Minimizing Learning Behavior in Experiments with Repeated Real-Effort Tasks*

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Abstract

In this paper, we introduce a new real-effort task which mitigates learning behavior in repeated real-effort tasks. In our task, participants need to encode three-letter words into numbers. The task is based on Erkral et al. (2011), however, in our version a double-randomization mechanism is applied to minimize learning. Existing experiments using repeated real-effort tasks report an increase of 15-30% in subjects' performance in the course of the experiment. By contrast, we find that when comparing performance in the first period with the last period, our task mitigates learning behavior down to 8%. The difference between the first and second half of the experiment is only about 3%.

JEL Classification numbers: C90, C91.

Keywords: Experimental Methods, Learning Behavior, Real-Effort.

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1 Introduction

Setting parameters exogenously is a very common practice in Experimental Economics. For instance, this may apply to endowments subjects receive in the form of "Windfall" gains, or to the cost functions that are used in an experiment. Both examples document simplifications in the experimental design.[1] However, while such simplifications enhance the experimenter's control, they may also be considered unrealistic. In the field, people are rarely endowed with windfall money and their cost of exerting effort will hardly comply with mathematical formulae. Such experiments are therefore often criticized as artificial or as having only little external validity. One popular possibility to increase the external validity of Economic experiments are "Real-Effort" tasks where subjects exert realistic work for the profits they gain. This increase of external validity does, however, often come at the expense of the experimenter's control.

A possible application of real-effort tasks are repeated experiments where subjects' performance is the main variable of interest. Here, real-effort tasks may come with an undesirable side effect. It may be that participants' performance increases in later periods as subjects get more efficient at conducting the real-effort task. In other words, they may be able to use their experience from prior periods to perform better in later periods.[2] The reason is that many real-effort tasks are characterized by simple components, e.g., counting numbers (Abeler, et al. 2011), adjusting sliders (Gill and Prowse, 2011) or a fixed encryption table (Erkral et al., 2011). This may especially bias the results in within-subjects designs. Think of a repeated experiment with two parts where subjects' performance under a low and a high piece rate is compared. In this settings it may not be clear when subjects increase their performance, whether the reason was the higher piece rate or subjects learned to use the task.

[1]E.g., windfall profits may help to reduce or to increase the asymmetry in the endowments of different subjects. Furthermore, mathematical cost functions provide a direct measure allowing the experimenter to derive theoretical predictions easily.

[2]We differentiate two different types of learning in this paper: learning the game and learning the task. In this experiment we focus on minimizing the learning behavior in the task, i.e., the fact that subjects perform better in later periods. That is, subjects simply do a better job because they are more familiar with the task per se. In contrast, learning in a strategic game occurs when subjects get a better understanding of the payoff functions and of the strategic interaction. Such learning has for example been found for beauty contests (Nagel, 1995), Cournot markets (Huck et al., 1999), or public-good games (e.g., Fehr and Gächter, 2000). The latter should not be affected by our randomization features.

In this paper we present a new task which minimizes learning behavior in repeated real-effort tasks. It builds on Erkral et al.'s (2011) word-encryption task where subjects encode combinations of letters to numbers. The innovation of our task is a double-randomization mechanism where the letter- and number allocation is shuffled whenever a puzzle is correctly solved. Moreover, the task also shuffles the position of the letters. We report data of a repeated experiment with 10 periods which shows that the task minimizes learning. When comparing the performance in periods 1-5 to periods 6-10 we find that subjects only increase their performance by 3%. A moderate increase of 8% can be found when comparing the performance in period 1 with the final period.

2 Learning in real-effort tasks

In this section we briefly review popular real-effort tasks and the learning behavior of subjects in these tasks. We restrict our review to tasks where we found papers reporting data of repeated tasks.

2.1 Counting Numbers Task

Abeler et al. (2011) introduce a z-Tree based task where subjects receive a grid full of numbers and have to count the occurrence of the number one.[3] After subjects have entered an answer they receive a new puzzle. The task counts the number of correctly solved puzzles. Table 1 displays an example of a possible grid.

110110100110010
010110000110101
111010000101010
101000011001011
001001101010001

Table 1: Schematic representation of a counting-numbers puzzle

Vranceanu et al. (2013) apply the task in a repeated setting with four periods. Instead of counting zeros, subjects in their task have to count sevens. In each period subjects were given 240 seconds to solve puzzles. Table 2 illustrates Vranceanu et al.'s (2013) data of the average performance in the four periods.

[3] There also exist other versions where subjects have to count different numbers. For instance Vranecanu et al. (2013) let subjects count sevens.

	period			
	1	2	3	4
mean	7.7	8.7	10.3	10.8

Table 2: mean of correctly counted sevens (Vranceanu et al., 2013)

The table shows that subjects always increase their performance. Participants solve on average 7.7 puzzles in period 1. Whereas their performance is 10.8 in period 4. Subjects thus show a pronounced learning behavior of 29%.

Advantages of the Counting Numbers Task

The Counting Numbers Task is very simple to understand and to implement. It does not require preexisting knowledge. Furthermore the task is tedious and may thus adequately resemble work effort.

2.2 The Slider Task

Gill and Prowse (2011) propose a z-Tree based real-effort task where subjects are asked to adjust sliders to the middle of a slider bar. A screen typically consists of 48 sliders. The authors arranged the sliders in a way that no slider is exactly placed under another one. This may also weaken learning behavior. Sliders can be adjusted by mouse clicks. A counter displays the cursor's position whenever it is moved. A puzzle is only correctly solved when the slider has exactly been adjusted to the middle of the bar, i.e., the cursor is placed at position 50. One period lasted 120 seconds. Figure 1 displays a slider's initial position as well as the position where it has to be set to.

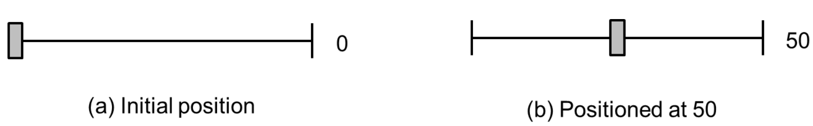

Figure 1: Schematic representation of a slider

Table 3 reports their findings. The data shows an ongoing increase in performance in the course of the game.

Focusing on the first half of the experiment (periods 1-5), the data shows that subjects on average solve 23.89 sliders. Whereas, the average performance is 25.88

	period									
	1	2	3	4	5	6	7	8	9	10
mean	22.20	22.68	24.80	24.61	25.18	24.66	25.91	26.88	25.65	26.31
sd	6.07	6.66	6.03	5.90	6.94	7.45	5.81	5.82	8.48	6.72

Table 3: mean of correctly adjusted Sliders in Gill and Prowse (2011)

in the second half (periods 6-10) of the experiment. Subjects therefore increase their performance by 8%. The data furthermore shows that subjects in period 1 solve 22.20 sliders, whereas they achieve 26.31 sliders in the final period. The latter corresponds to an increase of 16%. Subjects seem to develop their skills (how to move the mouse/ how to place the cursor) over time.

Advantages of the Slider Task

Although subjects show a learning behavior, it turns out that subjects learn at a lower level compared to the Counting Numbers Task. The task simple to communicate and to understand (Gill and Prowse, 2011). There is no scope for guessing. Benndorf, Clegg and Rau (2012) replicate their experiment and find no evidence for gender differences.

2.3 The Word Encryption Task

Erkral et al. (2011) present a word encryption task where subjects have to encode combinations of letters (words) to numbers. The numbers are given by an allocation table. A puzzle is correctly solved when the correct number of all letters was entered. Erkral et al. repeat the task in three parts of the experiment to endogenize money. Table 4 reports subjects' performance.

	part		
	1	2	3
mean	33.5	41.3	46.8

Table 4: mean of correctly solved words (Erkral et al., 2011)

The data shows that subjects increase their performance from part 1 to part 3 by 28%. Subjects seem to show a learning behavior over time. This can be due to the fact that they memorize the letter and number allocations. Furthermore it may play a role that subjects remember the positions of the letters in the table.

Advantages of the Word Encryption Task

Subjects in this task do not need any preexisting knowledge. The task is very simple and easy to communicate to the subjects. It can be processed in z-Tree without having performance problems (i.e., screen freezing etc.), even with a high number of participants. There is nearly no scope for guessing.

2.4 Other popular tasks

In Experimental Economics there exists many other popular task. However, since we could not find data of subjects' performance in repeated settings of these tasks (i.e., whether learning plays a role) we do not present these data. One reason might be that these tasks were developed for different purposes, i.e., to endogenize endowments (e.g., Cherry et al., 2002; 2008; Heinz et al., 2012) or to test for the willingness to compete (Niederle and Vesterlund, 2007; 2010).[4] Here, we briefly review these tasks.

Cherry et al. (2002) use a real-effort task to endogenize money in dictator games. Therefore dictators solve quiz questions from the *Graduate Record Examination* (*GRE*) test. A threshold (minimum amount of correctly solved questions) determined whether subjects receive a low/high endowment. The advantage of the task is, that it can be easily used as "pen-and-paper" version. However, the processing usually takes up a lot of time. The reason is that most of the single questions cannot be answered quickly.

Niederle and Vesterlund (2007) introduce a z-Tree based math task. The goal is to add up five two-digit numbers.[5] Subjects have to calculate the sum of the presented numbers by using scratch paper. Table 5 presents the input field of the task.

The task is computerized and therefore easy to evaluate. Subjects furthermore do not need preexisting knowledge. There is evidence that sometimes performance

[4]Gneezy et al. (2003) analyze with a one-period real-effort task gender differences in performances under different payment regimes.

[5]Usually the task is used to analyze whether men/women prefer to work under competitive (tournament) or non-competitive (piece rate) remuneration scheme.

58	83	76	13	85	

Table 5: Example of a problem in the real-effort task

problems may exist (e.g., the z-Tree clock runs not always synchronous.).

Gneezy et al. (2003) use another computerized task where subjects have to find the way out of a maze. The authors use this task to analyze gender differences under different remuneration schemes. The advantages are that the task is on-line available at "Yahoo.com" and subjects do not need preexisting knowledge. As the task is not connected to z-Tree, assistants are needed to record subjects' performance.

3 Experimental Design

We introduce a new real-effort task which extends Erkral et al. (2011).[6] The z-Tree code (in English language) can be downloaded at:
http://www.holger-rau.de/task/wedr.ztt.[7]

Subjects in the task have to encrypt combinations of three letters (words) into three-digit numbers (see Table 6). Participants are presented two rows: one which displays a word to encrypt ("word") and another one where the solution has to be entered ("code"). Below they find an encryption table (see next page) which allocates numbers to letters. The grid always displays all 26 capital letters of the German alphabet except mutations.[8] Subjects have to type in the correct three-digit numbers of each letter in the "code" row below the letter.

word:	**Z**	**N**	**T**

code:	113	154	

[6]Other papers applying the task are for instance: Cason et al. (2010), Nikiforakis et al. (2012), and McDonald et al. (2013).

[7]We friendly ask all people using the WEDR task to cite this paper.

[8]For reasons of space only 15 allocations are presented in the example of Table 6.

encryption table:

B	T	R	S	U	Z	F	N	C	Y	V	X	H	Y	K
384	118	201	543	386	113	980	154	745	265	432	262	110	960	245

Table 6: Example of a problem in the real-effort task.

After all three letters are encoded the subjects press a submit button and are informed about whether the puzzle was correctly solved. They also get information about the total number of correctly solved puzzles in the current period. However, while doing the real-effort task subjects receive no information on the total payoff they earned so far.

The allocation table randomly allocates a new number to all letters whenever subjects have correctly encoded a word. At the same time the positions of all letters are randomly re-arranged. This double randomization is a special feature of our task. The idea is that these mechanisms prevent subjects from learning behavior.[9] We thus call our task *Word Encryption task with Double Randomization* (henceforth: *WEDR* task).

When subjects enter a wrong answer they are informed by the computer program. Then, the number allocations and the locations of the letters will not be shuffled until subjects make a correct input. After the end of two minutes the real-effort task automatically stops and inputs are not possible anymore.[10] After the end of each period the computer program automatically proceeds to the next round. A further change in the *WEDR* task is, that our words only consist of three letters. Moreover, we do not use real words. Instead we let the computer program chose fictitious combinations of three letter combinations. We believe that this additionally complicates the task, which should additionally mitigate learning behavior.

Procedures

We conducted four sessions between December 2013 and March 2014. Each session comprised 32 participants. In total, we have 128 independent observations. The experiment was conducted in two parts of ten periods. Before the experiment started

[9]The data of Cason et al. (2011) shows that subjects in the original word-encryption task are prone to learning and thus increase their performance by 28%.

[10]The real-effort task only counts finalized inputs as correct, i.e., to increase the number of correctly solved puzzles a subject has to press the submit button before the two minutes are over.

subjects received a set of written instructions which explained the usage of the real-effort task. After all subjects confirmed that they understood the functioning of the task we started a trial period.[11] Here, the participants were asked to solve exactly 10 puzzles of the task without being paid. After all subjects successfully solved 10 puzzles, we provided them with a new set of instructions for the first part (periods 1-10). In the instructions it was explained that the experiment will consist of two parts and that the current instructions only cover the first part. The second part belongs to a second experiment where we study the impact of remuneration changes (Benndorf et al., 2014). Subjects were told that after the end of the first part they will get new instructions for the second part.[12] One period of the real-effort task lasted 2 minutes. On average the conduction of the first part lasted 35 minutes. We used z-Tree (Fischbacher, 2007) to run the experiment. The subject pool mainly consisted of Economic students which were recruited with ORSEE (Greiner, 2004). In the first part subjects earned on average 7.94 Euros.[13]

4 Results

We present the results in two parts. We first discuss the development over time of subjects' performance in our new task. Afterwards we conduct regression analyses controlling for the impact of demographics on subjects' performance in the task.

4.1 Word Encryption with Double Randomization (WEDR)

Figure 2 presents subjects' performance in periods 1-10 of the *WEDR* task. We present the average performance of each period in Table 8 in the Appendix.

The diagram includes the independent observations of 128 subjects.

On average participants solve 9.92 words correctly. The development of their performance is flat and it only moderately increases over time. We find that subjects show an average performance of 9.38 in period 1 and 10.18 in period 10. This corresponds to a moderate increase of 8%.

[11]The purpose of the trial period is to make subjects familiar with the task. This also promises to mitigate learning behavior.

[12]Subjects were only informed that a second part will follow. However, they received no information on the second part before it started.

[13]Subjects earned on average 15.94 Euros in both parts.

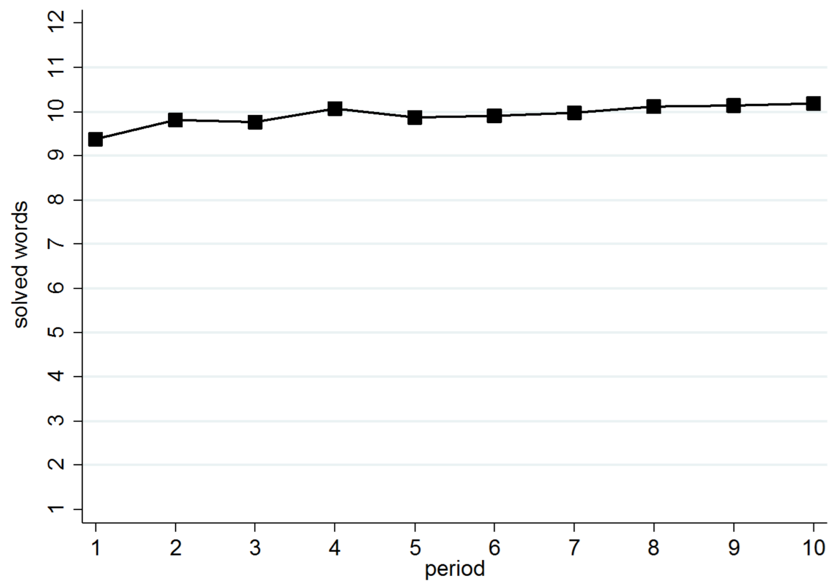

Figure 2: mean of correctly solved words

Figure 3 reports subjects' average performance in part 1 (periods 1-5) and part 2 (periods 6-10) of the experiment.

The diagram reveals a weak performance increase in the second part of the experiment (periods 6-10) when compared to the first part (periods 1-5). We find that subjects' performance is 9.77 in the first half, and 10.06 in the second half. The latter corresponds to a moderate performance increase of 3%. Although learning behavior is clearly mitigated, we find that the increase is significant (Wilcoxon matched-pairs test, $p < 0.001$). We summarize that the double randomization mechanism weakens subjects' learning behavior over time. Although the participants show a significantly higher performance in the second half, it can be concluded that the performance increase is small and thus it is not economically significant.

4.2 Regression Analysis

In this section we control with a regression analysis for the impact of different demographics on subjects' performance. We elicited the data in a post-experimental questionnaire.

Table 7 presents the results of an OLS regression model analyzing the impacts of different demographics on subjects' performance. The regression includes *female*, a dummy which is positive for female participants. Other independent variables

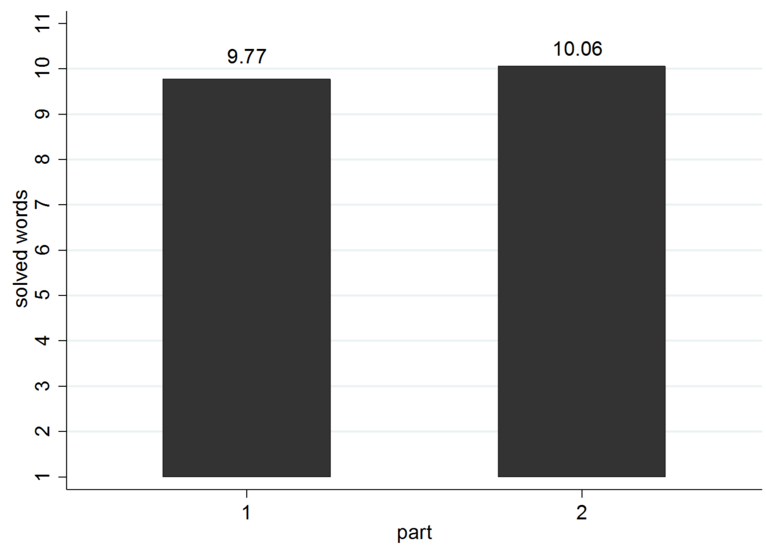

Figure 3: mean of correctly solved words

are: *age* which infers subjects' age, and *experience* which corresponds to the total number of experiment participations in our lab.[14] Furthermore *fun* is an independent variable which controls whether subjects who liked the task perform better. In the post-experimental survey they were asked to state on a Likert scale whether they liked the task (1 = not all; 10 = very much liked). *Period* analyzes learning behavior, i.e., it tests whether the average performance is increasing over time. Finally, *period squared* controls whether subjects' have a non-linear development of performance over time.

The regression shows that female is significant with a positive sign, i.e., women have a higher performance in the task.[15] We also find that there is no systematic learning of gender, i.e., men and women show the same learning behavior (men: 7%; women: 8%). The regression shows that *age* does not impact on performance. The same is true for *fun* which is also not significant. Importantly, subjects' experience does not have an effect on performance. Which again emphasizes that the task is also robust to potential learning advantages of experienced subjects. Moreover *period* is significant and positive. However, the coefficient is small. Interestingly, we find that *period squared* is weakly significant with a negative sign. The latter

[14] We elicited this number in a survey after the experiment. Here, subjects were asked to state how often they have participated in experiments so far.

[15] The average performance of men is 9.57, whereas women on average solve 10.26 puzzles correctly.

	average performance
female	0.618**
	(0.253)
age	0.003
	(0.036)
experience	0.039
	(0.029)
fun	0.076
	(0.048)
period	0.144***
	(0.045)
period squared	-0.007*
	(0.004)
constant	8.358***
	(0.925)
R^2	0.082
observations	1280

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 7: OLS regression on average performance.

suggests that subjects development of performance is not linear. Indeed the fact that *period* is positive and *period squared* is negative, confirms the previous finding that subjects in the beginning increase their performance. By contrast, after a while learning stops and subjects do not perform better.

Advantages of the WEDR task

The task also incorporates the advantages of Erkral et al.'s (2011) task, i.e., subjects do not need preexisting knowledge to understand it. It is a simple task which can be easily explained to subjects. There is no scope for guessing the results. Most importantly, we always run sessions where 32 participants simultaneously worked on the task. We could not find any evidence for performance problems, i.e., delays in the calculation of new grids or freezing screens. The double-randomization mechanism in the task seems to substantially mitigate learning behavior, i.e., it is appropriate to use it in within-subjects designs.

5 Conclusion

In this paper we present data of a new real-effort task. This word encryption task with double randomization builds on Erkral et al. (2011) and tackles to mitigate learning behavior in subjects' performance.

Although we find that subjects in the task still show a moderate performance increase over time, we conclude that the task minimizes learning behavior. Our experimental data documents that subjects show a slight increase of 3% in the second half of the experiment. Moreover, we observe an increase of 8% when comparing the period 1 performance with the performance in the final period. Comparing this to the performance in other real-effort tasks (which mainly do not focus on the elimination of learning), we are quite confident that this new task provides a helpful contribution in addressing the learning bias.

The results of the *WEDR* task have shown that applying modifications to complicate learning behavior in tasks, may help to overcome the potential learning biases in real-effort experiments. Therefore we believe that it is valuable to continue to think about additional improvements and new real-effort tasks to get appropriate new work horses for Experimental Economics.

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Appendix

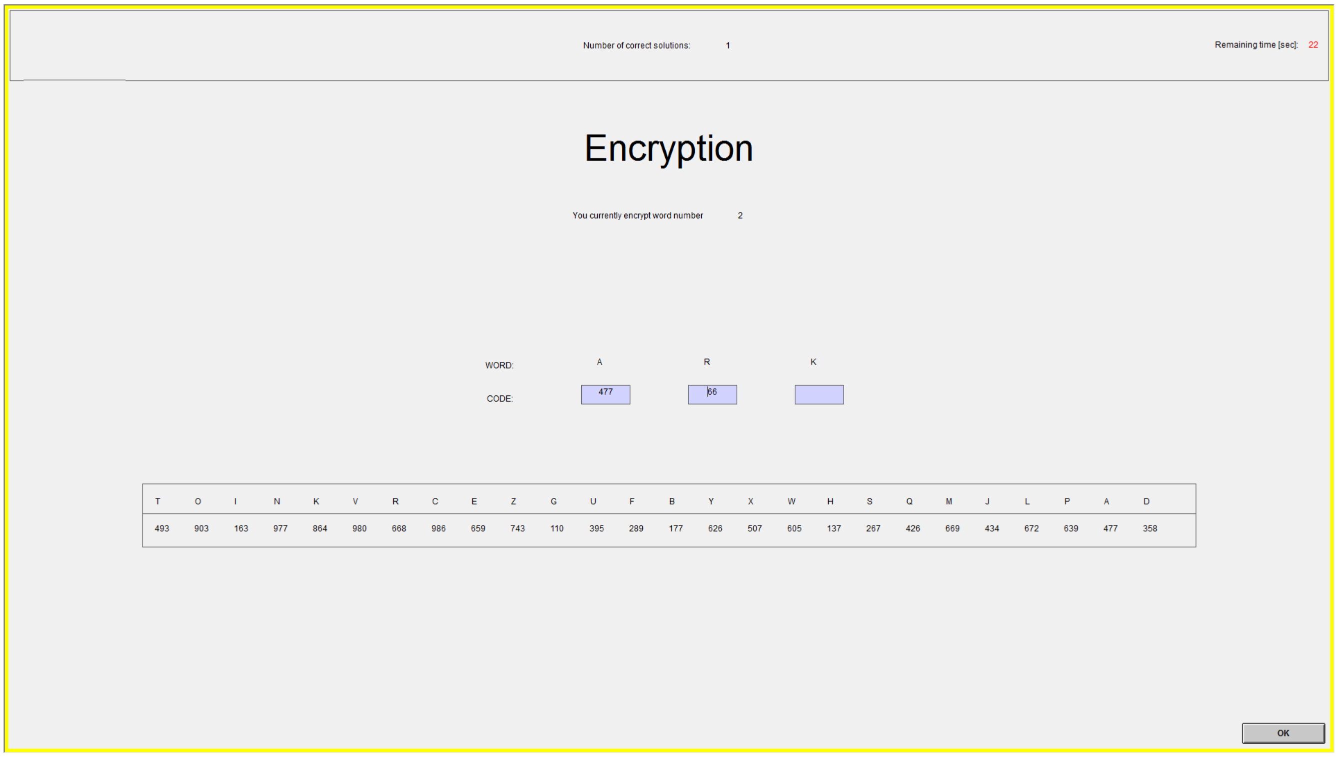


Figure 4: Screen shot of the WEDR task (Benndorf et al., 2014)

	period										
	1	2	3	4	5	6	7	8	9	10	overall
mean	9.37	9.80	9.76	10.06	9.87	9.90	9.98	10.12	10.14	10.18	9.92
sd	1.82	1.74	1.70	1.59	1.63	1.69	1.58	1.63	1.68	1.63	1.68

Table 8: mean of correctly solved words in the 10 periods of the WEDR task (Benndorf et al., 2014)

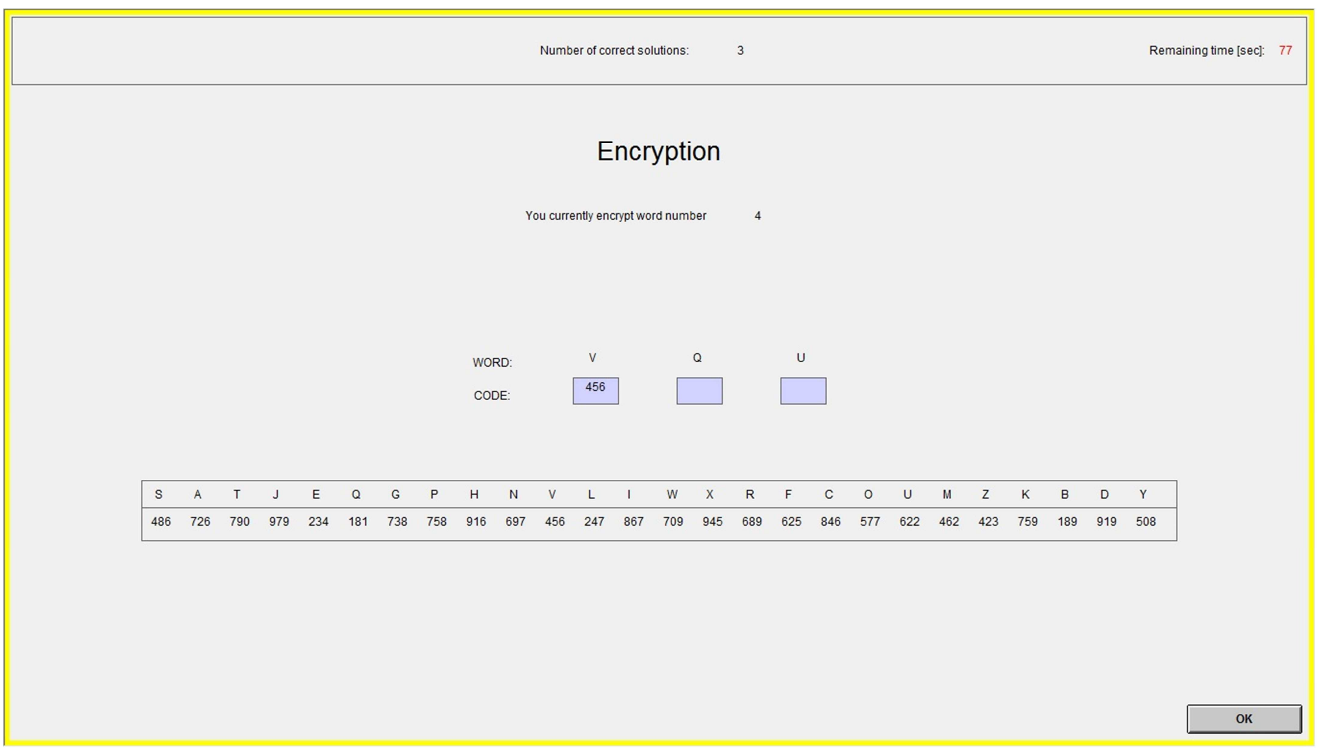
[not intended for publication]

Instructions to the experiment

In the following experiment you have the opportunity to earn money depending on your behavior. Please turn off your mobile phone and do not talk to other participants in the experiment. It is very important that you follow these rules. If you have any question while reading these instructions or during the experiment itself, we ask you to raise your hand. We will immediately come to your desk and answer your question individually.

1. General structure of the experiment

During the experiment you have the opportunity to do a task. The task consists of **encoding** combinations of letters **(words)** into numbers. In the task, **three capital letters** always yield a "word". You have to allocate a number to each capital letter. The encryption code can be found in a table below the corresponding letter. For that purpose, please consider the following screenshot:



In this example the participant has already encrypted three words correctly (see centered field: above). Here, the three capital letters: **"V", "Q" and "U"** have to be encoded. The solution follows immediately from the table:

- For “V” applies: 456 (see the current entry of the participant)
- For “Q” applies: 181
- For “U” applies: 622

To make an input please click on the blue box below the first capital letter.

<u>Important hints:</u>

- Please note that after having entered the three-digit number you can easily switch to the next blue box by using the **tabulator key** on your keyboard.

In the following picture you can see the position of the tabulator key on your keyboard:

- The input of the numbers can be performed faster by using the numpad (on the right) of your keyboard.

In the following picture you can see the position of the numpad on your keyboard:

Furthermore, the screen (see screenshot on page 1) provides the following information:

- “Number of correct solutions” = number of correctly encrypted words.
- “Remaining time [sec]” = remaining time in the current period.
- “You currently encrypt word number” = current word to encrypt.

If all 3 numbers have been entered, please click the “OK”

- The computer then checks whether **all** capital letters haven been encoded correctly. Only then the word is counted as correctly solved. Thereafter a new word (again consisting of three capital letters) is randomly drawn.
- Furthermore, a new encryption table is randomly generated in two steps:
    1) The computer program randomly selects in the table a new set of three-digit numbers to be used for the encoding of the capital letters.
    2) Additionally, the computer program shuffles the position of the capital letters in the table. Please note that the program always uses all 26 capital letters of the German alphabet.

Please note that if a new word appears, you have to click with your mouse on the first of the three blue boxes. Otherwise no input is possible!

- The computer will mark (in red font) wrong inputs after pressing the "OK" button.

Bear in mind:

- After wrong inputs the current word to encode will not change until a correct input was made.
- However, your previous inputs (in the 3 boxes below the capital letters) will all be deleted.
- Furthermore, the table stays unaltered, meaning that the allocated numbers remain identical. Also the position of the capital letters in the table does not change.

2. Trial period:

- The experiment starts with a trial period in which each participant has to encrypt exactly 10 words.
- Please note: Correct solutions do not lead to payments within the trial period.
- The general idea of the trial period is to make you as familiar as possible with the task before the actual experiment begins.

Therefore you should take the trial period serious and try to solve the ten words as fast as possible!

Please raise your hand if you still have further questions. We will come to your desk and answer them individually.