)	(3)
Prize	0.671*** (0.157)	0.656*** (0.240)	0.660 (0.828)
Intercept	20.894*** (0.508)	20.923*** (0.893)	20.944*** (2.878)
Subject fixed effects	Yes	No	No
Round dummies	Yes	Yes	Yes
Subject-round observations	600	600	60
Subjects	60	60	60

Notes: Heteroskedasticity-robust standard errors with clustering at the subject level are reported in parentheses in Columns (1) and (2). Heteroskedasticity-robust standard errors are reported in parentheses in Column (3). *, ** and *** denote, respectively, significance at the 10%, 5% and 1% levels (two-sided tests).

Table 3: Further regressions of First Movers' efforts.

Furthermore, comparing precision in Column (1) of Table 3 to that in Column (3) illustrates the importance of collecting many observations per subject in a short time frame, which the slider task facilitates. When we use only one observation per subject in Column (3), precision falls dramatically: the standard error of the prize effect increases to 0.828, making the prize effect appear statistically insignificant.¹⁰

To summarize, effort provision responds positively to financial incentives, effort tends to increase over rounds, and the high-quality repeated observations of effort provision generated by the slider task allow us to use panel data methods to appreciably increase the precision of the statistical analysis.

6 Estimating the cost of effort at the subject level

In this section we show how to use the high-quality panel data on repeated effort choices from the slider task to estimate the cost of effort at the subject level. This exercise exploits within-subject variation in incentives across repetitions of the slider task.

We continue to focus on the sample of 60 First Movers, each of whom was observed for 10 rounds in our experiment. First Movers are indexed by $i = 1, \dots, 60$, and rounds are indexed by $r = 1, \dots, 10$. At the start of each round, each First Mover is informed of the prize for the round, $v_{i,r}$, which will be awarded to either the First Mover or her opponent. According to our experimental design, described above in Section 4, the First Mover's probability of winning the prize is given by:

$$\Pr(e_{i,r}, e'_{i,r}) = \left(\frac{e_{i,r} - e'_{i,r} + 50}{100} \right), \quad (1)$$

where $e_{i,r} \in \{0, \dots, 48\}$ is the effort of First Mover i in round r and $e'_{i,r} \in \{0, \dots, 48\}$ is the effort of First Mover i 's opponent in round r . We assume that the First Mover is risk neutral and chooses her effort to maximize her expected utility

$$Eu_{i,r} = \left(\frac{e_{i,r} - e'_{i,r} + 50}{100} \right) v_{i,r} - C_i(e_{i,r}), \quad (2)$$

where $C_i(\cdot)$ is First Mover i 's cost of effort function. We include the subscript i on the cost of effort function because the cost of effort may be heterogeneous across subjects. Motivated by the finding reported in footnote 9 that effort increases linearly with the prize, we assume a quadratic cost of effort function $C_i(e_{i,r}) = c_i e_{i,r}^2 / 2$ with $c_i > 0$.¹¹ We also assume that the First Mover believes that she cannot affect her opponent's effort. We then have the following

¹⁰We eliminate the noise from the random selection of one observation per subject by repeating the random selection process 2,000 times and reporting the average parameter estimates and average standard errors over the 2,000 repetitions.

¹¹In the data effort never reaches its maximum level of 48, and so we assume that $c_i > 0$.

expression for optimal effort provision:

$$e_{i,r}^* = \frac{v_{i,r}}{100c_i}. \quad (3)$$

We augment (3) to include an additive error term and then use non-linear least squares to estimate the subject-specific cost parameters $c_i > 0$ for $i = 1, \dots, 60$.¹² In particular, for each First Mover, we estimate the cost parameter, c_i , by minimizing the sum of squares:

$$\sum_{r=1}^{10} \left(e_{i,r} - \frac{v_{i,r}}{100c_i} \right)^2. \quad (4)$$

Our estimation results reveal substantial heterogeneity in the cost of effort parameter: the Gini coefficient for c_i is 0.16 and the 90:10 ratio for c_i is 1.67. To facilitate interpretation of these findings, Figure 5 illustrates the estimated cost of effort function for a subject at the 90th percentile of the distribution of c_i , a subject with the median value of c_i , and a subject at the 10th percentile of the distribution of c_i .

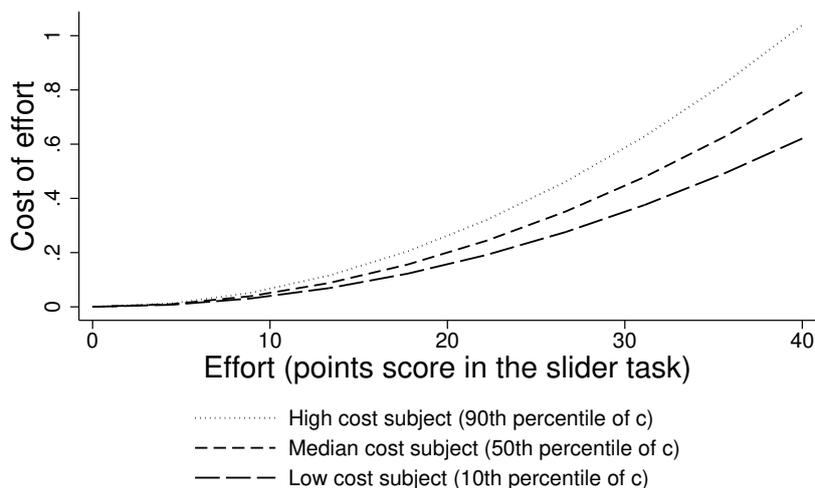


Figure 5: Heterogeneous effort costs.

Figure 6 shows how the estimated heterogeneity in costs translates into different levels of effort provision: at the average prize of £2, a subject at the 90th percentile of the distribution of c_i completes only 15 sliders, while a subject at the 10th percentile of the distribution of c_i completes around 26 sliders.

¹²Prior to estimation, we use the results from a regression of First Mover effort on a full set of round dummies to remove round effects from First Mover effort.

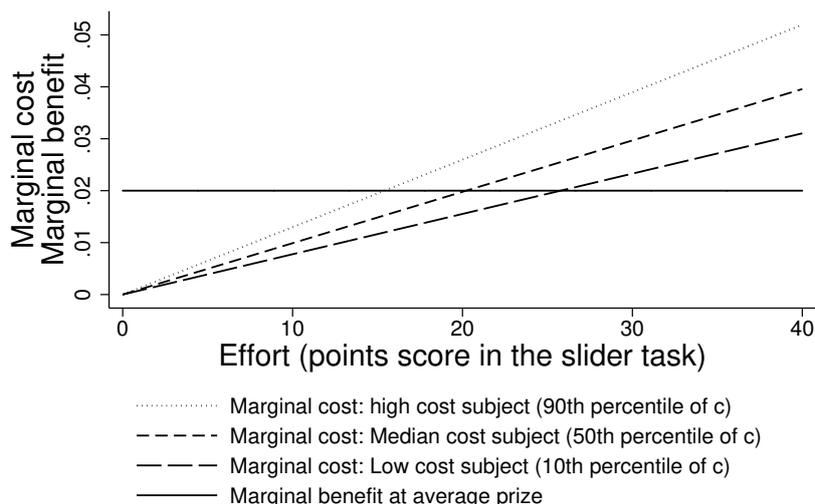


Figure 6: Heterogeneity in optimal effort provision.

7 A practical guide to using the slider task

This section provides a guide to researchers wishing to implement the slider task in the context of their own laboratory experiments. First, we describe the accompanying code, which allows researchers to implement easily the slider task in z-Tree (Fischbacher, 2007). We then list some practical considerations associated with the use of the slider task.

Code

The slider task was first developed and used by us in Gill and Prowse (2012) to study disappointment aversion.¹³ To help readers create real effort laboratory experiments that use the slider task, we have created a z-Tree code file that provides an implementation of the real effort slider task. The code accompanies this paper online (see footnote 4). The code provided takes the form of a .ztt file and should be run in z-Tree. The code consists of a single file, named GillProwseSliderExample.ztt. This is a z-Tree treatment file. The program implements the slider task for a single subject, with the number of rounds set to one. This code can easily be embedded into an experimental design in which a real effort task is required. Indeed, the code is based on the code used to program the real effort task in the repeated sequential-move tournament of Gill and Prowse (2012). The treatment GillProwseSliderExample.ztt consists of three stages:

Stage 1 The subject is shown a screen informing her that the task is about to start. This screen is displayed for 5 seconds and then the program automatically moves to stage 2.

Stage 2 The subject is shown a screen displaying 48 sliders. The round number and the remaining time are shown at the very top of the screen, and between this information and the sliders there is a banner displaying the subject's current points score, i.e., the number

¹³We also use the slider task in Gill et al. (2013) and Gill and Prowse (2014). Section 1 lists a number of other studies that have used the slider task.

of sliders currently positioned at exactly 50. This screen is displayed for 120 seconds and then the program automatically moves to stage 3.

Stage 3 The subject is shown a screen displaying her points score in the task. This screen is displayed for 20 seconds and then the program automatically ends.

We now give some more detail about this treatment. Prior to the treatment commencing a number of variables are created in the Background. First, the variable **Effort** is created. At any point during the treatment this variable equals the number of sliders currently positioned at exactly 50. Second, we create a set of 48 variables, denoted **qx** for $x = 1, \dots, 48$. The variable **qx** is the current position of the x^{th} slider. Third, we create the variables **sx** for $x = 1, \dots, 48$. The variable **sx** takes the value one if the current position of the x^{th} slider is equal to 50 and zero otherwise. All variables are initialized to zero.

Each time the position of a slider is adjusted, the values of **qx** and **sx** associated with the particular slider in question are updated. The value of **Effort** is then updated, and the banner at the top of the screen is then refreshed to display the subject's new points score. The values of all the variables at the end of the 120 second task are stored in the Subjects table, and can be accessed at later stages.

Practical advice and guidance

Screen size

The average time taken to position a slider at exactly 50 depends on the size of the screen on which the task is displayed. We used relatively large screens, specifically 22 inch widescreen monitors with a 1680 by 1050 pixel resolution. 48 sliders and a 120 second task length was an appropriate configuration given the hardware employed, but may need adjusting if run on a different set-up. We believe that with our configuration it is impossible for any subject to position correctly all of the sliders (see Section 5). This ensures that the subject's effort choice is not constrained by the design of the task, so there is no incentive to work hard for the purpose of being able to rest at the end of the task.

Mice and keyboards

To treat all subjects equally, they should use the same specification of mouse. Our subjects used 800 dpi USB mice with the scroll wheel disabled (by removing them from the mice) to prevent subjects from using the scroll wheel to position the sliders. (Using the scroll wheel makes positioning the sliders much easier and requires less effort than a dragging and dropping technique using the left mouse button). Christopher Zeppenfeld (Cologne Graduate School) has kindly informed us that it is also possible to use an AutoHotKeys script in conjunction with z-Tree to disable the scroll wheel. Similarly, the keyboards were also disabled (by unplugging them) to prevent the subjects using the arrow keys to position the sliders. As well as dragging and dropping, it is possible to move the sliders in large fixed discrete steps by clicking the left mouse button with the cursor to the right or left of the current slider position. We did not point

this out explicitly to our subjects, but told them that they could use the mouse in any way they liked to move the sliders.

Physical space and other environmental factors

Given subjects are being asked to complete a real effort task it is important that they all have the same amount of physical space, i.e., all the booths are the same size, and that all subjects have the same equipment, e.g., mouse mats, chairs etc.

Practice rounds

Practice rounds, with the opportunity for questions at the end of each round, are recommended to allow subjects to become familiar with the task. We used two practice rounds.

8 Conclusion

This paper describes the properties and advantages of the real effort slider task. The task was designed by us to overcome many of the drawbacks of real effort tasks. In particular, our slider task provides a precise finely gradated measure of effort provision in a short time frame and, therefore, can be repeated many times in an experimental session. As we explained in detail above, the resulting high-quality panel data allow the experimenter to: (i) estimate the cost of effort at the subject level; and (ii) increase precision by controlling for unobserved heterogeneity. The paper provides direction to experimental economists who are considering how to implement costly activities in their own experiments. We also provide z-Tree code and practical guidance to help researchers implement the slider task in the laboratory.

References

- Abeler, J., Falk, A., Goette, L., and Huffman, D.** (2011). Reference points and effort provision. *American Economic Review*, 101(2): 470–492
- Abeler, J. and Jäger, S.** (2015). Complex tax incentives. *American Economic Journal: Economic Policy*, 7(3): 1–28
- Ahlquist, J.S., Hamman, J., and Jones, B.** (2014). Dependency status and social insurance: An experimental investigation. *Mimeo, University of Wisconsin*
- Avram, S.** (2015). Benefit losses loom larger than taxes: The effects of framing and loss aversion on behavioural responses to taxes and benefits. Technical report, ISER Working Paper Series
- Besley, T. and Ghatak, M.** (2017). Profit with purpose? A theory of social enterprise. *American Economic Journal: Economic Policy*, 9(3): 19–58
- Bonein, A. and Denant-Boèmont, L.** (2015). Self-control, commitment and peer pressure: A laboratory experiment. *Experimental Economics*, 18(4): 543–568

- Bradler, C., Neckermann, S., and Warnke, A.J.** (2015). Incentives and creativity. *Mimeo, ZEW Centre for European Economic Research*
- Breuer, L.** (2013). Tax compliance and whistleblowing – The role of incentives. *Bonn Journal of Economics*, 2(2): 7–45
- Brown, A.L., Meer, J., and Williams, J.F.** (2013). Why do people volunteer? An experimental analysis of preferences for time donations. *NBER Working Paper 19066*
- Brown, A.L., Meer, J., and Williams, J.F.** (2017). Social distance and quality ratings in charity choice. *Journal of Behavioral and Experimental Economics*, 66: 9–15
- Bull, C., Schotter, A., and Weigelt, K.** (1987). Tournaments and piece rates: An experimental study. *Journal of Political Economy*, 95(1): 1–33
- Burrows, P. and Loomes, G.** (1994). The impact of fairness on bargaining behaviour. *Empirical Economics*, 19: 201–221
- Cettolin, E. and Riedl, A.** (2016). Justice under uncertainty. *Management Science*, 63(11): 3739–3759
- Charness, G., Masclet, D., and Villeval, M.C.** (2014). The dark side of competition for status. *Management Science*, 60(1): 38–55
- Chow, C.W.** (1983). The effects of job standard tightness and compensation scheme on performance: An exploration of linkages. *Accounting Review*, 58: 667–685
- Cooper, R., DeJong, D., Forsythe, R., and Ross, T.** (1996). Cooperation without reputation: Experimental evidence from prisoner’s dilemma games. *Games and Economic Behavior*, 12: 187–218
- Das, A., Liang, J., Liu, Y., and Xu, H.** (2013). Other-regarding or self-fulfilling – An experiment on working after disappointment. *SSRN Working Paper 2180813*
- Depoorter, B. and Tontrup, S.** (2012). How law frames moral intuitions: The expressive effect of specific performance. *Arizona Law Review*, 54: 673–717
- Dickinson, D.L.** (1999). An experimental examination of labor supply and work intensities. *Journal of Labor Economics*, 17(4): 638–670
- Djawadi, B.M. and Fahr, R.** (2013). The impact of tax knowledge and budget spending influence on tax compliance. *IZA Discussion Paper 7255*
- Djawadi, B.M., Fahr, R., and Turk, F.** (2014). Conceptual model and economic experiments to explain nonpersistence and enable mechanism designs fostering behavioral change. *Value in Health*, 17(8): 814–822
- Doerrenberg, P. and Duncan, D.** (2014a). Distributional implications of tax evasion: Evidence from the lab. *Public Finance Review*, 42(6): 720–744
- Doerrenberg, P. and Duncan, D.** (2014b). Experimental evidence on the relationship between tax evasion opportunities and labor supply. *European Economic Review*, 68: 48–70

- Doerrenberg, P., Duncan, D., and Zeppenfeld, C.** (2015). Circumstantial risk: Impact of future tax evasion and labor supply opportunities on risk exposure. *Journal of Economic Behavior and Organization*, 109: 85–100
- Dolan, P., Metcalfe, R., and Navarro-Martinez, D.** (2012). Financial incentives and working in the education sector. *Department for Education Research Report DFE-RR251*
- Dorough, A.R., Leszczyńska, M., Barreto, M., and Glöckner, A.** (2016). Revealing side effects of quota rules on group cooperation. *Journal of Economic Psychology*, 57: 136–152
- Drzensky, F. and Heinz, M.** (2016). The hidden costs of downsizing. *Economic Journal*, 126(598): 2324–2341
- Eacret, N.D., Lafferty, N.C., and Jhunjhunwala, T.** (2011). When is inequality fair? *Mimeo, University of Texas at Dallas*
- Erkal, N., Gangadharan, L., and Nikiforakis, N.** (2011). Relative earnings and giving in a real-effort experiment. *American Economic Review*, 101(7): 3330–3348
- Evdokimov, P. and Rahman, D.** (2014). Personality and bargaining power. *Mimeo, University of Minnesota*
- Fahr, R. and Djawadi, B.H.** (2013). The impact of risk perception and risk attitudes on corrupt behavior: Evidence from a petty corruption experiment. *IZA Discussion Paper, No. 7383*
- Fahr, R. and Irlenbusch, B.** (2000). Fairness as a constraint on trust in reciprocity: Earned property rights in a reciprocal exchange experiment. *Economics Letters*, 66(3): 275–282
- Falk, A. and Fehr, E.** (2003). Why labour market experiments? *Labour Economics*, 10(4): 399–406
- Fan, L. and Zhao, J.** (2014). Social identity and the theoretical justification of recusation system. *SSRN Working Paper 2519264*
- Feess, E., Lorz, O., and Schramm, M.** (2014). Under-delegation in case of pure moral hazard: Evidence from the laboratory. *SSRN Working Paper 2464908*
- Fehr, E., Gächter, S., and Kirchsteiger, G.** (1997). Reciprocity as a contract enforcement device: Experimental evidence. *Econometrica*, 65(4): 833–860
- Fischbacher, U.** (2007). z-Tree: Zurich toolbox for ready-made economic experiments. *Experimental Economics*, 10(2): 171–178
- Fonseca, M.A. and Myles, G.** (2012). Experimental evidence on taxpayer compliance: Evidence from students and taxpayers. *Her Majesty's Revenue and Customs Research Report 198*
- Friedl, A., Neyse, L., and Schmidt, U.** (2014). Payment scheme changes and effort provision: The effect of digit ratio. *MPRA Working Paper 59549*
- Gärtner, M. and Sandberg, A.** (2014). Omission effects in fairness behavior. *SSE Working Paper in Economics 2014:1*

- Gee, L.K., Migueis, M., and Parsa, S.** (2017). Redistributive choices and increasing income inequality: experimental evidence for income as a signal of deservingness. *Experimental Economics*, 20(4): 894–923
- Georganas, S., Tonin, M., and Vlassopoulos, M.** (2015). Peer pressure and productivity: The role of observing and being observed. *Journal of Economic Behavior & Organization*, 117: 223–232
- Gerhards, L. and Siemer, N.** (2014). Private versus public feedback - The incentive effects of symbolic awards. *Aarhus Economics Working Paper 2014-01*
- Gill, D. and Prowse, V.** (2012). A structural analysis of disappointment aversion in a real effort competition. *American Economic Review*, 102(1): 469–503
- Gill, D. and Prowse, V.** (2014). Gender differences and dynamics in competition: The role of luck. *Quantitative Economics*, 5(2): 351–376
- Gill, D., Prowse, V., and Vlassopoulos, M.** (2013). Cheating in the workplace: An experimental study of the impact of bonuses and productivity. *Journal of Economic Behavior and Organization*, 96: 120–134
- Gneezy, U., Niederle, M., and Rustichini, A.** (2003). Performance in competitive environments: Gender differences. *Quarterly Journal of Economics*, 118: 1049–1074
- Goerg, S.J., Kube, S., and Radbruch, J.** (2017). The effectiveness of incentive schemes in the presence of implicit effort costs. *IZA Discussion Paper 10546*
- Hammermann, A., Mohnen, A., and Nieken, P.** (2011). Whom to choose as a team mate? A lab experiment about in-group favoritism. *IZA Discussion Paper 6286*
- Hetzel, S.** (2010). The impact of financial incentives on individual performance: An experimental approach. *Diplomarbeit, University of Mannheim*
- Hoffman, E., McCabe, K., Shachat, K., and Smith, V.** (1994). Preferences, property rights, and anonymity in bargaining games. *Games and Economic Behavior*, 7: 346–380
- Ibanez, M. and Schaffland, E.** (2013). The effect of outside leaders on the performance of the organization: An experiment. *Courant Research Centre Discussion Paper 149*
- Imas, A., Sadoff, S., and Samek, A.** (2016). Do people anticipate loss aversion? *Management Science*, 63(5): 1271–1284
- Kesternich, M., Lange, A., and Sturm, B.** (2018). On the performance of rule-based contribution schemes under endowment heterogeneity. *Experimental Economics*, 21(1): 180–204
- Khadjavi, M.** (2014). On the interaction of deterrence and emotions. *Journal of Law, Economics, & Organization*, 31(2): 287–319
- Kimbrough, E.O. and Reiss, J.P.** (2012). Measuring the distribution of spitefulness. *Plos ONE*, 7(8): 1–8

- Kirchler, M., Bonn, C., Huber, J., and Razen, M.** (2014). The inflow-effect: Trader inflow and bubble formation in asset markets. *Working Papers in Economics and Statistics 2014-22, University of Innsbruck*
- Konow, J.** (2000). Fair shares: Accountability and cognitive dissonance in allocation decisions. *American Economic Review*, 90(4): 1072–1091
- Lee, J.** (2015). How does competition affect people economically and emotionally? *Mimeo, Cornell University*
- Lezzi, E.** (2014). Agents' performance and emotions: An experimental investigation. *Doctoral Dissertation, University of East Anglia*
- Lindner, F.** (2014). Decision time and steps of reasoning in a competitive market entry game. *Economics Letters*, 122(1): 7–11
- Malik, S., Mihm, B., and Timme, F.** (2018). An experimental analysis of tax avoidance policies. *International Tax and Public Finance*, 25(1): 200–239
- Meissner, T. and Pfeiffer, P.** (2017). Measuring preference over the temporal resolution of consumption uncertainty. *SSRN Working Paper 2654668*
- Monahan, J.** (2012). We're all Lockean now: A test of the prevalence of just-desert considerations in a dictator game experiment. *M.Phil. Thesis, University of Oxford*
- Niederle, M. and Vesterlund, L.** (2007). Do women shy away from competition? Do men compete too much? *Quarterly Journal of Economics*, 122(3): 1067–1101
- Riener, G. and Wiederhold, S.** (2013). Heterogeneous treatment effects in groups. *Economics Letters*, 120(3): 408–412
- Riener, G. and Wiederhold, S.** (2016). Team building and hidden costs of control. *Journal of Economic Behavior & Organization*, 123: 1–18
- Schmitz, J.** (2014). One good deed a day? *SSRN Working paper 2538410*
- Smith, J.** (2016). The motivational effects of mission matching: A lab-experimental test of a moderated mediation model. *Public Administration Review*, 76(4): 626–637
- Straub, T., Gimpel, H., Teschner, F., and Weinhardt, C.** (2014). Feedback and performance in crowd work: A real effort experiment. *Mimeo, Karlsruhe Institute of Technology*
- Sutter, M. and Weck-Hannemann, H.** (2003). Taxation and the veil of ignorance - A real effort experiment on the Laffer curve. *Public Choice*, 115: 217–240
- Teng, J.C.Y., Wang, J.T.Y., and Yang, C.C.** (2014). Primary social goods and the Rawlsian difference principle. *Mimeo, National Taipei University*
- van Dijk, F., Sonnemans, J., and van Winden, F.** (2001). Incentive systems in a real effort experiment. *European Economic Review*, 45(2): 187–214
- Zeppenfeld, C.** (2015). *Decisions under Uncertainty: Preferences, Institutions, and Social Interaction*. Ph.D. thesis, Universität zu Köln

Supplementary Web Appendix

(Intended for Online Publication)

Supplementary Web Appendix I: Experimental Instructions

Please open the brown envelope you have just collected. I am reading from the four page instructions sheet which you will find in your brown envelope. [**Open brown envelope**]

Thank you for participating in this session. There will be a number of pauses for you to ask questions. During such a pause, please raise your hand if you want to ask a question. Apart from asking questions in this way, you must not communicate with anybody in this room. Please now turn off mobile phones and any other electronic devices. These must remain turned off for the duration of this session. Are there any questions?

You have been allocated to a computer booth according to the number on the card you selected as you came in. You must not look into any of the other computer booths at any time during this session. As you came in you also selected a white sealed envelope. Please now open your white envelope. [**Open white envelope**]

Each white envelope contains a different four digit Participant ID number. To ensure anonymity, your actions in this session are linked to this Participant ID number and at the end of this session you will be paid by Participant ID number. You will be paid a show up fee of £4 together with any money you accumulate during this session. The amount of money you accumulate will depend partly on your actions, partly on the actions of others and partly on chance. All payments will be made in cash in another room. Neither I nor any of the other participants will see how much you have been paid. Please follow the instructions that will appear shortly on your computer screen to enter your four digit Participant ID number. [**Enter four digit Participant ID number**] Please now return your Participant ID number to its envelope, and keep this safe as your Participant ID number will be required for payment at the end.

This session consists of 2 practice rounds, for which you will not be paid, followed by 10 paying rounds with money prizes. In each round you will undertake an identical task lasting 120 seconds. The task will consist of a screen with 48 sliders. Each slider is initially positioned at 0 and can be moved as far as 100. Each slider has a number to its right showing its current position. You can use the mouse in any way you like to move each slider. You can readjust the position of each slider as many times as you wish. Your “points score” in the task will be the number of sliders positioned at exactly 50 at the end of the 120 seconds. Are there any questions?

Before the first practice round, you will discover whether you are a “First Mover” or a “Second Mover”. You will remain either a First Mover or a Second Mover for the entirety of this session.

In each round, you will be paired. One pair member will be a First Mover and the other will be a Second Mover. The First Mover will undertake the task first, and then the Second Mover will undertake the task. The Second Mover will see the First Mover’s points score before starting the task.

In each paying round, there will be a prize which one pair member will win. Each pair’s prize will be chosen randomly at the beginning of the round and will be between £0.10 and

£3.90. The winner of the prize will depend on the difference between the First Mover's and the Second Mover's points scores and some element of chance. If the points scores are the same, each pair member will have a 50% chance of winning the prize. If the points scores are not the same, the chance of winning for the pair member with the higher points score increases by 1 percentage point for every increase of 1 in the difference between the points scores, while the chance of winning for the pair member with the lower points score correspondingly decreases by 1 percentage point. The table at the end of these instructions gives the chance of winning for any points score difference. Please look at this table now. [**Look at table**] Are there any questions?

During each task, a number of pieces of information will appear at the top of your screen, including the time remaining, the round number, whether you are a First Mover or a Second Mover, the prize for the round and your points score in the task so far. If you are a Second Mover, you will also see the points score of the First Mover you are paired with.

After both pair members have completed the task, each pair member will see a summary screen showing their own points score, the other pair member's points score, their probability of winning, the prize for the round and whether they were the winner or the loser of the round.

We will now start the first of the two practice rounds. In the practice rounds, you will be paired with an automaton who behaves randomly. Before we start, are there any questions? Please look at your screen now. [**First practice round**] Before we start the second practice round, are there any questions? Please look at your screen now. [**Second practice round**] Are there any questions?

The practice rounds are finished. We will now move on to the 10 paying rounds. In every paying round, each First Mover will be paired with a Second Mover. The pairings will be changed after every round and pairings will not depend on your previous actions. You will not be paired with the same person twice. Furthermore, the pairings are done in such a way that the actions you take in one round cannot affect the actions of the people you will be paired with in later rounds. This also means that the actions of the person you are paired with in a given round cannot be affected by your actions in earlier rounds. (If you are interested, this is because you will not be paired with a person who was paired with someone who had been paired with you, and you will not be paired with a person who was paired with someone who had been paired with someone who had been paired with you, and so on.) Are there any questions?

We will now start the 10 paying rounds. There will be no pauses between the rounds. Before we start the paying rounds, are there any remaining questions? There will be no further opportunities to ask questions. Please look at your screen now. [**10 paying rounds**]

The session is now complete. Your total cash payment, including the show up fee, is displayed on your screen. Please leave the room one by one when asked to do so to receive your payment. Remember to bring the envelope containing your four digit Participant ID number with you but please leave all other materials on your desk. Thank you for participating.

Difference in points scores	Chance of winning prize for Mover with higher score	Chance of winning prize for Mover with lower score
0	50%	50%
1	51%	49%
2	52%	48%
3	53%	47%
4	54%	46%
5	55%	45%
6	56%	44%
7	57%	43%
8	58%	42%
9	59%	41%
10	60%	40%
11	61%	39%
12	62%	38%
13	63%	37%
14	64%	36%
15	65%	35%
16	66%	34%
17	67%	33%
18	68%	32%
19	69%	31%
20	70%	30%
21	71%	29%
22	72%	28%
23	73%	27%
24	74%	26%
25	75%	25%
26	76%	24%
27	77%	23%
28	78%	22%
29	79%	21%
30	80%	20%
31	81%	19%
32	82%	18%
33	83%	17%
34	84%	16%
35	85%	15%
36	86%	14%
37	87%	13%
38	88%	12%
39	89%	11%
40	90%	10%
41	91%	9%
42	92%	8%
43	93%	7%
44	94%	6%
45	95%	5%
46	96%	4%
47	97%	3%
48	98%	2%
49	Not possible as there are only 48 sliders	
50	Not possible as there are only 48 sliders	

Table SWA.1: Chance of winning in a given round.