The Effects of Stress and Executive Functions on Decision Making in an Executive Parallel Task

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THE EFFECTS OF STRESS AND EXECUTIVE FUNCTIONS ON DECISION MAKING IN AN EXECUTIVE PARALLEL TASK

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The aim of this study was to investigate the effects of acute stress on parallel task performance with the Game of Dice Task (GDT) to measure decision making and the Stroop test. Two previous studies have found that the combination of stress and a parallel task with the GDT and an executive functions task preserved performance on the GDT for a stress group compared to a control group. The purpose of this study was to create and use a new parallel task with the GDT and the stroop test to elucidate more information about the executive function contributions from the stroop test and to ensure that this parallel task preserves performance on the GDT for the stress group. Sixteen participants (Mean Age: 26.88) were randomly assigned to either a stress group with the Trier Social Stress Test (TSST) or the control group with the placebo-TSST. The Positive and Negative Affect Schedule (PANAS) and the State-Trait Anxiety Inventory (STAI) were given before and after the TSST or placebo-TSST and were used as stress indicators. The results showed a trend towards the stress group performing marginally better than the control group on the GDT but not significantly. There were no significant differences between the groups for accuracy on the Stroop test trial types. However, the stress group had significantly slower mean response times on the congruent trial type of the Stroop test, p < .05, though. This study has shown further evidence that stress and a parallel task together preserve performance on the GDT.

Decision making is a very important part of everyday life. It is especially important in situations where multiple tasks involve risky decisions that must be completed under acute stress, such as surgeons performing surgery, law enforcement officials deciding how to deal with an armed person, or decisions made by government figures that affect many
people’s lives. Thus, these situations are becoming more common in different occupations. Stress has many debilitating and terrible effects but there appear to be some redeeming qualities and advantages to becoming acutely stressed in certain situations, such as acute stress improving the selectivity of attention or narrowing of the attention according to the attention view (Chajut & Algom, 2003; Wells & Matthews, 2014).

It has been posited that there are two cognitive strategies for processing information, System 1 and 2. System 1, is a more parallel, simplified, automatic, and intuitive cognitive process and System 2 is more serial (i.e., one thing after the other), requires a higher level of thoughtfulness, more time-consuming, and able to evaluate the various advantages or disadvantages of different situations (Kahneman, 2003). Throughout this study, System 1 will be referred to as parallel processing and System 2 will be referred to as serial processing.

To evaluate decision making in a controlled setting there have been two particularly widely used decision making tasks. First, the Iowa Gambling task (IGT) which evaluates ambiguous decision making where no outcome is calculable and feedback is not given throughout the game, leading participants to rely on their own hunches as to whether each decision is advantageous or disadvantageous (Bechara, A., Damasio, A.R., Damasio, H., & Anderson, S.W., 1994). Second, the Game of Dice Task (GDT) which evaluates decision making under risk with explicit, stable rules and feedback is given so that the participant knows how they are doing throughout the game and if a new strategy may help the outcome (Brand, Labudda, & Markowitsch, 2006). The GDT has been found to utilize more executive functions while being performed compared to the IGT (Brand et al., 2005). Individuals with Korsakoff syndrome (i.e., a disorder from alcohol abuse), which have frontal lobe disturbances and other possible neuropsychological impairments, displayed significantly impaired performance (i.e., made riskier decisions) on the GDT compared to the healthy control group providing evidence that executive functions play a role in low risk decision making (Brand et al., 2005). It has also been found that individuals with low levels of executive functions or intelligence display significantly impaired performance compared to healthy controls on the GDT (Brand, Laier, Pawlikowski, & Markowitsch, 2009).

It has been shown that acute stress can impair decision making on the GDT in a single task (Starke, Wolf, Markowitsch, & Brand, 2008) as well as a parallel task, with the GDT and the n-back (Starke, Pawlikowski, Wolf, Alstötter-Gleich, & Brand, 2011), but when the two variables of stress and a parallel task are combined they appear to cancel themselves out. Pabst, Schoofs, Pawlikowski, Brand, and Wolf (2013) found that stressed participants performing a parallel task displayed preserved performance, and even marginally improved performance, on the GDT in a parallel task compared to the non-stressed participants. The results found that the stressed group did not perform significantly better than the control group on the GDT but there was a significant interaction found between stress and the parallel task (Pabst et al., 2013). Gathmann et al. (2014) also found preserved performance for the stressed group compared to the non-stressed group on a fMRI modified GDT task with the n-back task in a parallel task.
Previous studies have used the GDT and n-back as a parallel task because the n-back stimulates the working memory as well as the prefrontal areas and the parietal areas of the brain (Pabst et al., 2013; Gathmann et al., 2014). The n-back has been employed to put more load on the executive functions of the brain because the GDT already utilizes working memory and other executive functions. The GDT administered with the n-back to healthy participants showed that GDT performance decreased as the n-back test became harder (Starcke et al., 2011). There has been no significant effect of acute stress found on the working memory performance (i.e., the n-back) in the parallel task with the GDT (Pabst et al., 2013; Gathmann et al., 2014).

The traditional Stroop Color-Word Interference Test is a test that evaluates interference and response conflict that was first introduced in 1935 (Stroop, 1935). These two tasks, the GDT and the Stroop test, when performed alone activate very similar brain regions (Labudda et al., 2008; Derbyshire et al., 1998). Thus, the Stroop test appeared be an acceptable replacement for the n-back task in the parallel task with the GDT since it utilizes the executive functions and activates very similar parts of the brain. It may be able to offer insight into the response conflict aspect of the executive functions instead of working memory.

Acute stress has been shown to shift the cognitive processing of information from serial processing, which is more analytical, to parallel processing, which is more basic, simplified processing mode (Gathmann et al., 2014). Gathmann et al. (2014) performed fMRI scans throughout an experiment with a fMRI modified GDT and n-back parallel task and found significant activations in brain regions, such as the Anterior Cingulate Cortex (ACC), that are responsible for parallel processing. This supports the theory that there was a shift from serial to parallel processing under acute stress during a parallel task, which was posited as a possible explanation for the results in Pabst et al. (2013). This evoked acute stress brings the mental or cognitive processing of a stressed person to a more parallel form of cognitive processing compared to the non-stressed person who will be in a serial processing mode that analyzes more information and will not be as able to cope with the parallel processing components of the parallel task (Pabst et al., 2013). This parallel processing mode has been shown to preserve performance on parallel tasks but not on single tasks because it has been reasoned that the situation of a single task does not require the brain to move to a parallel processing mode under stress because the task does not require more resources, whereas the parallel task does (Pabst et al., 2013; Gathmann et al., 2014).

Pabst et al. (2013) also found a significant interaction between Dividing Attention (DA) ability and the experimental conditions (i.e., the stressed group and the control group) on the GDT net score. DA-ability is a measure of how well a person can divide their attention between audible and visual stimuli while attending to both. Pabst et al. found that participants performing a parallel task with a high DA-ability displayed improved performance on the GDT compared to participants with a low DA-ability in the stress group but this relationship was not present in the control group. The participants in the control group with high and low DA-abilities performed similarly on the GDT in the parallel task. It
appeared as though that when a person is under acute stress, a high DA-ability may improve decision making on the GDT in a parallel task, while a low DA-ability may only preserve decision making ability.

The present study used the GDT combined with the Stroop test to further elucidate the roles of executive functions employed in a parallel task as well as evaluate GDT performance under acute stress. The participants were randomly assigned to a stressed group and a control group. The choice of the Stroop test allowed the executive function of response interference or conflict rather than working memory to be evaluated, while maintaining the extra load on the executive functions in the parallel task with the GDT.

It was hypothesized that performance would be preserved or enhanced (i.e., lower risk decisions) on the GDT in the parallel task for the stress group compared to the control group because both tasks utilize very similar brain regions including the ACC which has been found to be very important for parallel processing, which is the processing mode that the stressed participants were in. Furthermore, it was hypothesized that the individuals in the stress group with a higher DA-ability would have better performance, or less risky decision making, on the GDT in the parallel task compared to participants with a lower DA-ability. It was also hypothesized that no significant differences would be found between the high and low DA-ability participants in the control group as previously found by Pabst et al. (2013). This may be due to a more efficient exchange and communication between the ACC and the prefrontal regions which is referred to as the fronto-parietal network in the stressed group (Pabst et al., 2013).

It is further hypothesized that the stress group would perform similarly or better on the accuracy and response times on the three trials of the Stroop test compared to the control group. This is because a stressed individual has been found to display a cognitive shift from serial to parallel processing which may assist and improve performance on multiple tasks (Gathmann et al., 2014).

Methods

Design and Procedure

The present study had a between-subjects experimental design. When the participants arrived they were given an informed consent paper to sign and given the Test of Attentional Performance (TAP 2.3) subtest Dividing Attention (TAP-DA) to perform and fill out demographic information. Then, the participants were given the Positive and Negative Affect Schedule (PANAS) and the State Anxiety Inventory (STAI) to fill out. After that, the participants either started the Trier Social Stress Test (TSST) or placebo-TSST (p-TSST). Directly after the TSST or p-TSST, the participants were given the PANAS and the STAI to complete again. Ten minutes after the TSST or p-TSST was completed, the participants were given the parallel task with the Game of Dice Task (GDT) and the Stroop test. Then the participants were debriefed about the experiment and the aims of the study.
Participants
Sixteen participants were recruited from Umeå University. Recruitment was done through posters displayed in public areas throughout Umeå University. The participants were randomly assigned to either a stress group (7 male, 1 female) or a control group (7 male, 1 female) for a between-subjects experimental design. The stressed group and the control group did not differ in respect to sex, age in years (M = 26.88, SD = 3.81), or executive functions which was measured by the TAP-DA (M = 1.44, SD = 1.31), all ps > .708.

Materials and Apparatus
The TAP 2.3 was displayed on a HP L2245w 22" monitor and Logitech USB headphones were used for sound. The GDT and the Stroop test for the parallel task were created with Millisecond Software in Inquisit 4 Lab, version 4.0.9.0. A Canon video camera with a tripod was used to record participants during the TSST.

Dividing Attention Ability
The Test of Attentional Performance Version 2.3 (TAP 2.3) subtest Dividing Attention (TAP-DA) measured each participant’s DA-ability before the experiment (Zimmermann & Fimm, 2009). This task uses visual and audible stimuli to evaluate how well a person can divide their attention between the two modalities being presented and pay attention to both. The participants were placed 50cm in front of a computer screen and told to focus on a specific area of the screen consisting of a 4x4 rectangle of dots where crosses would appear and were instructed to press a key on a keypad whenever four crosses formed a square. At the same time, the participants had headphones on with high and low tones occurring and were instructed to press the same key on the keypad if the same tone was heard twice in a row. The total score of missed stimuli or omissions was calculated and 2 or less omissions corresponded to high DA-ability according to previous analyses (Zimmermann & Fimm, 2009).

Acute stress Induction
There were two groups with randomly assigned participants, the stressed group and the control group. The stressed group was induced with acute stress from the Trier Social Stress Test (TSST) (Kirschbaum, Pirke, & Hellhammer, 1993) and the control group was given a placebo-TSST (p-TSST) that has been shown to not elicit stress. In the TSST, the participants were told to prepare shortly for a speech and a mental math task that would be videotaped and in front of a committee of 2 individuals, consisting of one man and one woman. The individuals in the committee looked reserved and non caring during the experiment. The committee and the video camera were there to facilitate the social evaluative threats. The participants were told to imagine themselves as an applicant for a job interview, and they were told that they had five minutes to write a 5-minute speech or outline on a piece of paper, about why they were the best applicant for the job position of their choosing. The participants were instructed that the committee was to be thought of as the company managers and that the video tape of the speech would be examined at a
later time. The participants were also informed about an arithmetic task after the speech but were told that they didn’t need to prepare for it. After the participants had finished their 5-minute preparation time, the committee entered the room and the paper used to write the speech or outline was taken from the participants and they were instructed to stand in a specific area in the room to deliver their speech in front of the committee which was seated and a video camera was turned on that was set up beside the committee. The p-TSST was given to the control group similarly but without the videotaping, the committee, and in addition had an easier arithmetic task (Het, Rohleder, Schoofs, Kirschbaum, & Wolf, 2009).

Positive and Negative Affect and State Anxiety Inventory

To assess the changes in stress levels of participants in the stressed group and the control group, the participants were given the Positive and Negative Affect Schedule (PANAS; Watson, Clark, & Tellegen, 1988), which is a 20 question questionnaire made up of 10 positive affect questions and 10 negative affect questions on a 5-point scale, which starts at 1 for "very slightly or not at all" to 5 for "extremely". The answers for both the positive and negative affect questions were added up and the higher the score corresponds to more positive or negative affect, respectively. The State Anxiety Inventory (STAI; Spielberger, Gorsuch, Lushene, Vagg, & Jacobs, 1977), which is also a 20 question questionnaire evaluating one’s current state of anxiety, or state of anxiety at the moment. The questions are answered on a 4-point scale, where "1" corresponds to "Not at all" to "4" which corresponds to "Very much so". The PANAS and the STAI were given to both groups before and after the TSST or p-TSST.

Parallel Task

Both groups will be given a parallel task that has the GDT displayed simultaneously with the Stroop test. The tasks were made available for use by Millisecond Software. The GDT is a computerized program with explicit and stable rules, as well as feedback as to how the game is going, and how much money is currently being held. There is a starting amount of money of 1,000 kr and one dice is thrown every trial for 18 trials. The participants have the choice of choosing 1, 2, 3, or 4 dice alternatives for each trial. The choice of 1 dice leads to a chance to win/lose 1000 kr, the choice of 2 leads to the chance to win/lose 500 kr, 3 dice leads to win/lose 200 kr, and the choice of 4 dice leads to win/lose 100 kr, with the probabilities being 1 out of 6, 2 out of 6, 3 out of 6, and 4 out of 6, respectively, meaning that the more dice chosen for each round offers a higher probability of winning but a smaller amount earned. The 1 or 2 dice choices are considered disadvantageous, or riskier choices because the chance of winning is less than 50% but the 3 or 4 dice choices are advantageous, or less risky choices because the probability of winning is 50% or more for both. Feedback is given throughout the game as to how each trial went, the total amount of capital currently being held, and number of trials remaining. There is no time limit on this task. (Brand et al., 2005).

The Stroop test has three trial types: congruent, incongruent, and control (Stroop, 1935). The congruent trial type will display a word such as "green" and the ink will be
colored green and the correct answer is to name the color of the word, which in this example is green. The incongruent trial type will show a word such as "green" in red ink and the participant is instructed to say the color of the word instead of the written word, which in this example the answer would be red. The control trial types will display a rectangle, which is colored green and the correct answer to this example is green.

The Stroop test used in the current study was a computerized version with 4 keyboard responses. The participants were instructed to place the left hand over the letters: a, s, d, f, and informed that "a" is the response for "black words", "s" is the response for "blue words", "d" is the response for "red words", "f" is for "green words". Since the stroop task was in parallel with the GDT, the response time for each answer on the stroop task was 3 seconds. If the participant took longer than 3 seconds to answer a question on the Stroop test it was counted wrong and a red "X" was displayed on the screen. The number of possible trials each participant performed on the Stroop test was dependent on how long it took them to complete the GDT, which was not timed.

For the parallel task, the participants were placed 50 cm away from the middle of 2 identical computer monitors. The Stroop test was on the left monitor and the GDT was on the right monitor. The participants were shown written instructions on how to perform each task on the respective monitor. The participants were told to, "Try to make the most money on the GDT that you can." Then, the participants read the GDT instructions and were informed that there were 18 rounds total, that they would be given feedback about how much money they currently held throughout the game, that only one dice would be thrown each round, and how each dice combination worked (e.g., if you chose a 2 dice combination, of 4 and 6, and 4 or 6 comes up as the single dice for that round, then you win 200kr, but if 1, 2, 3, or 5 come up then you lose 200kr). After the instructions were read for the GDT, and there were no questions that needed to be answered, there was a short practice of 3 rounds. Then, the instructions for the Stroop test were read and if there weren’t any questions, the participants were given a practice of 15 trials. After this the participants were given a practice session with both the Stroop test and the GDT in parallel, which lasted for 3 rounds of the GDT. After this, the participants were instructed to start the parallel task and to continue until the 18 rounds of the GDT were completed, at which time the parallel task was concluded. The number of Stroop trials was dependent on the time it took to complete the GDT. The three Stroop trial types were randomly presented in the parallel task with the probability of approximately 33% of each trial type being shown.

Ethical Considerations
Participants were given papers to sign stating that they could choose to leave at anytime and were not obligated in any way to continue the experiment if they did not want to. It was understood that it could potentially cause discomfort for some participants and they were explicitly informed that they could leave at any time. In addition, if a participant felt a bit uncomfortable after the experiment, they were instructed sit down and relax for about 15-45 minutes before they left. The knowledge that could be discovered by this type of experiment outweighed the possible discomforts associated with it, because the knowledge
attained could possibly be used to lower the negative effects that are brought about by stress in the future.

Statistical Analysis

All Statistical calculations were performed with SPSS 23.0. The alpha level was set at .05. In regards to sex differences between groups, Pearson’s \( \chi^2 \) was used. The comparisons of age and the executive functions between groups were each analyzed with a one-way analysis of variance (ANOVA). Nonparametric Mann-Whitney tests were used for the GDT net score between groups. An independent samples t-test and a nonparametric Mann-Whitney test as well as a repeated measures ANOVA were conducted to evaluate the positive and negative affect between groups. For the STAI, independent samples t-tests were performed. For the Stroop test, the accuracy percentages for each of the three trial types were evaluated with Mann-Whitney nonparametric tests and the mean response times for the correct answers on the 3 trial types were analyzed with independent samples t-tests. Nonparametric Mann-Whitney tests were used to evaluate the DA-ability effects on GDT performance between groups. For the GDT choice alternatives, the data was logarithmically transformed and analyzed in independent samples t-tests. The last analysis of the GDT choice alternatives was omitted from the results section because there was too small of a sample size to properly analyze the data, so the results could only be looked at as trends and is discussed in the discussion.

Results

Positive and Negative Affect Schedule and State Anxiety Inventory

The self reported affect scores were compared between the stressed group and the control group. The positive affect scores were normally distributed before and after the TSST or p-TSST, but the negative affect scores were not normally distributed so the data was logarithmically transformed. The positive affect scores were compared with independent samples t-tests and the negative affect was compared with both a nonparametric Mann-Whitney test with two independent samples as well as the logarithmically transformed data with an independent samples t-test. There were no significant differences in positive affect before, \( t(14) = -2.04, p = .84 \), or after the stress induction, \( t(14) = .178, p = .86 \), between the groups. There was a significant difference between the stressed group and the control groups’ scores on the negative affect after the stress induction (i.e., TSST or the p-TSST), where the stressed group had a significantly higher negative affect score compared to the control group on both the non transformed data evaluated in a Mann-Whitney two samples nonparametric test (stressed group: \( Mdn = 18.50 \); control group: \( Mdn = 12.00 \)), \( U(16) = 10.00, p = .02 \), and the logarithmically transformed data compared with a two independent samples t-test (stressed group: \( M = 1.25, SD = .15 \); control group: \( M = 1.09, SD = .07 \); \( t(14) = -2.90, p = .012 \), but there were no significant differences between groups negative affect scores before the stress induction, \( t(14) = -.902, p = .382 \) (Table 1). There were no significant differences found with the
independent samples t-tests for the STAI scores before, \( t(14) = -0.81, p = .43 \), or after the stress induction, \( t(14) = -1.64, p = .12 \), between groups.

An ANOVA with repeated measures was performed for both the positive and negative affect, where the within-subject factor was time (before the TSST or p-TSST, and after the TSST or p-TSST) and the between-subject factor was the experimental conditions, the stressed group and the control group. The data for the negative affect was logarithmically transformed because it was not normally distributed. For positive affect, there were no significant changes for the main effect over time \( F(1, 14) = .807, ns, \eta^2 = .06 \) nor an interaction between Time X Condition \( F(1, 14) = .172, ns, \eta^2 = .01 \).

For the negative affect, there were no significant differences in negative affect over time \( F(1, 14) = 2.031, ns, \eta^2 = .13 \), nor was there an interaction between Time X Condition, \( F(1, 14) = 2.909, ns, \eta^2 = .17 \). However, there was a significant between-subjects effect for Condition, where the stressed group displayed a larger increase of negative affect over time (before the TSST: \( M = 1.15, SD = .14 \); after the TSST: \( M = 1.25, SD = .15 \)), compared to the control group (before p-TSST: \( M = 1.10, SD = .11 \); after p-TSST: \( M = 1.09, SD = .07 \)), \( F(1, 14) = 4.78, p = .046 \). This significant difference in negative affect over time between groups is illustrated in Figure 1.

Table 1.

<table>
<thead>
<tr>
<th>Questionnaire</th>
<th>Stress Group M (SD)</th>
<th>Control Group M (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PANAS-Positive Affect</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Before TSST or p-TSST</td>
<td>28.63 (6.07)</td>
<td>27.88 (8.44)</td>
</tr>
<tr>
<td>After TSST or p-TSST</td>
<td>26.25 (7.25)</td>
<td>27 (9.50)</td>
</tr>
<tr>
<td><strong>PANAS Negative Affect</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Before TSST or p-TSST</td>
<td>15 (5.71)</td>
<td>12.88 (3.44)</td>
</tr>
<tr>
<td>After TSST or p-TSST</td>
<td>18.88 (6.24) *</td>
<td>12.38 (1.92) *</td>
</tr>
<tr>
<td><strong>STAI</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Before TSST or p-TSST</td>
<td>39 (10.62) *</td>
<td>34.63 (11.06)</td>
</tr>
<tr>
<td>After TSST or p-TSST</td>
<td>45.63 (9.32)</td>
<td>37.13 (11.36)</td>
</tr>
</tbody>
</table>

Note. The Positive and Negative Affect Schedule and the State-Trait Anxiety Inventory mean scores before and after the TSST or p-TSST for the stress group and the control group. PANAS = Positive and Negative affect schedule; STAI = State-Trait Anxiety Inventory; TSST = Trier Social Stress Test; p-TSST = Placebo Trier Social Stress Test; \( M = \) Mean Score; \( SD = \) Standard Deviation.

* \( p < .05 \)
Figure 1. The mean negative affect scores before and after the Trier Social Stress Test (TSST) and the placebo-Trier Social Stress Test (p-TSST) for the stress group and the control group, respectively. The stressed participants' negative affect increased more over time compared to the non-stressed participants, which displayed a slight decrease in negative affect.

Decision-Making Performance

GDT Net scores were not normally distributed so the data was transformed with logarithmic transformation to normally distribute the data. However, the logarithmic transformation changed the trend of the results. The raw data shows that the stressed group performed slightly better than the control group (stressed group: \( M = 12.88, SD = 8.31 \); control group: \( M = 9.75, SD = 12.49 \)), but the transformed data displayed a trend in the opposite direction, albeit neither was a significant difference, so the transformed data was not evaluated to avoid distorting the data. The results from a Mann-Whitney nonparametric test revealed that there were no significant differences in the GDT net score between the stressed group (Mdn: 17) and the control group (Mdn: 15). \( U(16) = 27.00, ns \). The raw mean GDT net scores between groups is illustrated in Figure 2.

Figure 2. Mean net scores (calculated by subtracting the disadvantageous choices from the advantageous choices) for the Game of Dice Task (GDT) during a parallel task for the stress and control groups. Error bars represent the standard error of the mean.
Stroop Parallel Task Performance

Stroop test performance accuracy, or percentages of correct answers for each trial type (i.e., congruent, incongruent, control) were compared between the stressed group and the control group as well as the mean response times for correct answers on each trial type. The percentages of correct answers for all three trials were not normally distributed and had to be logarithmically transformed. Mean response times for incorrect answers were not included for analysis (Salo, Henik, & Robertson, 2001). Results from the Mann-Whitney nonparametric tests revealed no significant differences between groups in accuracy for all three trial types on the Stroop test: Congruent, U(14) = 23.50, p = .370; Incongruent, U(14) = 26.50, p = .563; control, U(14) = 26.00, p = .527 (Table 2). However, for the mean response times, the stressed group had significantly slower mean response times in the congruent trial type compared to the control group, t(14) = -2.79, p = .015, (Table 3 & Figure 3). There were no significant differences for the incongruent, t(14) = -1.70, p = .11, or control trial types, t(14) = -1.43, p = .18.

Table 2.  
*Accuracy Results of the Stroop Test Trial Types in the Stress and Control Groups*

<table>
<thead>
<tr>
<th>Stroop Trial type</th>
<th>Stress Group M (SD)</th>
<th>Control Group M (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Congruent</td>
<td>91.38 (7.44)</td>
<td>87.63 (10.39)</td>
</tr>
<tr>
<td>Incongruent</td>
<td>84.5 (10.07)</td>
<td>79.13 (17.24)</td>
</tr>
<tr>
<td>Control</td>
<td>91.38 (5.04)</td>
<td>87.38 (10.91)</td>
</tr>
</tbody>
</table>

*Note. Stroop Mean percentages of correct answers for the different trial types during the parallel task. M = Mean; SD = Standard Deviation.*

Table 3.  
*Mean Response Time Results of the Stroop Test Trial Types in the Stress and Control Groups*

<table>
<thead>
<tr>
<th>Stroop Trial type</th>
<th>Stress Group M RT (SD)</th>
<th>Control Group M RT (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Congruent</td>
<td>1,254 (221.13) *</td>
<td>973.75 (178.76) *</td>
</tr>
<tr>
<td>Incongruent</td>
<td>1,296.25 (217.72)</td>
<td>1,115.63 (206.85)</td>
</tr>
<tr>
<td>Control</td>
<td>1,126.25 (185.98)</td>
<td>1,003.75 (155.59)</td>
</tr>
</tbody>
</table>

*Note. Stroop task mean response times for the different trial types during the parallel task. Mean reaction times were measured in milliseconds. M RT = Mean Reaction time; SD = Standard Deviation.

*p < .05.*
Figure 3. Mean response times for the congruent, incongruent, and control Stroop test trial types between groups. The control group performed the congruent Stroop trial type faster than the stress group. Error bars represent the standard error of the mean. *p ≤ .05.

Dividing Attention Ability and GDT Performance

There were not enough participants to properly evaluate the contribution of one's DA-ability but what was available was analyzed in a Mann-Whitney nonparametric test with two independent samples. There were 12 high DA-ability participants and 4 low DA-ability participants in the study, with 6 high DA-ability and 2 low DA-ability participants in both the stressed group and the control group. Mann-Whitney nonparametric tests were conducted on the stressed group and the control group with the GDT net score as the dependent variable and the high or low DA-ability as the between-subjects factor. The Mann-Whitney test for the stressed group revealed that the high DA-ability participants performed significantly better on the GDT (Mdn: 18), with less risky decision making, compared to the low DA-ability participants (Mdn: -5), U(8) = 0.00, p = .032. However, there were no significant differences between the high (Mdn: 15) and the low DA-ability (Mdn: 14) participants in the control group, U(8) = 5.00, ns. Regrettably, due to the small sample size, this can only be looked at as a trend and will be reflected further in the discussion.

Discussion

This study investigated the effects of acute stress on decision making during a parallel task with the Stroop test. The stressed participants displayed more negative affect after the TSST than before while the non-stressed participants displayed slightly less negative affect after the p-TSST compared to before, providing evidence that the stressed participants were effectively acutely stressed (Figure 1).
The results from the GDT net scores from the untransformed data shows a trend towards the stressed group performing slightly better on the GDT during the parallel task compared to the non-stressed group (Figure 2). Although this was not significant, still, according to Starke et al. (2008) where it was shown that stress by itself will significantly decrease performance on the GDT. Thus, this equivalent or slightly better performance on the GDT supports the hypothesis that stress and a parallel task either preserves or improves performance on the GDT for the stressed group compared to the control group. This result provides more evidence that acute stress can preserve decision making skills when a person is giving their attention to more than one task.

This is the first study to create an alternative parallel task from those used by Pabst et al. (2013) and Gathmann et al. (2014) which had the GDT and the n-back task performed in parallel under very similar conditions. Since there have been no significant differences found in working memory performance on the n-back in a parallel task with the GDT (Pabst et al., 2013; Gathmann et al., 2014), this study used the Stroop test to attempt to elucidate the executive functions of response conflict and interference in a parallel task with the GDT. The results from this study on GDT performance in the parallel task are similar to Pabst et al. & Gathmann et al., providing evidence that the combination of the GDT and the Stroop test effectively made an executive parallel task that, when combined with acute stress, was able to preserve decision making skills on the GDT.

One explanation for this preservation of decision making skills in the parallel task may be that there was a performance criteria alteration for the stressed participants compared to the non-stressed participants. The stressed participants preserved and displayed slightly enhanced decision making skills on the GDT (i.e., a higher GDT net score) and modestly achieved more accurate correct answer percentages on each of the trial types in the Stroop test, however their mean response times on each of the Stroop test trial types were slower compared to the non-stressed participants. This may provide evidence that the stressed participants chose to focus more on accuracy rather than speed, producing an accuracy-speed trade-off. There were, however no significant differences in the mean response times in the Stroop incongruent and control trial types so this explanation doesn’t appear to fit the results of the current study. If there was a speed-accuracy trade-off, it would be expected that the stressed participants would display significantly slower response times on the incongruent and control trial types as well as the congruent trial type compared to the non-stressed participants, but this was not the case. This accuracy-speed trade-off explanation appears partially correct but there may be a theory or an explanation that is more supported by the results of the current study.

Another possible explanation may be that the combination of stress and a parallel task may have temporarily changed the way the mind distributes resources for a particular task. An unequal distribution of mental resources may be partially true for this situation. The GDT performance was preserved for the stressed participants and this preservation and slight improvement compared to the non-stressed participants may have slowed mean response times for the three trial types in the Stroop test, albeit not significantly. Although, at the same time, the percentages of correct answers on each of the three trial types in the Stroop test were slightly better, although not significantly, for the stressed participants compared to the non-stressed participants. This redistribution of resources doesn’t appear to fit the results. It doesn’t appear from the results that the mental resources were taken from the Stroop test to perform the GDT better or it would be expected that the Stroop
accuracy would have been impaired as well, so this possibility will also be rejected because the results from the current study do not support it.

Another explanation may be that the acute stress put the stressed participants in a more selective attention mode as postulated in the attention view (Chajut & Algom, 2003). The attention view appears to be gaining more support in recent years since the concept, that selective attention improves when a person is stressed, was first posited in 1959 by Easterbrook. It states that when a person becomes stressed they don’t have as many attentional resources available compared to when they are not stressed, so the prioritized tasks take center stage in the attentional focus and all irrelevant information is not allowed into the focus of attention. This phenomenon can be explained by social facilitation, where person performs better at a particular task when they are looked over by someone, such as a worker having to perform some tasks under the supervision of a boss. The boss’s presence may make the worker slightly stressed and, in turn, cause the worker to lose some of the attentional resources available, which allows the worker the ability to focus on the prioritized task while successfully not acknowledging irrelevant information (Baron, 1986; Huguet, Galvaing, Monteil, & Dumas, 1999). This selective attention on the prioritized task has been shown to increase performance on the tasks seen as relevant. This more selective attention mode may have improved performance on the GDT and the Stroop test accuracy so that it was marginally better than the non-stressed participants but the response times on the Stroop test may have not been a prioritized part of the task. The response time for the Stroop test was possibly acknowledged as an irrelevant aspect of the parallel task as long as the response was given within 3 seconds. This explanation is more in line with the results from the current study, but more can be discovered from evaluating this phenomenon with fMRI or PET scans.

It was hypothesized that the stressed participants would have preserved or better performance on the Stroop test during the parallel task compared to the control group which was partially true. There were marginal increases in accuracy but there were also slightly longer mean response times on the Stroop test trial types for the stressed participants which may be explained by the attention view as well. From the results, it appears reasonable that there was a narrowing of attention towards the two tasks (i.e., the GDT and the Stroop test) for the stressed participants that preserved and marginally enhanced performance on the GDT net score and the Stroop test accuracy compared to the non-stressed participants. The increased mean response times for the stressed participants on the Stroop trial types can possibly be explained by the theory of switching costs, which states that when a person is acutely stressed it takes longer to switch one’s attention between two tasks increasing the task duration compared to non-stressed participants (Plessow, Kiesel, & Kirschbaum, 2012).

Interestingly, the congruent trial type was performed with significantly slower mean response times for the stressed participants compared to the non-stressed participants but the incongruent trials that are responsible for interference during the Stroop test were not significantly different between groups. It was expected that if some sort of decline in mean response time was produced by the acute stress during the parallel task it would be found in the incongruent trial type.

Several studies have shown robust activations in the Anterior Cingulate Cortex (ACC) for the GDT (Labudda et al., 2008) and the Stroop test (Beste et al., 2012; Derbyshire, Vogt, & Jones, 1998; Pardo, J.V., Pardo, P.J., Janer, K.W., & Raichle, M.E., 1990) as well as for
acute stress (Gathmann et al., 2014). One possible explanation for the stressed groups’ impairment in the congruent trial type compared to the control group is that the GDT, acute stress, and the Stroop test all activate the ACC. This increased activation of the ACC may have led to this brain region being overloaded. The n-back task, which was used in the previous parallel tasks, does not activate the ACC so this may have produced a difference in the parallel task performance (Schmidt et al., 2009). The results from the current study, however, do not appear to support this explanation that the ACC was overloaded because a higher level of impairment would have been expected for the stressed participants in the GDT and Stroop test if that was the case, so this explanation was rejected.

Roelofs, Van Turennout, & Coles (2006) found that, for healthy participants, there was more ACC activation during incongruent compared to congruent and control trial types in the Stroop test. In addition, less activation has been found in healthy participants during the congruent compared to the control trial types (Laird et al., 2005). The conflict detection hypothesis states that when there is conflict such as in incongruent trials in the Stroop test, there is a conflict monitor in the ACC that recruits the lateral prefrontal brain regions to help with the conflict (Botvinick, Braver, Barch, Carter, & Cohen, 2001). This may be the reason why there was no significantly impaired mean response time on the incongruent trial type for the stressed participants compared to the non-stressed participants. Since the ACC was already more activated by acute stress (Gathmann et al., 2014) as well as the two tasks in the parallel task, the GDT (Labudda et al., 2008) and the Stroop test (Beste et al., 2012; Derbyshire et al., 1998; Pardo et al., 1990), it appears reasonable that the ACC may have had better communication with other brain regions, possibly the lateral prefrontal regions, preventing impairment on the incongruent trial type in the Stroop test in the parallel task.

The decreased level of activation in the ACC during the congruent trial type in the Stroop test was possibly not able to be executed because acute stress has been shown to increase ACC activity (Gathmann et al., 2014). This may have produced a significant decline in the stressed participants’ mean response time in the congruent trial type compared to the non-stressed participants. This may have been due to the stressed participants possibly exhibiting enhanced activation in the ACC because of the acute stress during the congruent trial types that produced altered behavioral performance compared to the non-stressed participants.

It appears that the acute stress has hindered the performance on the congruent trial type for the stressed participants and made it so that they performed very similarly in the congruent and incongruent trial types. This may have also been due to the increasing conflicting demands from the parallel task. There was, more than likely, conflict management occurring in the parallel task because the GDT responses had to be suppressed every couple of seconds to complete the Stroop test, because each Stroop trial only lasted three seconds. It appears reasonable that the acute stress and this increase in conflict very likely increased activity in the ACC and altered the stressed participants’ behavior but neuroimaging studies are needed to find out more.

Another possible explanation for the decline in performance on the congruent trial type in the Stroop test was that when the acute stress was induced, there was a shift from System 1, serial processing to System 2, parallel processing, which was shown to occur through specific brain region activations, primarily the ACC, in a study by Gathmann et al. (2014). This parallel processing, as stated in the introduction is more intuitive, less
analytical, and much quicker. Since this change, very likely, took place for the stressed participants, the connection between the automatic reading behavior utilized in the congruent trial type to the conscious attention may have been somehow delayed. This could be due to the fact that the ACC deals with the processing of parallel task as well as conflict monitoring. Automatic reading ability or the automaticity theory (Laberge & Samuels, 1974; MacLeod, 1991) is a possible reason that the congruent Stroop trial type is performed with a faster response time compared to the incongruent trial type. Even though the participant is told to not read the word, a person's automatic reading ability is faster and more trained throughout life than naming a color so the brain will automatically read the word first before naming the color. In the congruent trial type (e.g., the word "blue" printed in blue ink), this automatic reading behavior usually assists in the process improving response time because the reading can assist the response, but with the incongruent trial type (e.g., the word "blue" printed in red ink), this automatic reading behavior usually impairs response time because the reading primes the participant to the wrong answer and this response conflict has to be corrected before the correct response can be given. The congruent trial type mean reaction time impairment for the stressed participants compared to the non-stressed participants may be due to the automatic reading behavior possibly having a delayed communication with the conscious attention because of the acute stress. Thus, the automatic reading behavior probably occurred for the stressed participants but the decrease in analytical reasoning, brought on by the parallel processing because of the acute stress, may have delayed the read information from reaching the selective attention in a timely manner.

In regards to DA-ability, there were not enough participants to effectively look at the main effects or interactions of this variable. There were 12 high DA-ability participants and 4 low DA-ability participants based on the omission number recommended by the TAP 2.3. Results from the current study were similar to Pabst et al. (2013) that found a significant interaction between DA-ability and experimental condition (i.e., the stressed group or the control group), that showed preserved or even enhanced performance on the GDT for the high DA-ability compared to the low DA-ability participants in the stress group, but no differences in the control group. In the current study the interaction between DA-ability and condition could not be properly evaluated but the relationship where the participants in the stressed group with a high DA-ability performed better than the low DA-ability participants on the GDT but no differences found for DA-ability for the non-stressed participants. Although, there was a significant effect found, due to the small sample size, this finding can only be looked at as a trend.

It is also noteworthy that the standard deviations for the Stroop test mean reaction times for the stressed participants were all larger than the non-stressed participants. This may be due to the contribution of the DA-ability in the stress group. It may be that DA-ability may have contributed to this larger variance of response time scores because the participants with a high DA-ability may have displayed faster and the participants with a low DA-ability may have displayed slower response times on the Stroop test in the parallel task.

Furthermore, it is noteworthy that the different choice alternative selections of the different options of dice (i.e., 1, 2, 3, 4 dice combinations) were looked at. The 1 and 2 dice combination options were the riskier, more disadvantageous decisions and the 3 and 4 dice combination options were less risky, advantageous decisions. Out of the 16 participants in
the current study, eight in each group, 2 of the non-stressed participants chose the 1 dice combination, which is the riskiest, most disadvantageous decision but none of the stressed participants chose this option. The data was transformed logarithmically and evaluated with independent samples t-tests and there was a significant effect found, where the non-stressed participants chose the 1 dice block choice alternative significantly more than the stressed group. This finding possibly provides further support that the acute stress and a parallel executive task, combined together, preserve decision making on the GDT because it has been found that a parallel task by itself will significantly impair decision making performance for non-stressed participants, meaning choosing riskier choices (Starke et al., 2011). Since the non-stressed participants chose riskier choices compared to stressed participants it may have been because of an impairment in their decision making ability due to the parallel task. This significant finding, however, can only be looked at as a trend instead of a significant effect since there were not enough participants to properly evaluate this phenomenon.

One limitation of the present study was that cortisol and salivary alpha-amylase (sAA) concentrations could not be collected during the study due to budget issues. This would have allowed further confirmation that the participants in the stressed group were successfully acutely stressed and that the participants in the non-stressed group were not. Another limitation was the small sample size.

Conclusion

This study provides further evidence that the combination of acute stress and a parallel task preserve decision making performance on the GDT. This study has also created a new parallel task, which consists of two executive function tasks: the GDT and the Stroop test, that found results in line with the other parallel task utilized (Pabst et al., 2013; Gathmann et al., 2014). The results showed that there were no significant differences found on the GDT performance between the stressed and non-stressed participants, however the stressed participants performed slightly better on the GDT which is possibly explained by an increase in selective attention due to acute stress according to the attention view (Chajut & Algom, 2003). The results from the current study for this parallel task offer a new opportunity to conduct fMRI and PET scans to gain a better understanding into the parallel processing and ACC activations that are taking place during this parallel task under acute stress. It would also be of great interest to increase the level of parallel processing by increasing demands in a parallel task and evaluate how high of a threshold of multi-tasking can be preserved or slightly improved for a stressed participant compared to a non-stressed participant.

The Stroop test performance only had a significant difference in the mean reaction time for the Stroop congruent trial type between groups. This may be due to a delay in reading comprehension or altered ACC activations for the stressed participants. Further studies are needed to fully understand why the congruent trial type mean reaction time was significantly impaired. The DA-ability appears to have, at least, shown a trend where the participants with a high DA-ability perform better on the GDT compared to the low DA-ability participants in the stress group, but the high and low DA-abilities had no effect on the non-stressed participants.
If further studies find that individuals with a high DA-ability have better performance, or less risky decision making on the GDT during the parallel task during stress, this information can be further studied and possibly lead to utilizing one’s DA-ability to see how well they will make decisions under stress in many types of different situations. How a person deals with stress may have more to do with their level of executive functions, possibly certain aspects of executive functions such as one’s DA-ability. If a person is in regularly stressful work situations making important decisions on many tasks that have a lot of risk it may possibly be better suited for an individual, with a high DA-ability, that can effectively make low risk decisions when there are many lives on the line. The results from the current study could give further evidence toward a phenomenon that could have far reaching effects. This DA-ability may be a very important indicator as to how stress affects one’s abilities to make decisions on multiple tasks simultaneously. Multiple tasks and important decisions are very common factors in everyday life situations, often under stress, and this executive function of DA-ability may be a predictor as to how well a person can effectively cope with a stressful situation or not. In occupations this could lead to lives saved directly or indirectly. If further studies confirm this phenomenon this could be an aspect that could potentially be included in the evaluation of an individual for a position that requires making decisions under risk on multiple tasks and at the same time under stress.

Another trend that was found was that non-stressed participants chose riskier dice alternatives in the GDT compared to the stressed participants, which is in line with Starke et al. (2011) which found that a parallel task will impair performance on the GDT for non-stressed participants. In future studies, larger sample sizes are needed so that DA-ability effects, gender, and risky choice options on the GDT and the interactions between these variable can be properly evaluated. Further studies on different nationalities are needed as well since the current study applies to a sample from the Swedish population and different nationalities may deal with and be affected by acute stress in various ways. The results from the current study for this parallel task offer a new opportunity conduct neuroimaging studies to gain a better understanding into the parallel processing and ACC activations that are taking place during this parallel task under acute stress. There is a need to increase the knowledge about stress and all of its effects on humans because it is becoming a more common and central part of everyday life. In order to deal with the detrimental and sometimes positive aspects of stress more efficiently and effectively, a more developed understanding about acute stress is needed.

References


Plessow, F., Kiesel, A., & Kirschbaum, C. (2012). The stressed prefrontal cortex and goal-directed behaviour: acute psychosocial stress impairs the flexible implementation of task goals. Experimental Brain Research, 216(3), 397-408.


