The Effects of Different Cognitive Manipulations on Decision Making

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Cognitive manipulation techniques are heavily being utilized in the context of dual-process models as a method to tilt behavior toward impulsive decision making. Recent literature indicates that not all methods are made equal. This paper experimentally tests the effects of four commonly used techniques for manipulating cognitive capacity: a number memorization task, a visual pattern task, an auditory recall task, and time pressure. In a within-subject design, subjects complete a series of risk taking decisions, allocation decisions, pattern recognition logic problems, and math problems under each load manipulation and no load control. The results indicate that number memorization and auditory recall have comparable sized effects with both leading to poorer performance on math and logic problems as well as more risk aversion, but no discernable impact on allocation choices. Time pressure has the same pattern of effects and a larger impact, but it increases the frequency of errors in control tasks. The visual pattern technique yields only modest difference from the baseline, but the directional patterns match those of the other techniques. Further, the evidence shows that the impact on an individual is consistent across techniques and tasks. Also, people who score highly on a cognitive reflection test are the most affected by cognitive load. These results provide robust support for dual-system decision making. From a methodological perspective, the results suggest that number memorization and auditory recall are the most reliable techniques for inducing cognitive load among those considered.

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1. Introduction

Cognition is an economically scarce resource. When more cognitive effort is directed to one decision, less can be directed toward others. Indeed, doing multiple things simultaneously often results in lower performance across tasks, which is why texting while driving is illegal in many places and why many professors do not allow students to browse the web during class. Dual process models are a common approach to study cognition (e.g., Fudenberg and Levine, 2006; Kahneman, 2011). In that framework, the first process, commonly referred to as System 1, is associated with primitive and intuitive behavior while the second process, referred to as System 2, is associated with deliberate and methodical decision making. Schematically, System 1 employs little cognitive effort to quickly arrive at decisions while System 2 consumes cognitive resources to reach a more calculated decision. Due to scarcity of cognitive resources or time, System 2 may not wish to devote full effort towards a task. As cognitive resources diminish, decisions will be influenced more by System 1 than by System 2.

There is a fast growing literature examining how cognitive load impacts economic decision making, with a general finding is that cognitive load reduces performance across economic decisions. Deck and Jahedi (2015), for example, manipulate the cognitive load placed on subjects in a laboratory experiment. Using a within-subjects design, they examine the effect of holding a large number or a small number in memory, a common technique for varying cognitive load, on multiple tasks including: risk-taking, impatience, susceptibility to anchoring, and math performance. They find that people become more risk averse, more impatient, more susceptible to anchoring, and correctly answer fewer math problems under a higher cognitive load. The effect is driven mainly by those people who are identified to be most susceptible to load. These results are supportive of a theory of dual processes, and suggest that increased cognitive load has a systemically negative effect on decision making, and increases impulsive behavior. Similar conclusions are reached by Hinson et al. (2003) regarding analytical performance and by Benjamin et al. (2013) regarding risk and impatience. Cognitive load has also been found to impact a wide variety of other behaviors including forecasting ability (Rydval, 2011), snack choice (Shiv and Fredorikhin, 1999), generosity (Van den Bos et al., 2006), and strategic behavior (Duffy and Smith, 2014; Allred et al., 2016).

Other mechanisms have also been tested as a means of distorting cognitive function. Mani et al. (2013) find, for instance, that poverty impedes cognitive function: being poor leads people to make bad choices. Specifically, they find that having shoppers think about large future expenses as opposed to small future expenses led to poorer performance on Raven’s Progressive Matrices (Raven 1998, 2003), which are a common tool for measuring cognitive performance. In Bregu et al. (2017), the authors compare performance of a group of subjects given alcohol with a control group, hypothesizing that drinking alcohol will diminish performance in a similar fashion as cognitive load. Despite a target blood alcohol concentration of 0.08, the legal limit in most US states, they find no substantive effect of alcohol on performance on risk taking or math performance. Jahedi et al. (2017) study how exposure to sexually arousing images impacts performance, and they too find little evidence that arousal impacts behavior for college males. For both Bregu et al. (2017) and Jahedi et al. (2017), the method used to disrupt cognition was not able to cause a change in behavior.[1]

A relatively new technique that has been shown to disrupt the dual systems, and one that recently received substantial attention, is time pressure. Rand et al. (2012), for example, find that time pressure leads to more contributions to a public good. They interpret this result as evidence that people are intuitively cooperative. Rubinstein (2016) provides a typology of players based on how much time they take to make a decision, with the fast actions interpreted as more impulsive and the slow actions as more deliberative. In a follow-up experiment, he provides evidence for such a typology.

Given the apparent success of, and broad reliance on, increasing cognitive load to study impulsive economic behavior, it is surprising that there has not been a systematic evaluation of alternative load inducing techniques and time pressure in the discipline. This paper seeks to provide such a comparison and achieve the following goals using an experimental design. The first goal is to catalog the relative magnitude of the impact that different load inducing techniques have on different economic tasks to provide researchers with a basis for selecting an appropriate approach given their research objective. The second goal is to determine the degree to which different techniques are manipulating the same aspects of decision making. If different techniques lead to opposing behavioral responses or affect the same subject in different ways then researchers should not view cognitive load as a generic tool or instrument.

Our experiment has a control, and four treatments that are commonly employed to study cognitive capacity in economics, psychology, and neuroscience. The four treatments include: a number memorization task, a visual pattern task, an auditory recall task, and time pressure. In a within-subject design, subjects complete a series of risk taking tasks, allocation tasks, pattern recognition logic problems, and math problems under the control and each treatment.

The results of our experiment indicate that having people memorize a number or recall an auditory string, have comparable effects: behavior in allocation tasks are similar, both lead to poorer performance on math and logic problems, as well as more risk aversion. Making decisions under time pressure has a strong effect on behavior, but it seems to increase the frequency of errors in the control tasks. Having people recall a visual pattern pushes behavior in the same direction as the other techniques

[1] Given these results, it would appear that inducing cognitive load or encouraging people to think about financial difficulties are more effective at reducing cognitive ability and identifying impulsive behavior than intoxicating or sexually arousing subjects.

but not substantially. These results suggest that number memorization and auditory recall are the most reliable techniques for inducing cognitive load among those considered.

The results indicate that the various techniques used to disrupt the cognitive process lead to similar behavioral responses. Moreover, the same individual is impacted in a similar way across treatments. Specifically, we find strong evidence that the subjects who are most affected by one technique are also the ones most affected by another technique. We also find that subjects who score highly on cognitive reflection test, indicating that they are able to suppress System 1, are most affected cognitive load. Jointly, these results offer compelling evidence for dual-system decision making.

The remainder of the paper is organized as follows. The next section discusses the background literature. Separate sections then detail the experimental design and behavioral findings. The final section contains a concluding discussion.

2. Background Literature

A nice survey that highlights the effect of cognitive load in economics experiments is provided by Deck and Jahedi (2015). A general theme in the literature is that increased cognitive load leads to poor decision making. This section focuses on the different approaches that have been used to induce cognitive load.

By far, the most common approach in economics for increasing cognitive load is to have subject memorize strings of various lengths. This approach can be traced back to the pioneering work of Miller (1956) who argued that people can typically hold seven pieces of information in their short-term memory. It is thus assumed that people asked to memorize short strings (i.e., fewer than seven characters) have mental slack, whereas those memorizing long strings (i.e., more than seven characters) are approaching their cognitive limits. Shiv and Fedorikhin (1999), Roch et al. (2000), Hinson et al. (2003), Cornelissen et al. (2007), Capelletti et al. (2011), Benjamin et al. (2013), Carpenter et al. (2013), Duffy and Smith (2014), Hauge et al. (2014), Zimmerman and Shimog (2014), Deck and Jahedi (2015), and Allred et al. (2016) all have subjects memorize numbers with 5 to 9 digits to induce a high cognitive load. In many of these papers, the researchers ask the participants to make choices that involve calculations, such as whether or not to take a risky gamble, to trade of money now for money later, or to allocate money between one's self and someone else. The fact that the cognitive load technique and the decision of interest are both numerical may be good or bad depending on the researcher's purpose, but intuitively this approach can bias the effect size if numerical processing becomes more/less difficult with scale.[2]

[2] Other researchers, such as Whitney et al. (2008), Sprenger et al. (2011), and van Boven and Robinson (2012), have used strings of letters. Van den Bos et al. (2006) have subjects memorize sequences of symbols.

A second approach, that is common in some disciplines, is to have subjects memorize a visual pattern, typically dots placed in a grid. For example, Gerhardt (2013) shows subjects the location of some dots in an 11×9 grid for one second, asks them to make a risky choice, and then asks them to identify if a randomly selected grid location contained a dot. De Neys (2006) presented subjects with a 3×3 grid with dots in three locations for 850 milliseconds before giving them a logic test and then asking them to recall the location of the dots. The short amount of time that subjects are given to memorize the pattern compared to the several seconds that subjects typically have to memorize a string of numbers is due the different nature of the two stimuli. Further, this stimuli is distinct from the stimuli that subjects receive regarding their decision tasks.

A third approach used to induce cognitive load is known as an n-back procedure. For this technique, a subject is exposed to a sequence of stimuli. They are asked to indicate whether the most recent element to be displayed, the N^{th} element of the sequence, is the same as the $N\text{-}n^{th}$ element. Getz (2013) visually presents subjects with a sequence of letters in a 3-back task and found that doing so led subjects to be more impatient. Schulz et al. (2014) use a 2-back task, but instead of being showing the letter on the subject's screen, the subject wears earphones and hears a letter every three seconds. They find that subjects under this type of high cognitive load are more generous in dictator games. As compared to both the number memorization and the dot pattern memorization, an auditory n-back task relies on a separate sense than the visual stimuli used for most economics experiment decision tasks. While the n-back procedure is relatively rare in economics, the procedure has a long history in psychology other disciplines going back Kirchner (1958).

The above approaches all rely on imposing competing demands on a subject's cognitive resources in order to induce cognitive load. Another method used by researchers to disrupt the dual systems is time pressure. Primarily, most of the research has focused on issues related to altruism. For example, Cappelletti et al. (2011) compare the effects of time pressure to the effects of cognitive load via number memorization in ultimatum game behavior. They report that time pressure leads to higher proposals relative to a baseline while cognitive load did not. Rand et al. (2012) find that time pressure leads to more contributions to a public good, which they interpret as more generous behavior (see also Cone and Rand 2014).[3]

3. Experimental Design

[3] However, Tinghög et al. (2013) fail to replicate the result of Rand et al. (2012) and Recalde et al. (2015) show that the effect reported by Rand et al. (2011) is likely an artefact of the design and due to subject error, a criticism that could apply to Cappelletti et al. (2011) as well. More recently, Tinghög et al. (2016) examine the effect of time pressure and ego depletion on altruism and moral judgment and find no effect of either treatment on either behavior.

The study employs a within-subject design. Each individual engages in all five treatments in random order: a control treatment, and four cognitive disruption treatments. Each treatment is described in Section 3.1 and each type of decision task is described in 3.2. The within-subject design is summarized in Table 1, as is the total number of observations in each treatment.

3.1. Load Techniques

In addition to a no cognitive load baseline, four different cognitive load inducing techniques are studied. Each subject experiences each load technique in a randomly determined order.

Baseline. A subject has 21 seconds to make a decision.[4]

Number. Prior to being presented with a decision, subjects are given 6 seconds to memorize an 8-digit number. The subject then has 21 seconds to make a decision. After 21 seconds passes, the subject is asked to recall the 8-digit number. Correctly entering the 8-digit number within 10 seconds is worth $35 and otherwise the subject earns $0.

Dot Pattern. Prior to being presented with a decision, subjects are given 3 seconds to memorize a pattern of dots in a 4×4 grid. The subject then has 21 seconds to make a decision. After 21 seconds passes, the subject is asked to reconstruct the pattern of dots. Correctly reconstructing the pattern within 10 seconds is worth $35 and otherwise the subject earns $0.

Auditory 3-Back. For this load technique, subjects wore headphones. Starting 9 seconds before a decision task is presented, the subject hears a spoken letter every three seconds until the subject has had 21 seconds to make a decision (a total of 30 seconds from the time the first letter is heard). Each letter is randomly drawn from the set {F, K, L, R, S, Q} and a subject has to identify if a spoken letter is a repeat of the letter spoken 9 seconds earlier or 3-back in the sequence.[5] A subject starts with an endowment of $25 and earns an extra $8 every time she correctly identifies that a letter is a repeat of the one 3-back, but losses $4 every time she fails to identify a 3-back repeat. A subject identifies a 3-back repeat by clicking an onscreen button.

Time Constraint. A subject has 3 seconds to make binary decisions that require a single button click and 5 seconds to make decisions requiring inputting an answer.

3.2. Decision Problems

[4] Except where time limits are based on previous research, durations of different parts of the study were calibrated based upon results from a pilot study. The baseline time limit needed to be a multiple of 3 seconds for compatibility with the auditory 3-back technique described below.

[5] The letters are a subset of those used by Schulz et al. (2014), who identified letters with a distinct sound. A subset is used so that the probability a letter is a 3-back repeat is one sixth, after the first three letters. Hence, in expectation there are 3.5 3-back repeats in 21 seconds keeping the incentives consist with the Number and Dot Pattern load techniques. The audio files for each letter, available upon request, are in feminine computer generated voice.

For each of the treatments described above, subjects will be required to answer a total of 20 decision problems. There will be five questions in each type of following decision problem categories: multiplication problems, lottery tasks, pattern recognition, and allocation tasks. In each category, four of the five questions are standard, while one of the five questions is trivial and meant to serve as a control to ensure that subjects making meaningful choices.

Multiplication Problems. For this type of task, subjects are given two factors to multiply together. In each standard multiplication problem one factor is a single digit integer between 4 and 9, inclusive, and the second factor is a two digit integer between 14 and 19, inclusive.[6] The actual integers a subject observes are generated randomly. Correct answers are worth $17 while incorrect or blank answers are worth $0. For the control version of a multiplication problem, the single digit integer is a 0.

Lottery Tasks. For this type of task, subjects select between two options. Option A is a certain payment. Option B is a 50-50 gamble between two amounts. In the standard version, the certain payment is a randomly generated integer amount between $11 and $20, inclusive. The gamble is then constructed as follows. The lower payoff for the gamble equals the certain amount minus a randomly generated integer amount between $1 and $6, inclusive. The larger payoff for the gamble adds this same randomly generated amount to the certain amount and also adds an additional randomly determined integer amount between $1 and $4, inclusive. Thus, the 50-50 gamble always has an expected value greater than the certain payment option.

In the control version, the safe option is generated in the same way as for the standard lottery tasks. The 50-50 gamble for the control question is constructed as follows. The lower payoff for the gamble equals the certain amount plus $2. The larger payoff for the gamble is the certain payoff plus $7. Thus, in the control version the gamble first order stochastically dominates the certain option. Any subject who does not make a selection in the allotted time earns $0 for both the standard and control versions of the task.

Pattern Recognition. For this task, subjects are asked to identify the missing element that completes a pattern. The patterns are based on the work of Civelli and Deck (2016) and Matzen et al. (2010), which in turn was based on earlier work with Raven Progressive Matrices (Raven 1981, 2000). The pattern consists of a 3×3 table of images with the lower right entry removed. Each element of the table is defined by its shape, shading, size, orientation, border, and other characteristics. The elements' characteristics vary (or don't vary) in systematic ways across the table either by columns, rows, or diagonally. Civelli and Deck (2016) and Matzen et al. (2010) document how respondents' ability to correctly identify the missing element deteriorates with the number of characteristics that change and the

[6] Deck and Jahedi (2015) found that performance on multiplication problems with these types of numbers varied greatly with the number of digits a subject was holding in memory.

pattern over which they vary. A control pattern recognition task involves a single characteristics that changes with the row or column. The standard tasks vary more characteristics with different patterns. The level of difficulty varies for the standard tasks within a load technique, but the types of changes are held constant across load techniques. Unlike, the other tasks in which the specific parameters of the task are randomly generated during the experiment, the set of pattern recognition tasks is preselected and can be found in Appendix A. Figure 1 shows a sample control pattern, and a more complicated standard pattern. A correct response is worth $17 while an incorrect or nonresponse is worth $0.

Allocation Tasks. For this type of task a subject selects between two possible allocations in a modified dictator game. The choices are always of the form ($X, $X) or ($Y, $Z), where the first amount in the ordered pair indicates the decision maker's payment and the second amount indicates the payment to a randomly selected other subject. For each allocation task, X is randomly selected from the set {14.25, 14.75, …, 19.75}. For the control task, $Y = Z = X + e_c$ where e_c is randomly drawn from the set {1, 2, …. 4}. Hence, for the control version of the task, the choice is to equally split a smaller amount of money or to equally split a larger amount or money. As far as we know, all behavioral models as well as the material self-interest model predict that people would prefer an equal split of a larger amount to an equal split of a smaller amount. For the four standard tasks $Y \neq Z$, but their relationship to X varies in specific ways to allow us to identify motives. The construction of Y and Z involve drawing two random integers, e_y and e_z, from the set {1, 2, …, 4}. For the generous task $Y = X - e_y$ and $Z = X + e_y + e_z$ so a subject can incur a small loss to increase the other person's outcome by a larger amount. For the spiteful task $Y = X - e_y$ and $Z = X - e_y - e_z$ so a subject can incur a small loss to reduce the other person's payoff by a larger amount. For the selfish choice $Y = X + e_y$ and $Z = X - e_y - e_z$ so a subject can claim a small gain at a larger cost to the other person. For the magnanimous choice $Y = X + e_y$ and $Z = X + e_y + e_z$ so a subject can attain a gain for both people if the subject is willing to have a smaller share. The various allocation tasks are shown graphically in Figure 2.

For a given load technique, a subject faces exactly one generous, one spiteful, one selfish, and one magnanimous allocation task along with one control allocation task. If a subject fails to make an allocation decision in the allotted time, the decision maker earns $0 while the other person earns $X. If a subject is paid based upon her own allocation decision, this decision also determines the only salient payment the randomly selected other subject receives. However, there is no feedback between subjects regarding the allocation decisions of others during the experiment.

3.3. Other Procedures

The data consists of the responses of 120 subjects from Chapman University. Sessions lasted for about 75 minutes each and involved a group of 10-14 subjects. Subjects did not interact with each other while in the lab and thus one subject's responses could not influence another subject. Upon entering the lab, subjects were seated at individual workstations separated by privacy dividers. Subjects first read directions describing the different types of decision problems. Subjects then read the direction for the first load technique and proceeded to complete the 20 decisions with a 5 second pause between tasks. After each block of tasks, subjects received summary feedback regarding their earnings in that block. Subjects then read the directions for the next load technique in the block of 20 decisions. This process repeated until the subjects had completed all 5 blocks. After completing the experiment, subjects answered a brief survey. The directions can be found in Appendix B.

Subjects received a $7 participation payment in addition to their salient earnings. To determine a subject's salient earnings, one of the 100 decisions (= 5 load techniques × 20 decisions) was randomly selected. If the decision was made under the baseline or time constraint load technique, the earnings were based on the selected task. However, if the decision was made under the number, dot pattern or auditory 3-back load technique, then the subject was randomly paid for the decision or for the load technique performance. The stakes for the load technique were intentionally greater than the stakes in the decision problems so that a subject had an incentive to place themselves under cognitive load.[7] The average salient payment was $18.

4. Results

4.1. Aggregate Results

To verify that subjects make deliberate and meaningful responses on the relevant tasks, we begin by reporting performance for the control tasks. The overwhelming majority of subjects answered these tasks correctly. The experiment was designed such that each subject would observe one control question for each type of task for each condition. However, for the pattern recognition tasks, analysis of the data indicates that subjects also answered another task equally well. In essence, subjects viewed one of the standard tasks to be as simple as the control. For this task only, we consider both question types to be control tasks, though the results do not differ if we only consider the ex-ante designated control task.

Table 2 gives the percentage of subjects who answered a multiplication problem correctly when one of the factors was 0; selected the risky, but first order stochastically dominant, lottery option;

[7] This selection procedure means that there is a greater chance a subject is paid for a specific task in the baseline or time constrained load techniques. To keep those incentives fixed would require either a different number of decision problems being implemented under different load techniques or not drawing each task with a uniform chance. Both of these approaches have pitfalls as they could be perceived as placing greater emphasis on certain load techniques.

completed a simple pattern recognition task; and chose to equally split a larger rather than a smaller amount of money with someone else.

The key result of Table 2 is that subjects are overwhelmingly making reasonable choices for the control questions. Further, there is clear evidence that subjects are not making random choices, as argued by Franco-Watkins et al. (2006) and Franco-Watkins et al. (2010). In fact, for every cell in Table 2, the p-value < 0.001 for the one sample proportion test of the hypothesis that the percentage is 50%.

Result 1: Subjects make reasonable choices in control tasks.

The data in Table 2 also suggests that some decision problems are harder than others. Under the no cognitive load baseline, subjects performed better on the math and allocation control tasks than they did on the lottery and pattern recognition control tasks. This pattern holds for all four load inducing techniques. Finally, Table 2 also provides evidence to suggest that time constraint as a load is the most detrimental to performance, although even under the time constraint subjects were able to answer 98% of the math problems correctly.[8]

Table 3 reports the regression results comparing performance across the load techniques for each of the control decision types.[9] For Math Problems and Pattern Recognition the dependent variable is 1 if the subject answered correctly and is 0 if the subject answered incorrectly or failed to answer in the allotted time.[10] For the Lottery Tasks the dependent variable is 1 if the subject selected the higher expected value option and is 0 if the subject selected the lower expected value option. For Allocation Tasks, the dependent variable is 1 if the subject selected the lower equal payment option and is 0 if the subject selected the higher equal payment option. This labeling is done for consistency with subsequent analysis of allocation decisions in which only one of the options involves an equal payment. For both Lottery Tasks and Allocation Tasks, if a subject did not respond in the allotted time the observation was excluded. The analysis includes dummies for the block (of time) in which the task was presented, both suppressed for brevity, as well as standard errors clustered by subject.[11]

The regression results in Table 3 indicate that each load inducing technique had some impact on performance on control question, but that this effect was generally small and similar across techniques. The main exception is that the time constraint substantially prevented subjects from being able to identify simple patterns.

[8] Using pilot sessions, the time limit was calibrated so that subjects could answer the math control questions.
[9] Probit analysis yields similar conclusions.
[10]The implications of the results are similar if attention is restricted to those who actually provide a response for Math Problems and Pattern Recognition. Lottery and Allocation tasks do not have an objectively correct response and therefore nonresponse are excluded from analysis of those tasks. The only instances of substantial non-response arise with Time Constrain for standard Math Problems and Pattern Recognition.
[11] Including subject fixed effects leads to similar results.

Result 2: All cognitive load inducing techniques have some impact on performance on control questions, but this effect is generally small and similar across techniques.

Next, we verify that the intended manipulation was effective. Subjects were placed under cognitive load in the Number, Dot Pattern, and Auditory 3-Back load techniques. The performance pay for correctly responding to load recall was high, so subjects should focus their efforts on this task. However, given that subjects had the ability to choose whether or not to commit cognitive effort, we have to check whether the treatment was effective. For the Time Constraint treatment, we exogenously impose the time limit on to subjects. Table 4 provides the average performance for the three relevant load techniques: percentage of 8-digit numbers correctly recalled, percentage of 16-dot patterns correctly recalled, and percentage of 3-back repeats correctly identified. Note, that these measures give a lower bound on the degree to which subjects are under cognitive load because, for example, since subjects could try hard to recall a number but still not be able to correctly recall it.[12]

Result 3: Subjects endogenously choose to stay under cognitive load.

Our analysis now turns to the impact of the various load treatments on the standard decision tasks. Table 5 reports aggregate choices for each task and load treatment. The results suggest that the techniques all lead to poorer performance on the math problems, more risk aversion, and reduced ability to identify logical patterns. The results also suggest that in terms of magnitude, the number memorization and auditory 3-back treatments have similar sized effects, while the dot pattern technique has a milder effect, and the time constraint has a more dramatic effect. The impact of the load inducing techniques on allocation decisions is less consistent. All of the techniques lead to nominally less magnanimous and nominally more spiteful behavior, but there is not a uniform impact on generosity or selfishness.

To formally compare the effect of different load techniques on behavior, we rely upon the regression analysis reported in Table 6, which is similar to that reported in Table 3, though it includes time block dummies that are suppressed in the table. Standard errors are clustered at the subject level.[13] For the allocation tasks, the dependent variable is 1 if the subject selected the equal split outcome and is 0 otherwise.

Overall, the regression results in Table 6 confirm the general observations from Table 5. For math problems and pattern recognition all four lead to poorer performance, although the Wald test rejects that the effect sizes are identical across techniques (p-values < 0.001 for both tasks). This performance reduction is significant for each technique except for dot pattern memorization and it is most pronounced

[12] The analysis presented in the remainder of this section is based on all relevant task responses regardless of whether or not the subject performed the load inducing component correctly or not. The results are similar if attention is restricted to only those tasks for which the load inducing technique was completed correctly. Given this, there is little anticipated gain from using measures like the Jaro-Winkler index to determine instances in which a subject was close to completing the load technique correctly.

[13] Including subject fixed effects leads to qualitatively similar conclusions as does probit regression.

under the time constraint. Further, we note that a Wald test indicates number memorization and auditory 3-back have similar effect sizes (p-values = 0.301 and 0.857 for the math and pattern problems, respectively).

As for risk taking, each technique has a negative coefficient indicating an increase in risk aversion and there is only marginal evidence that the four techniques have different effects (p-value = 0.083). Again, we note that a Wald test indicates number memorization and auditory 3-back have similar effect sizes (p-value = 0.233). With respect to the allocation tasks, for both the magnanimous and the selfish tasks, the four techniques essentially have no effect. Although there is marginally statistically significant evidence that dot pattern memorization affects selfishness, Wald tests fail to reject the hypothesis that the effects of the four techniques are the same. Generosity is statistically increased with the dot pattern technique, but not affected by any of the other three techniques. As a result the four techniques are found to have marginally statically different effects (Wald test p-value = 0.060). For spitefulness, the four techniques are significantly different (Wald test p-value = 0.047) with number memorization having the greatest increase in spitefulness. However, it is worth noting that in the no load baseline no spiteful behavior is observed, so even with these increases there is very little evidence of spiteful behavior. Finally, we note that Wald tests indicate the coefficients on number memorization and auditory 3-back are statistically similar for magnanimous, generous, and selfish behavior (p-values of 0.737, 0.174, and 0.447 respectively), but differ in magnitude for spitefulness (p-value = 0.005).

Result 4: All cognitive load inducing techniques lead to poorer performance on the math problems, more risk aversion, and reduced ability to identify logical patterns. Also, there is evidence that higher cognitive load leads to more spiteful behavior.

4.2. Individual Results

Up to this point, the results have focused on the aggregate effect of different load inducing techniques on performance. We now exploit the within-subject nature of our experimental design to answer whether the subjects whose performance on one task is most affected by a particular technique also the most affected by that technique for another task?

To examine how subjects are impacted across load inducing techniques for a given type of task, we present Table 7, which gives the correlation in the change in performance between one technique and the baseline and the change in performance between another technique and the baseline. The unit of observation is a subject and we exclude allocation tasks because subjects only faced a single allocation decision of each type under each technique. The reduction in a subject's performance on math problems due to a given treatment is highly correlated with the reduction in performance for other treatments (p-value < 0.001 for every comparison in Panel A of Table 7). The same is true for the increased risk aversion in lottery tasks (Panel B of Table 7) and the decreased performance on patterns (Panel C of Table 7). That is, there is strong evidence that the more one technique affects a subject, the more another technique will too.

To examine how a particular load technique impacts a subject across tasks, we rely upon the regression results presented in Table 8. Here, we conduct a median split of our sample, based on how math performance changed from the control treatment to the number memorization treatment. We use this because it is the most objective measure, though using other decision tasks does not substantially change the result. Subjects for whom number memorization had the most detrimental effect on math performance are referred to as the *impacted* group and the other subjects are referred to as the *non-impacted* group.[14] Table 8 provides separate regression results for the *impacted* (Panel A) and *non-impacted* (Panel B) subjects for each task.

The results in Table 8 clearly indicate that the *impacted* subjects are generally more affected on other tasks under other load inducting techniques. For example, increase in risk aversion under any technique is greater for the *impacted* group than for the *non-impacted* group. Also, the negative impact on pattern recognition for any technique is greater for the *impacted* group than for the *non-impacted* group. Further, other techniques reduce the math scores of the *impacted* group more than the other techniques reduce the math scores of the *non-impacted* group. In fact, only for the allocation decisions do the *impacted* and *non-impacted* subjects not respond to different load techniques in broadly different ways, largely because the techniques have little impact on allocation behavior.

Result 5: There is strong evidence that the subjects who are most affected by one technique are also the ones most affected by another technique.

Finally, we report some additional patterns that we observed in our data. After the experiment, subjects completed a six question cognitive reflection test (CRT).[15] This test is designed to identify the degree to which people think deeply about a problem and is distinct from the notion of cognitive ability. Essentially, the CRT can be viewed as a measure of a person's ability to suppress System 1. Thus, one should expect cognitive load to have a minimal effect on those who score poorly on the CRT as these people rely on System 1. However, for those who typically rely on System 2, one would expect increased cognitive load to have a detrimental effect. Table 9 reports the results of analysis similar to that in Table 8, but conducted after splitting our sample based on CRT performance. The results reveal that it is in fact subjects who score well on the CRT who are most affected by cognitive load.

[14] Given the coarse nature math performance (out of 4 questions), splitting the sample exactly in half would mean including people who experienced the same deterioration in both groups. Instead the separation between groups was set so as to balance the groups as evenly as possible while maintaining that everyone in the impacted group had a larger math performance reduction due to number memorization than anyone in the non-impacted group.

[15] The six questions include the three original questions of Frederick (2005) plus additional questions taken from Toplak et al. (2014) and Primi et al. (2016).

Result 6: Subjects who score highly on cognitive reflection test are the most affected by all cognitive load techniques.

Analysis of our data also reveals some other interesting patterns. First, both across treatment blocks and within treatment blocks, there is some evidence that subjects tend to do better at the math and pattern problems as the experiment progresses.[16] However, there is little evidence to suggest that risk taking or allocation decisions change over the course of the experiment. That is, we do not observe ego depletion that leads people to become more self-interested over time. Second, we find that women are more risk averse than men, and find that women answer fewer math questions correctly as compared to their male counterparts. However, we find no evidence that the various cognitive load techniques have a differential effect on men and women.[17]

Discussion

There is a fast growing literature in economics examining how cognitive load impacts behavior. To examine this question, researchers either directly increase cognitive load or impose time pressure. Under dual process models of decision making, one would expect that these different techniques of imposing cognitive load or increasing time pressure would have comparable effects. However, recent research shows that not all techniques are equal: some do not work at all, and others have behavioral effects that are directionally different. This study looks at four specific procedures used to induce cognitive load, and the degree to which these techniques generate comparable effects, and offers a systematic evaluation and comparison of these approaches.

In our experiment, subjects are placed under time pressure and experience increased cognitive load via 8-digit number memorization, memorization of a dot pattern in a 4×4 grid, and an auditory 3-back recall procedure in addition to a no-load baseline. For each of these conditions our subjects answer a series of multiplication problems, a series of pattern recognition problems, a series of risky lottery choices, and a series of dictator allocation decisions. The subjects also respond to a series of control questions to verify that observed effect are not simply due to increased noise or error by the subjects.

Our results show that the directional effect of each technique is the same for the math, pattern, and risky choice tasks. People make more multiplication mistakes, perform more poorly at pattern recognition, and are more risk averse when under load. The results are quite consistent with previous work (see Deck and Jahedi, 2015). With respect to allocation decisions, we find little systematic impact of any manipulation on behavior. Our data also suggest that the impact of one treatment on a subject is predictive of the impact of another treatment on the same subject. Further, the results demonstrate that

[16] This result is consistent with previous results by Deck and Jahedi (2015).
[17] Regression analysis regarding time, CRT, and gender are available upon request.

those who score highly on a cognitive reflection test are the ones who are most affected as these are people who normally suppress impulsive responses. In total, our results offer compelling evidence for dual-system decision making.

Based on our data, we conclude that number memorization is the best technique for research seeking to disrupt dual system processing. Generally, the visual approach of dot pattern memorization has only a very small effect and leads to behavior that is not much different from the baseline. Time pressure is found to have a large effect, but time pressure is also found to have a sizeable effect on responses to control questions, introducing potential concerns about the reliability of other data collected with this approach. Number memorization and the auditory 3-back techniques have similar sized effects, but as a procedural matter the 3-back approach is much more difficult to implement, thus leaving number memorization as our preferred approach.

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Table 1. Cognitive Load Techniques and Decision Problems

	Decision Types			
Load Technique	Math Problems	Lottery Tasks	Allocation Tasks	Pattern Recognition
Baseline	4+1	4+1	4+1	4+1
Number	4+1	4+1	4+1	4+1
Dot Pattern	4+1	4+1	4+1	4+1
Auditory 3-Back	4+1	4+1	4+1	4+1
Time Constraint	4+1	4+1	4+1	4+1

The entry in each cell give the number of standard decisions + the number of control decisions of a particular type a subject faces for a given load technique.

Table 2. Percentage of Optimal Responses to Control Tasks by Load Technique

	Control Decision Type			
Load Technique	Math Problems	Lottery Tasks	Pattern Recognition	Allocation Tasks
Baseline	99%	93%	93%	99%
Number	98%	91%	88%	91%
Dot Pattern	98%	85%	87%	95%
Auditory 3-Back	99%	87%	86%	97%
Time Constraint	98%	81%	78%	86%

Table 3. Regression Analysis of Control Tasks

	Math Problems	Lottery Tasks	Pattern Recognition	Allocation Tasks
Constant (Baseline)	0.987***	0.922***	0.788***	-0.026
	[0.069]	[01.38]	[0.106]	[0.089]
Number	-0.007	-0.003	-0.061**	0.076***
	[0.019]	[0.035]	[0.030]	[0.025]
Dot Pattern	0.002	-0.067*	-0.037	0.033
	[0.019]	[0.035]	[0.030]	[0.025]
Auditory 3-Back	-0.041**	-0.046	-0.075**	0.01
	[0.019]	[0.035]	[0.030]	[0.025]
Time Constraint	-0.023	-0.073**	-0.232***	0.045*
	[0.019]	[0.035]	[0.030]	[0.026]
Observations	600	593	1200	587
R^2	0.43	0.452	0.232	0.319
Wald test p-value	0.117	0.175	<0.001	0.066

Standard errors, clustered by subject, are presented in brackets. Regressions include dummies for each block of the experiment to control for time. *,**, and *** denote significance at the 10%, 5%, and 1% levels respectively. The Wald test is for the null hypothesis that the coefficients for the four load inducing techniques are the same. Math Problems and Pattern Recognition are considered wrong if the subject does not answer correctly or if no answer is given. For Lottery Tasks and Allocation Tasks, if a subject does not answer in the allotted time the task is excluded.

Table 4. Performance on Load Techniques

Load Technique	Percentage of Correct Responses
Baseline	NA
Number	47.9%
Dot Pattern	60.5%
Auditory 3-Back	25.0%
Time Constraint	NA

In only 19% of cases should a subject have indicated at least one 3-back during a task and fail to indicate any. Even so, these 19% may have been attempting to identify 3-backs but simply have failed to correctly remember the sequence. By comparison, subjects did not provide responses in 17% of cases when asked to recall a number and did not provide responses in 1% of the cases when asked to recall a dot pattern.

Table 5. Task Performance by Load Technique

Load Technique	Math	Risk	Pattern	Allocation Behavior			
	Correct	Taking	Recognition	Magnanimous	Generous	Spiteful	Selfish
Baseline	81%	57%	60%	85%	6%	0%	59%
Number	69%	44%	53%	81%	10%	8%	54%
Dot Pattern	79%	52%	58%	81%	13%	4%	68%
Auditory 3-Back	67%	47%	51%	79%	2%	4%	58%
Time Constraint	24%	45%	35%	73%	4%	4%	58%

Table 6. Regression Analysis of Behavior of Tasks of Interest

	Math	Lottery	Pattern	Allocation Tasks			
	Problems	Tasks	Recognition	Magnanimous	Generous	Spiteful	Selfish
Constant	1.017***	0.716***	0.354***	0.162	1.019***	1.017***	0.155
(Baseline)	[0.092]	[0.099]	[0.116]	[0.134]	[0.111]	[0.084]	[0.202]
Number	-0.102***	-0.121***	-0.086***	0.008	-0.039	-0.080***	0.023
Memorization	[0.026]	[0.027]	[0.033]	[0.038]	[0.031]	[0.024]	[0.051]
Dot	-0.001	-0.051*	-0.005	0.017	-0.066**	-0.039*	-0.097*
Pattern	[0.026]	[0.027]	[0.032]	[0.037]	[0.031]	[0.024]	[0.050]
Auditory	-0.128***	-0.088***	-0.092***	0.021	0.003	-0.015	-0.015
3-Back	[0.026]	[0.027]	[0.032]	[0.038]	[0.031]	[0.024]	[0.051]
Time	-0.567***	-0.089***	-0.253***	0.022	0.007	-0.040*	-0.044
Constraint	[0.026]	[0.028]	[0.032]	[0.039]	[0.032]	[0.024]	[0.052]
Observations	2400	2353	1800	581	585	593	586
R^2	0.355	0.343	0.138	0.551	0.38	0.272	0.504
Wald test p-value	<0.001	0.083	<0.001	0.983	0.060	0.047	0.112

Standard errors, clustered by subject, are presented in brackets. Regressions include dummies for each block of the experiment to control for time. *,**, and *** denote significance at the 10%, 5%, and 1% levels respectively. Math Problems and Pattern Recognition are considered wrong if the subject does not answer correctly or if no answer is given. For Lottery Tasks and Allocation Tasks, if a subject does not answer in the allotted time the task is excluded.

Table 7. Correlation in Impact of Load Inducing Technique by Task

Panel A. Deterioration in Performance on Math Problems			
	Dot Pattern	Time Constraint	Auditory 3-Back
Number Memorization	0.45***	0.37***	0.43***
Dot Pattern		0.49***	0.56***
Time Constraint			0.44***
Panel B. Deterioration in Performance on Pattern Problems			
	Dot Pattern	Time Constraint	Auditory 3-Back
Number Memorization	0.53***	0.45***	0.61***
Dot Pattern		0.53***	0.54***
Time Constraint			0.46***
Panel C. Increase in Risk Aversion on Lottery Tasks			
	Dot Pattern	Time Constraint	Auditory 3-Back
Number Memorization	0.47***	0.45***	0.52***
Dot Pattern		0.43***	0.50***
Time Constraint			0.49***

*** denotes significant correlation at the 1% level.

Table 8. Comparison of *Impacted* and *Non-Impacted* Subjects

Panel A. I*mpacted* Subjects

	Math Problems	Lottery Tasks	Pattern Recognition	Allocation Tasks: Magnanimous	Generous	Spiteful	Selfish
Constant (Baseline)	1.091***	0.732***	0.399***	0.157***	1.025***	1.024***	0.212***
	[0.029]	[0.028]	[0.037]	[0.052]	[0.044]	[0.029]	[0.077]
Number Memorization	-0.223***	-0.129***	-0.132***	0.005	-0.044	-0.084**	-0.049
	[0.029]	[0.030]	[0.042]	[0.053]	[0.037]	[0.036]	[0.064]
Dot Pattern	-0.069**	-0.084**	-0.042	0.035	-0.067	-0.042*	-0.104*
	[0.027]	[0.033]	[0.036]	[0.045]	[0.043]	[0.023]	[0.055]
Auditory 3-Back	-0.639***	-0.111***	-0.293***	0.055	-0.007	-0.041	-0.097
	[0.032]	[0.034]	[0.033]	[0.048]	[0.038]	[0.026]	[0.061]
Time Constraint	-0.206***	-0.128***	-0.133***	0.039	0.014	-0.008	-0.022
	[0.029]	[0.033]	[0.039]	[0.038]	[0.032]	[0.013]	[0.064]
Observations	1840	1804	1380	446	447	454	447
R^2	0.393	0.330	0.139	0.54	0.276	0.275	0.535

Panel B. *Non-Impacted* Subjects

	Math Problems	Lottery Tasks	Pattern Recognition	Allocation Tasks: Magnanimous	Generous	Spiteful	Selfish
Constant (Baseline)	0.379***	0.644***	0.167**	0.421***	1.029***	1.019***	0.631***
	[0.052]	[0.034]	[0.064	[0.061]	[0.057]	[0.033]	[0.124]
Number Memorization	0.297***	-0.099*	0.054	0.014	-0.023	-0.079	0.250*
	[0.033]	[0.058]	[0.068]	[0.088]	[0.069]	[0.055]	[0.124]
Dot Pattern	0.214***	0.053	0.102	-0.053	-0.065	-0.038	-0.086
	[0.061]	[0.051]	[0.072]	[0.095]	[0.083]	[0.038]	[0.134]
Auditory 3-Back	0.133**	0.06	0.051	-0.042	-0.037	-0.042	0.003
	[0.063]	[0.069]	[0.071]	[0.127]	[0.041]	[0.041]	[0.139]
Time Constraint	-0.335***	-0.039	-0.136***	-0.078	0.07	-0.044	0.115
	[0.062]	[0.066]	[0.040]	[0.123]	[0.057]	[0.044]	[0.124]
Observations	560	549	420	135	138	139	139
R^2	0.329	0.412	0.165	0.603	0.574	0.286	0.451

Standard errors, clustered by subject, are presented in brackets. Regressions include dummies for each block of the experiment to control for time. *,**, and *** denote significance at the 10%, 5%, and 1% levels respectively. Impacted (Non-Impacted) subjects are those who suffered the greatest (least) decrease in math problem performance under number memorization as compared to the baseline. Math Problems and Pattern Recognition are considered wrong if the subject does not answer correctly or if no answer is given. For Lottery Tasks and Allocation Tasks, if a subject does not answer in the allotted time the task is excluded.

Table 9. Comparison of *High CRT* and *Low CRT* Subjects

Panel A. *High CRT* Subjects

	Math Problems	Lottery Tasks	Pattern Recognition	Allocation Tasks			
				Magnanimous	Generous	Spiteful	Selfish
Constant (Baseline)	0.846***	0.649***	0.394***	0.067***	0.933***	1.000***	0.400***
	[0.031]	[0.042]	[0.034]	[0.033]	[0.033]	[0.000]	[0.064]
Number	-0.183***	-0.149***	-0.094*	0.083	-0.017	-0.067**	0.000
Memorization	[0.048]	[0.040]	[0.052]	[0.055]	[0.045]	[0.033]	[0.072]
Dot	-0.037	-0.113***	0.017	0.067	-0.100*	-0.067**	-0.133*
Pattern	[0.039]	[0.041]	[0.046]	[0.047]	[0.052]	[0.033]	[0.070]
Auditory	-0.154***	-0.131***	-0.106**	0.05	-0.017	0.000	0.041
3-Back	[0.039]	[0.041]	[0.051]	[0.050]	[0.045]	[0.000]	[0.077]
Time	-0.562***	-0.155***	-0.306***	0.047	0.048	-0.053*	-0.122*
Constraint	[0.048]	[0.043]	[0.038]	[0.051]	[0.038]	[0.030]	[0.062]
Observations	1200	1175	900	293	293	297	293
R^2	0.177	0.013	0.063	0.008	0.029	0.027	0.022

Panel B. *Low CRT* Subjects

	Math Problems	Lottery Tasks	Pattern Recognition	Allocation Tasks			
				Magnanimous	Generous	Spiteful	Selfish
Constant (Baseline)	0.767***	0.502***	0.339***	0.233***	0.950***	1.000***	0.417***
	[0.033]	[0.046]	[0.031]	[0.055]	[0.029]	[0.000]	[0.065]
Number	-0.042	-0.111***	-0.061	0.000	-0.067**	-0.100**	0.100
Memorization	[0.039]	[0.037]	[0.049]	[0.059]	[0.033]	[0.039]	[0.078]
Dot	0.012	0.002	-0.006	0.017	-0.033	-0.017	-0.033
Pattern	[0.039]	[0.038]	[0.045]	[0.061]	[0.041]	[0.017]	[0.063]
Auditory	-0.113**	-0.055	-0.078*	0.030	0.015	-0.033	-0.027
3-Back	[0.044]	[0.046]	[0.045]	[0.058]	[0.017]	[0.024]	[0.077]
Time	-0.579***	-0.02	-0.211***	-0.037	-0.023	-0.034	0.028
Constraint	[0.039]	[0.040]	[0.039]	[0.067]	[0.040]	[0.024]	[0.077]
Observations	1200	1178	900	288	292	296	293
R^2	0.209	0.007	0.03	0.003	0.012	0.032	0.01

Standard errors, clustered by subject, are presented in brackets. Regressions include dummies for each block of the experiment to control for time. *,**, and *** denote significance at the 10%, 5%, and 1% levels respectively. Impacted (Non-Impacted) subjects are those who suffered the greatest (least) decrease in math problem performance under number memorization as compared to the baseline. Math Problems and Pattern Recognition are considered wrong if the subject does not answer correctly or if no answer is given. For Lottery Tasks and Allocation Tasks, if a subject does not answer in the allotted time the task is excluded.

Figure 1. Sample Pattern Recognition Tasks

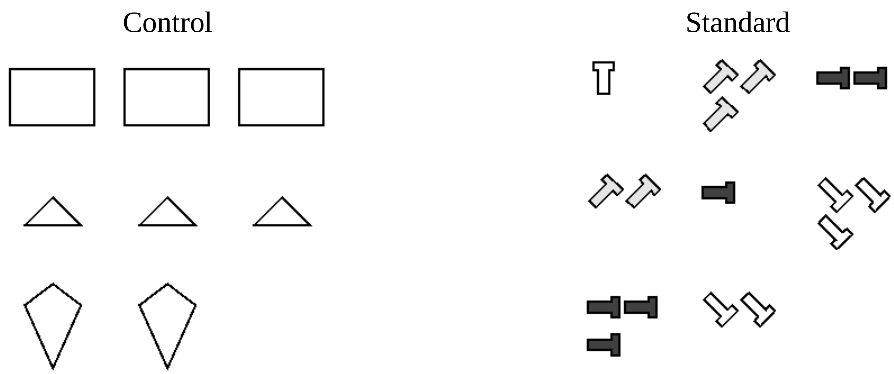
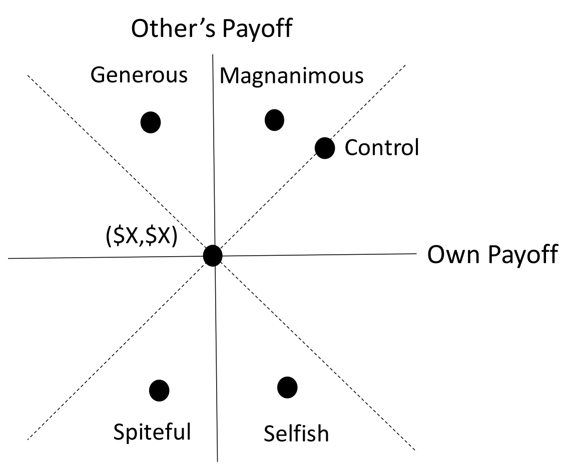
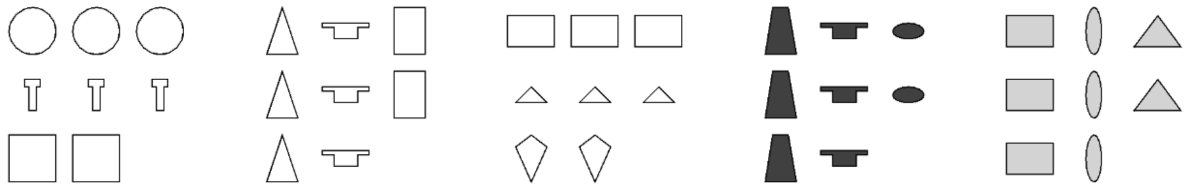


Figure 2. Allocation Tasks

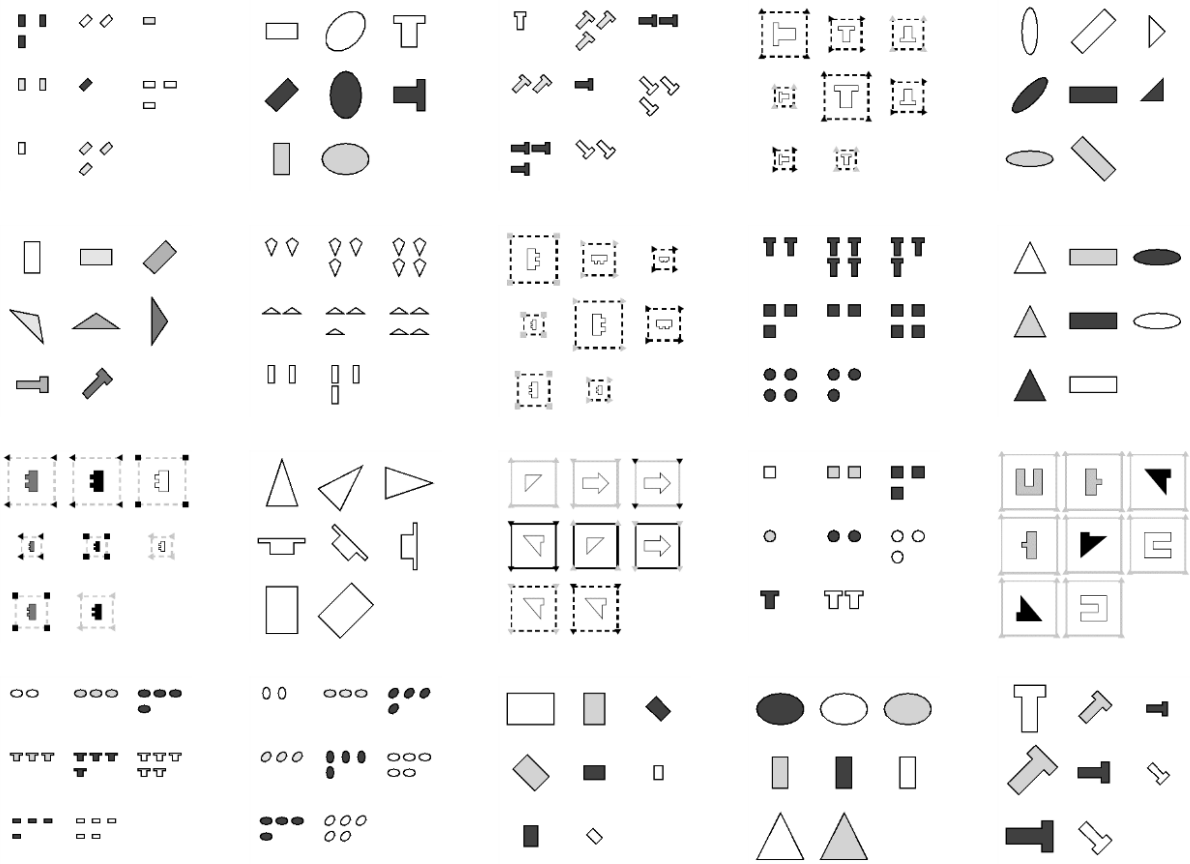


Appendix A: Pattern Puzzles

Control



Standard



Appendix B: Instructions

Introduction and Task Descriptions

Welcome, and thank you for participating in this study. For participating in today's study, you will receive $7. In addition to this, you will have the opportunity to earn money based on the decisions that you make. Therefore, it is important that you read the directions carefully. If you have a question at any point, please raise your hand and someone will assist you. When possible, try to ask your questions prior to starting as the study is timed, and once you begin, neither you nor the researchers can pause the program. Please do not talk or communicate with other participants during the experiment.

The study is broken into 5 blocks, and each block is comprised of 20 periods. Specific directions for the block will be given to you prior to the start of each block. For each period in the block, you will be asked to respond to a question. At the end of the study, you will be paid based on the outcome for one and only one randomly selected period. Your payoff from the randomly selected period will be displayed on your screen. Note that the periods are independent from one another so nothing that occurs in one period has any bearing on what happens in other periods.

There are only four types of questions in this study.

The first type of question is a multiplication problem such as 4 x 10 = __? For this type of question, a correct answer is worth $17, but an incorrect answer is worth $0.

The second type of question is a choice among two lotteries. In each case, Option A will pay a set amount of money with certainty, whereas Option B will be a gamble between two amounts, each equally likely with 50% chance. The lottery is presented as a circle with two dollar amounts in it, separated by a line.

The third type of question is a choice among two allocation payments. Each allocation will specify the amount you will be paid and the amount that a randomly selected person in the study will be paid. If this type of task is used to determine your payoff, it will also be the only payment the person you are randomly matched will receive. Similarly, your only payment may be the result of an allocation choice that the person you are matched with makes. If this is the case, you will be informed that at the end of the study by the researcher that your payment is based on someone else's allocation decision as it will not show up on your screen. The person that you are matched with may have different allocation tasks than you have.

The fourth type of question is a pattern recognition task. For each task, you will be shown a 3x3 table and asked to identify the missing element that completes a pattern of shapes. There are 8 multiple choice answers to choose from. For this type of question, a correct answer is worth $17, but an incorrect answer is worth $0.

If you have a question, please raise your hand. Otherwise, press the blue Continue button to learn about the first block of periods.

Continue

Baseline

In this block of 20 periods you will have 21 seconds to give your response to the question for the period.

If you have any questions, please raise your hand now. Once you press start, the computer program cannot be stopped. If you are ready to begin, press Start.

Start

Number Memorization

In this block of 20 periods you will first be given a number to memorize. This number will be shown to you for 5 seconds. You will then have 21 seconds to give your response to the question for the period. After that you will be given 10 seconds to enter the number you were asked to memorize. If a period in this block is randomly selected to determine your payoff, there is a 50% chance you will be paid based on the question you answer and a 50% chance you are paid for correctly recalling the number you were asked to memorize. Correctly recalling the number is worth $30, but an incorrect answer is worth $0.

If you have any questions, please raise your hand now. Once you press start, the computer program cannot be stopped. If you are ready to begin, press Start.

Start

Dot Pattern

In this block of 20 periods you will first be shown a grid of 16 boxes, some of which will be checked, to memorize. This pattern will be shown to you for 3 seconds. You will then have 21 seconds to give your response to the question for the period. After that you will be given 10 seconds to recreate the pattern you were shown. If a period in this block is randomly selected to determine your payoff, there is a 50% chance you will be paid based on the question you answer and a 50% chance you are paid for correctly recreating the pattern. Correctly recreating the pattern is worth $30, but an incorrect answer is worth $0.

If you have any questions, please raise your hand now. Once you press start, the computer program cannot be stopped. If you are ready to begin, press Start.

Start

Auditory 3-Back

In this block of 20 periods you will have 21 seconds to give your response to the question for the period. If a period in this block is randomly selected to determine your payoff, there is a 50% chance you will be paid based on the question you answer and a 50% chance you will be paid for a listening task. The listening task is called 3-back. Starting 6 seconds before the question appears and continuing until the period ends, you will hear a letter spoken every 3 seconds. The listening task is to determine if the letter you hear is the same as the letter you heard 3-back. For example in the sequence A B B A C A B C B, the second letter A is a repeat of the one 3-back (the first A). The last C is also a repeat of the letter 3-back. No other letter in this example is a repeat of the one 3-back. Initially your payment for the listening task is $25. Each time you correctly identify a 3-back repeated letter, by pressing the 3-back button, your payment for the listening task will increase by $8, but everytime you miss a repeated letter or incorrectly identify a letter as having repeated, $4 will be deducted from your payment. Please go ahead and place the headphones on now. This is the only block of questions for which you will need the headphones.

If you have any questions, please raise your hand now. Once you press start, the computer program cannot be stopped. If you are ready to begin, press Start.

Start

Time Constraint

In this block of 20 periods you will have only have 3 seconds to give your response to lottery choice and allocation choice tasks. You will only have 5 seconds to give your response to the multiplication and pattern recognition tasks.

If you have any questions, please raise your hand now. Once you press start, the computer program cannot be stopped. If you are ready to begin, press Start.

Start