The Effects of a Cognitive Control Manipulation on Anxiety: A Longitudinal Study

An honors thesis for the Department of Psychology

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Abstract

Proactive control is the ability to approach a task with top-down recruitment of attention focusing on the tasks' goals, which are cognitively maintained prior to attention-demanding tasks. People suffering from high anxiety perform poorly on attention-demanding tasks, unlike healthy individuals, who tend to employ proactive control while doing so. It may be that low proactive control actually causes high anxiety but previous research has not yet examined whether experimentally manipulating proactive control reduces anxiety. In this study, participants experiencing moderate-to-high anxiety were randomly assigned to a proactive or control cognitive training condition, which took place across four days to ensure participants were fully equipped with their respective strategies. Electrocardiography (ECG), skin-conductance (SCL), and self-reported anxiety levels were used to measure anxiety levels. On the final day, participants completed a stress-task to see the effect of the four-day training on stress-induced anxiety. Immediately following the training on day four, there was no difference in anxiety levels between proactively trained and control participants. However, consistent with the hypothesis, following the stressor, participants in the proactive cognitive training condition experienced less of an increase in somatic anxiety than participants in the control condition. In addition, ECG data indicated that the proactively trained participants' increase in heart rate was significantly less than the control participants' increase in heart rate. The absence of an effect prior to the stressor on day four indicates that the difference in training strategies lead to the differential response to the stressor between groups. This suggests that proactive cognitive training has an anxiolytic effect, and thus, with further research, can be implemented into anxiety treatment programs.

Keywords: anxiety, cognitive control, attention

The Effects of a Cognitive Control Manipulation on Anxiety: A Longitudinal Study

Anxiety is the most common mental illness in the U.S., affecting 18% of adults (Anxiety and Depression Association of America, 2014). It is characterized by internal unrest thereby triggering bodily nervousness and cognitive apprehension of particular situations. People who suffer from anxiety often see ordinary situations as particularly menacing, and consequently, anxiety negatively affects their daily life. Despite its treatable nature, only one-third of those suffering from anxiety receive treatment (Anxiety and Depression Association of America, 2014). Anxiety is associated with increased substance abuse, decreased academic performance, and has even been shown to have negative effects on social interactions, to name a few debilitating effects of anxiety on daily functioning (Neighbors, Kempton, Forehand, 1992; Wood, 2006). A plethora of research has been conducted in an attempt to identify the causes of anxiety in order to develop effective treatments. One of the most compelling proposed causes of anxiety is cognitive control.

According to Edwards, Barch, and Braver (2010), cognitive control is the ability to perform a task in the service of particular goals. According to these authors, people with anxiety often suffer from cognitive control deficits, thereby resulting in atypical attentional deployment. As a result, people with anxiety tend to perform a task without directing their attention to the goal. For example, if someone is playing an amusement park game where they slam the gavel when they see a target, someone using proactive control would have their arms up, ready to hit when the target appeared. Contrarily, someone who does not prepare would have his or her arms at ease and react only once the target appears, thereby reducing his or her chance of having a successful hit. Eysenck, Derakshan, Santos, and Calvo (2007) explain that people in an anxious state are often distressed about threats to a current goal; thus, they strive to develop effective strategies to lessen anxiety in order to achieve the goal. Often, these strategies weaken attention to task-relevant information, as participants are

preoccupied with eliminating the threats. This reduces their ability to accomplish the goal successfully.

Based on this, Braver (2012) developed the dual mechanisms of control (DMC) framework, which suggests that there are two modes of cognitive control: proactive and reactive. The DMC framework differentiates proactive and reactive modes of control based on temporal differences. Braver, Gray, and Burgess (2007) argue that properly selecting the mode of cognitive control is important in defeating cognitive challenges and thereby enhancing overall quality of life. When there is over-reliance on one mode over the other, problems tend to arise.

Proactive control involves maintaining anticipation for goal-relevant information within the lateral prefrontal cortex (PFC), resulting in optimum performance of the task. Proactive control engages top-down attention processing, since the goals are cognitively sustained and tended to prior to the emotionally or cognitively demanding task. Reactive control engages bottom-up processing, since attention is directed as a delayed correctional mechanism. Proactive and reactive modes of control may be distinguished behaviorally using the AX-Continuous Performance Task (AX-CPT; Paxton, Barch, Storandt, & Braver, 2006).

In the AX-CPT, participants are asked to respond to cue-probe letters presented in a sequence. A "target" is composed of "A" (cue) followed by "X" (probe), which was also the most frequent sequence. A "nontarget" is composed of any other sequence of cue-probe letters letters. With proactive training, participants are told to focus on whether the cue is "A" or "not A," to help prepare them for their response. If it is "A" and a "X" follows, they are more likely to respond with higher accuracy and lower reaction time following the probe, than if they did not say "A" or "not A."

The task often misleads participants, causing them to make incorrect responses, which indicates the type of cognitive control used. Due to the high frequency of "AX" trials,

participants tend to get complacent and make mistakes when they see the cue "A" but some other "nontarget" probe "Y." These mistakes indicate that participants are using proactive control because they are actively attending to the cue that could signal an impending "X" probe. Mistakes on "BX" trials indicate that participants are using reactive control, since participants respond to the "X," failing to recall that a non-A preceded it. Such training of proactive control with the AX-CPT has increased overall proactive control in patients with schizophrenia (Edwards et al., 2010) as well as in older adults (Paxton et al., 2006). Preliminary research in our lab has also been conducted to see the effect of proactive control training on lowering anxiety symptoms in people with moderate-to-high trait anxiety (Rogers, 2014).

Rogers (2014) conducted a preliminary study that trained high anxiety participants in proactive control versus reactive control to test whether proactive control training would reduce anxiety symptoms, measured by mood ratings, state-anxiety self-report measures, as well as physiological measures like heart rate and skin conductance. There was a marginally significant reduction in heart rate for participants in the proactive condition compared to the reactive condition in an anxiety-provoking situation. However, overall Rogers (2014) speculated that the strategies did not have a distinct enough difference, since both proactive and reactive training conditions were cognitively demanding. Comparing the proactive training condition to a control condition, in which no strategy is instructed, may result in an effect. Additionally, Rogers' study implemented a one-time dose of the AX-CPT training, which may not have been sufficient to equip participants with proactive control strategies. Thus, it remains unclear if proactive control training reduces anxiety in younger adults.

As a result, the previous study's findings informed the design of the present study, which implemented a modified version of the AX-CPT training. It was designed to examine the effect of proactive training on high anxiety participants compared to a control condition,

rather than in comparison to a reactive training condition. The control condition does not equip the participants with any strategy on how to approach the task. This allows one to precisely conclude if proactive training reduces anxiety symptoms compared to participants who lack such strategies. Supporting the decision to test proactive versus control instead of proactive versus reactive, Paxton et al. (2006) implemented a proactive training versus control training method and found significant decreases in "BX" trial reaction time (RT) in the proactive training condition. However, this was found in the context of older adults, as there has not yet been research conducted on anxiety patients.

Contrary to Rogers (2014) study where participants underwent a one-time AX-CPT training, participants in the present study would undergo the proactive training over four days, to assure that the dose of proactive training was sufficient.

The training itself may not lead to alleviated anxiety symptoms, but the anxiolytic effect may only emerge in the context of a stressful, anxiogenic situation. Davis, Dunlop, Shea, Brittain, and Hendrie (1985) found that there were little biological baseline differences between high and low trait anxious students. Group differences increased in stressful conditions, indicating that trait anxiety is primarily distinguishable in the presence of a stressor.

In the present study, it was hypothesized that when high anxiety participants undergo proactive training over the course of four days there would be a reduction in anxiety measured via self-reported subjective experience, heart rate, skin conductance, compared to a control condition. Based on the background research, a control condition was used to ensure a conclusive difference between the training programs, and because it is more clinically applicable. This effect may only emerge in the context of a stressful or anxiety-provoking experience.

Method

Participants

There were 59 participants (40 females) between the ages of 18 and 55 years (M_{age} = 22.56). Participants were recruited from Craigslist.com and tuftslife.com. They were compensated $15 per hour. Participants were 67% female, 3.5% Hispanic or Latino, 39% Asian, 11% Black or African American, 37% White, and 13% declined to provide information. Participants were eligible to participate in the study if they had elevated levels of trait anxiety, which was determined via online administration of the State Trait Anxiety Inventory (STAI-Y2; Spielberger, 1983). If participants' trait anxiety score on the STAI-Y2 were above a score of 42, the median level for a college-aged population (determined based on an independent sample of undergraduates at Tufts University), they were considered eligible. This research was approved by the Social, Behavioral, and Education Research Institutional Review Board at Tufts University.

Materials

AX-CPT. The AX-CPT, established by Edwards et al. 2010, is a training paradigm designed to manipulate cognitive control. Participants were randomly assigned to either a proactive training condition or a control condition, and completed the AX-CPT on all four days of the experiment. On days one and four, the AX-CPT task was administered in the lab using E-prime 2.0 software (Psychology Software Tools, Pittsburgh, PA). On days two and three, it was administered remotely using Inquisit Millisecond 4.0 software (Millisecond Software LLC, Seattle, WA).

Both conditions displayed cue-probe pairs of letters, which were separated by 1000 ms. The cue-probe pair was a target if it was an A followed by an X, while any other cue-probe pair was a non-target. Participants responded to targets and non-targets with the mouse, with the left and right click counterbalanced across the participants. The target pair, A

followed by X (AX trials), was presented 70% of the time. The three other trial types (AY, BX, BY), where B and Y are letters that are not A or X, respectively, were presented with 10% frequency.

All participants completed nine training blocks of ten trials each, followed by the actual task, which included three blocks of 100 trials each. The sequence of each trial was as such: there was a black screen (800 ms) followed by the cue (250 ms), which was a white letter (size 48 Helvetica) on a black screen. Following the cue, there was the cue-probe interval, which was a black screen (1000 ms) followed by the probe (250 ms), which was another white letter (size 48 Helvetica). After the probe there was a black screen (700-900 ms) serving as the participants' response window, where each subject indicated whether the trial was a target or non-target sequence. There was an auditory "ding" sound if the response was not made within 800 ms after the probe, instructing the participant to respond faster, however no other accuracy feedback was provided to participants.

Proactive training condition. Participants in the proactive training condition were instructed to focus their attention on the cue and maintain proactive control when responding to targets. In the nine training blocks containing ten trials each, the first three training blocks notify participants to focus on the cue, the first letter in the pair, and determine if it is "A" or "not A." In block one, the computer states the correct answer while the subject listens. In block two, the subject states the answer without the computer, and in block three, the subject was told to state the answer and click the correct button on the mouse. The objective of the instructions in blocks four, five, and six, was to assist the participants in identifying target sequences by preparing them to respond when they saw an "A" as the cue. In block four, the subject was instructed to click and listen as the computer said "if X, target" immediately after an A was presented. Accordingly, the participant was instructed to click "non-target" if a non-A was presented, immediately after hearing the computer say "non-target." In block five,

participants stated the answer without computer assistance while clicking. In block six, participants stated the answer with computer assistance while clicking. In blocks seven, eight, and nine, participants were told to continue clicking and say "if X, target" and "non-target" without computer. Following the nine practice blocks of 10 trials each, the main blocks began, which contained three blocks of 100 trials without speaking. The goal of the proactive condition was to ensure that participants were preparing to respond to each cue-probe pair based on a controlled decision about the cue before the probe was presented. As a result, participants in the proactive condition should be more susceptible to AY trial errors, as they are prepared to hit "target" after seeing the cue, and mistakenly do so after seeing the probe, even though it is not an X.

Control training condition. Participants in the control training condition did not receive any special instructions about how to focus their attention on cues or probes in each trial. No strategy was provided to these participants. In the first two training blocks, participants were instructed to not click anything and simply observe the cue and probe for each trial presented on the screen. In the remaining seven training blocks, participants were instructed to click to respond to the targets and non-targets with the correct mouse button, respectively. Unlike the proactive control condition, they were not instructed to state anything nor did the computer verbally assist them at any time. Since these participants were not given any cognitive controlling strategy that demanded attention, this training should have made participants susceptible to BX errors, as they selected "target" after seeing the X, failing to remember what the cue was.

Trier Social Stress Test (TSST)

The TSST was a tool implemented as a stress-task to induce anxiety on day four in the laboratory (Kirschbaum et al., 1993). Participants were asked to perform a speech and mathematics task. Participants learned that they would be assessed and video recorded as

they spoke for five minutes regarding their organizational skills and ability to accomplish deadlines under pressure. They were given three minutes of preparation time in which they were allowed to take notes, but the notes were taken away before the speech performance began. When the speech began, participants were able to see their faces being video recorded in the screen before them. The speech lasted for five minutes and if participants got quiet before the five-minute mark, the experimenter told them how much time was remaining and that they should continue. The math task began immediately after. In this task, participants were told to count backwards from 2,223 in increments of 17. They were also told that the task is easy and that if they made a mistake, they would have to start again from 2,223.

Self-reported Anxiety

State anxiety was evaluated using the state version of the State Trait Inventory for Cognitive and Somatic Anxiety (STICSA; Ree et al., 2000). The goal of this measure is to assess participants' self-reported cognitive and somatic anxiety at different points of the experiment. The STICSA contains 21 items for participants asking them to rate how they feel at that moment. Participants responded using a Likert scale, which ranged from 1 (*not at all*) to 4 (*very much so*). Eleven of the 21 items addressed somatic symptoms of anxiety (for example, "*My heart beats fast"*) while the remaining ten assessed cognitive symptoms of anxiety (for example, "*I have trouble remembering things"*).

Autonomic Physiology

The physiological measures used were electrocardiography and electrodermal activity. These data were collected using Biopac technology in a MP150 system (Biopac, Goleta, CA) and processed in ANSLAB (Wilhelm & Peyk, 2005).

Electrocardiography (ECG). ECG was used to measure heart rate, which is determined by the parasympathetic and sympathetic branches of the autonomic nervous system. Two Ag/AgCl electrodes were placed underneath the participants' collarbones,

which contained 7% chloride gel (1 cm circular contact area). Prior to the electrode placement, the two locations were swabbed with an alcohol prep pad and then an electrode prep pad. The frequency at which ECG was measured was 1000 Hz. The two electrodes were disposable and thus thrown away after each participant.

The ECG signal, monitored on AcqKnowledge software 3.2 (Biopac, Goleta, CA) was downsampled to 400 Hz and bandpass-filtered from 0.5 to 40 Hz. ANSLAB algorithms automated R-spike identification and created interbeat intervals (IBI). R-spikes that ANSLAB missed, causing a long period between consecutive R-spikes, were interpolated manually. Conversely, when R-spikes were identified mistakenly, they were manually removed. After artifacts were corrected, the IBI series was converted to heart rate in beats per minute. Following this, the heart rate data were decimated to 10 Hz and then smoothed with a one-second prior moving average filter.

Skin Conductance Level (SCL). The sympathetic activation of the autonomic nervous system was measured using skin conductance. Two Ag/AgCl electrodes were placed on the distal phalanges of participant's index and middle finger on their non-dominant hand, which contained 0.5% chloride isotonic gel (1 cm circular contact area). A third electrode was placed on the back of the participant's neck serving as a ground. SCL activity was recorded with DC coupling and constant voltage electrode excitation at 31.25 Hz (sensitivity =0.7 nS). Following this, the SCL data were decimated to 10 Hz and then smoothed with a one Hz low-pass filter.

A number of additional questionnaires were administered, but the results will focus on the primary goals outlined in the introduction. Accordingly, results based on these additional measures will not be presented in this manuscript (see Appendix A for descriptions of the additional measures).

Procedure

On day one, participants came into the lab and provided written informed consent. Participants completed STICSA and Mood Ratings in a packet, and then completed the AX-CPT training and task having been randomly assigned to either the proactive training condition or the control training condition. Participants were instructed through practice trials and then completed the actual task. Following the AX-CPT, STICSA and Mood Ratings were recorded again.

On days two and three, participants accessed the tasks remotely and completed this part of the study at their convenience outside of the lab. On day one, the participants indicated available times on days two and three for the task links to be sent to them. Participants also received brief instructions orally on day one, explaining how to complete days two and three. The links were emailed at the scheduled times and the email included instructions on how to complete the tasks. The online STICSA and Mood Ratings redirected participants to the AX-CPT task programmed via Inquisit millisecond software. Participants then completed the STICSA and Mood Ratings again following the AX-CPT task. Note that participants who were randomly assigned to proactive or the control training condition on day one remained in that condition throughout the four days of the study. Thus, on days two and three, they were sent the script that would direct them to the training condition in accordance with their day one assignment (see Figure 1 for the procedures followed on days one, two, and three).

On day four, participants returned to the lab. ECG sensors were placed below the collarbones, and skin conductance SCL sensors were applied on the index and middle finger of their non-dominant hand. Physiological data were collected as participants completed day four tasks. Participants were first asked to fix their eyes on a fixation cross presented to them

in the middle of their screen for two minutes while physiological measures were recorded. This served as a baseline to account for individual differences in self-reported anxiety and physiology. Participants then completed STICSA and Mood Ratings and then completed the AX-CPT training and task reflecting their condition assignment one last time. Following AX-CPT, STICSA and Mood Ratings were completed. Participants then moved on to a modified TSST. After the TSST, participants once again completed STICSA and Mood Ratings. Questionnaires were then administered on the computer and participants watched a comedic video clip to lighten the induced anxiety from the TSST. Participants were debriefed and any questions or concerns were addressed (see Figure 2).

Data Retention and Analysis

All AX-CPT data from the 59 participants were analyzed for the behavioral data, self-report questionnaires, ECG, and SCL. Three participants exhibited outlying values for heart rate and one participant exhibited outlying values for skin conductance; excluding these participants from those analyses yielded similar results, thus the results reported below do not exclude them. Some data were missing as two participants opted out of the TSST and one participant's ECG and SCL signal was illegible, so it could not be used.

Inquisit Millisecond data was not included in the analysis. This is because examining the shift in somatic and cognitive anxiety and physiology from days one to four were considered sufficient to test the stated hypotheses.

General linear models (GLM) were used to analyze data, and baseline scores were used to account for individual differences in self-reported anxiety and physiology.

Results

Preliminary Analyses

AX-CPT Manipulation Check. Using a 4 (cue-probe trial: AX, AY, BX, BY) x 2 (group: proactive reactive) x 2 (day: day 1, day 4) GLM, a significant main effect of cue-probe trial was detected for accuracy, $F(3,48) = 20.97$, $p < 0.001$, and for response time, $F(3,46) = 222.03$ $p < 0.001$. Accuracy and response time differences between the proactive and control groups were examined using pairwise comparisons (see Figure 3 for mean accuracies and Figure 4 for mean reaction times). Pairwise comparisons across the two groups resulted in significant differences among all cue-probe trial types except between BX and BY trials, which yielded similar mean accuracies and reaction times. This indicates that participants responded as they should have: the most slowly and the most errors in the AY trials and the fastest and the least errors in the BX and BY trials.

The AY and BX trials were considered to be the most sensitive to validate proactive versus control conditioning, so they were used to investigate the extent of success in the training paradigm. There was no difference between groups in cue-probe trial accuracy, $F(3,48) = .69$, $p = 0.56$, nor in cue-probe trial reaction time, $F(3,46) = .77$, $p = 0.52$. According to all pairwise comparisons, there was no difference between groups in cue-probe trial accuracy or reaction time for all cue-probe trial types, as all p-values were above 0.05 (see Table 1).

Overall, the above findings suggest, surprisingly, that there were little behavioral differences between the proactive and the control groups. However, some of the expected effects did not emerge. Participants in the proactive condition were expected to have higher reaction times and lower accuracy on AY trials than participants the control condition, while participants in the control condition were expected to have higher reaction times and lower accuracy on BX trials than participants in the proactive condition.

TSST Manipulation Check. Using a 3 (time: baseline, pre-TSST, post-TSST) x 2 (group: proactive reactive) GLM, a main effect of time was present across both proactive and

control groups for self-reported somatic anxiety, $F(2,56) = 14.10$, $p < 0.001$, and to some extent for self-reported cognitive anxiety, $F(2,56) = 1.96$, $p = 0.15$. Both groups showed significant somatic anxiety increases from pre-TSST ($M = 15.90$, $SD = 4.69$) to post-TSST tasks ($M = 17.39$, $SD = 5.05$). This indicates that the TSST successfully induced somatic anxiety across groups (see Figure 5). Self-reported cognitive STICSA scores showed the expected trend, however the difference from pre-TSST ($M = 17.59$, $SD = 5.73$) to post-TSST ($M = 18.37$, $SD = 6.37$) was not significant (see Figure 6).

Using a 4 (task: baseline, speech preparation, speech, math) x 2 (group: proactive, control) GLM, a significant main effect of task was observed for heart rate, $F(3,50) = 23.83$, $p < 0.001$. As expected, all participants had significant increases in HR from baseline to the TSST speech preparation (see Figure 7). Additionally, a main effect of task for SCL was observed, $F(3,52) = 31.69$, $p < 0.001$. As expected, all participants had significant increases in SCL from baseline to the speech task. Together, these data suggest that the TSST produced a state of acute anxiety (see Figure 8).

Hypothesis Testing

Primary goal: Did proactive training reduce anxiety relative to the control condition? A 3 (time: baseline, pre-TSST, post-TSST) x 2 (group: proactive, control) GLM was used to analyze self-reported STICSA data on day four. For cognitive self-reported anxiety, there was no significant main effect for time, $F(2,56) = 1.96$, $p = 0.15$, nor for group, $F(2,56) = 1.15$, $p = 0.29$. The control group demonstrated a higher increase in anxiety from pre-TSST ($M = 16.76$, $SD = 5.16$) to post-TSST ($M = 18.03$, $SD = 6.51$), $p = 0.031$, than the proactive group's increase from pre-TSST ($M = 18.40$, $SD = 6.22$) to post-TSST ($M = 18.70$, $SD = 6.31$), $p = 0.59$, and this interaction was marginally significant, $F(2,56) = 3.15$, $p = 0.051$. There was no significant difference between the mean scores of the proactive group ($M = 18.73$, SD = 6.15) and control group ($M = 16.31$, SD = 6.22) for self-reported cognitive

anxiety at baseline, $p = 0.11$ (see Figure 6). For somatic self-reported anxiety, there was a significant main effect for time, $F(2,56) = 14.07$, $p < 0.001$, but none for group, $F(2,56) = 0.003$, $p = 0.957$. The control group demonstrated a higher increase in anxiety from pre-TSST ($M = 15.66$, $SD = 4.39$) to post-TSST ($M = 18.00$, $SD = 5.85$), $p = 0.001$, than the proactive group's increase from pre-TSST ($M = 16.13$, $SD = 5.02$) to post-TSST ($M = 16.80$, $SD = 4.15$), $p = 0.33$, $F(2,56) = 2.04$, $p = 0.14$. There was no significant difference between the mean scores of the proactive group ($M = 15.10$, SD = 3.49) and the control group ($M = 14.21$, SD = 3.82) for self-reported somatic anxiety at baseline, $p = 0.35$ (see Figure 5).

A 4 (task: baseline resting state, speech preparation, speech, math) x 2 (group: proactive, control) GLM was used to analyze ECG data. A main effect of task is present, as all subjects experienced an increase in heart rate from pre-TSST to the post-TSST, $F(3,50) = 23.83$, $p < 0.001$. There is no main effect of group, $F(3,50) = 1.72$, $p = 0.195$. Amplified heart rate anxiety symptom differences between the proactive and control groups were dependent on the time point, as the control group had a significantly greater increase in heart rate ($M_{difference} = 12.69$, $SD = 1.92$), $p = 0.001$, than the proactive group ($M_{difference} = 4.24$ $SD = 1.92$), $p = 0.032$, following the TSST induction, $F(3,50) = 3.196$, $p = 0.031$ (see Figure 7). There was no significant difference between the proactive group ($M = 75.49$, SD = 2.25) and the control group ($M = 74.73$, SD = 2.25) at baseline, $p = 0.81$.

A 4 (task: baseline resting state, speech preparation, speech, math) x 2 (group: proactive, control) GLM was used to analyze SCL data as well. A main effect of task is present, as all subjects experienced increase skin conductance from the pre-TSST to post-TSST, $F(3,52) = 31.70$, $p < 0.001$. There was no main effect of group, $F(3,52) = 0.953$, $p = 0.33$. Skin conductance anxiety symptoms were depended on time point, as there were significant differences between the increases in SCL in the proactive ($M_{difference} = 2.62$, $SD = 0.41$), $p = 0.001$, and control group ($M_{difference} = 3.10$, $SD = 0.42$), $p = 0.001$, following TSST

induction, $F(3,52) = 0.803$, $p = 0.498$ (see Figure 8). There was no significant difference between the proactive group ($M = 7.8$ SD = 0.75) and the control group ($M = 6.6$, SD = 0.77) at baseline, $p = 0.28$.

Across all analyses reported above, there were no significant differences between the groups at baseline. However, consistent with hypotheses, according to the self-reported STICSA scores and heart rate, the proactive training prevented an increase in anxiety significantly more than the control condition immediately following the TSST primarily.

Discussion

Summary of Results

This aim of this study was to determine if proactive cognitive training would reduce anxiety relative to a control cognitive training. Self-report, and autonomic physiology data were used to index anxiety levels during the study. The primary hypothesis was that the proactive training would prevent increased anxiety following the TSST stressor. The somatic self-report data indicated that proactive training prevented an increase in anxiety significantly more than the control condition immediately following the TSST. This pattern was consistent with self-reported cognitive anxiety as well. ECG data indicated that the increase in HR for the control condition was significantly greater than that of the proactive condition following the TSST, which is consistent with the hypothesis. SCL data did not reveal any treatment effect.

As demonstrated by Edwards, Barch, and Braver (2010), cognitive control was manipulated using the AX-CPT. Participants in the proactive condition were trained to use proactive strategies when attempting the task at hand. There was a significant effect within participants across both proactive and control conditions, indicating that participants were responding as expected: slower on the AY trials and faster on the BX and BY trials. All participants were the slowest on the AY trials, possibly because they are prepared to hit

'target' when they see the A, and are taken aback when the probe is not what was expected. The significant differences among all cue-probe trial types except between the BX and BY trial types indicate that the non-A cue in such trials immediately signal the participant to select "nontarget," regardless of the following probe. Since the AY and BX trials were considered to be the most sensitive to validate proactive versus control conditioning, they were used to investigate the extent of success in the training paradigm. However, there were no significant differences between groups on trial accuracy or reaction time.

The TSST successfully induced stress, as self-reported somatic anxiety levels, heart rate, and skin conductance across proactive and control groups increased following the task. This indicates that the manipulation worked.

The proactive group felt marginally more cognitively anxious immediately following the AX-CPT than the control group. There was no group difference in HR and skin conductance following the AX-CPT on day 4.

Explanation of Results

For AX-CPT manipulation, there were trends in the expected directions, but no significant group differences in cue-probe response reactions times or accuracy. Thus, it is unclear exactly how successful the AX-CPT manipulation was. The TSST manipulations worked as expected: self-reported anxiety levels, ECG, and SCL all indexed increased anxiety from pre-TSST to post-TSST.

Consistent with Paxton, Barch, Storandt, and Braver (2006), the expected errors on AY trials for the proactive condition and the BX trials for the control condition trended as expected, however there was no significant differences between the groups in performance. The lack of difference could have resulted from insufficient power due to the small sample size. It could also be because the group differences in training instructions was distinct

enough to yield differences in self-reported anxiety and physiology, but not sensitive enough to yield differences in AX-CPT behavior.

The control conditions in previous studies differed from the control condition in the present study. For example, Paxton et al. (2006) studied cognitive control manipulation in older adults using the AX-CPT and included two control conditions in addition to their proactive condition that had similarities and differences to the control condition used in the present study. Similar to the present study, the first control condition called the instruction control group, did not contain any strategy specific instructions, but did utilize refamiliarization with task rules throughout the practice trial blocks. Paxton et al. included an additional practice control condition, in which participants did not receive any practice, and jumped straight into a three blocks of 100 trials each without reinstructions or reminders. However, participants in both of these control conditions also had to estimate the change in their performance, which they did not have to do in the present study. They found group differences in AY and BX errors and reaction time. A potential reason they found the group differences that were expected in this present study could be because of the nature of the *two* control conditions used. BX trial errors decreased in the proactive training group and the instruction control group, but did not decrease in the practice control group. AY trial errors increased in the proactive training group and the practice control group, but did not increase in the instruction control group. This indicates that implementing these two differing control groups may lead to the behavioral differences we expected in the AX-CPT.

Despite the lack of difference between proactive and control performance on the AX-CPT, we found a significant effect following the induction of the stressor. How can this be? Some participants in the proactive condition had perfect accuracy, while others did not, and yet there was still an anxiolytic effect following the TSST. This insinuates that the success on the training does not matter as much as the effort does. As long as the participants completed

the four-day dose of training, regardless of their performance, the anxiolytic effect was present.

Self-reported somatic anxiety and HR revealed significant differences between the proactive and control groups for the TSST. The increase in somatic anxiety for the control group following the TSST was significantly greater than that of the proactive group. Correspondingly, the increase in HR from the baseline to the induction of the TSST for the control group was significantly greater than that of the proactive group. This indicates that the proactive training equipped participants to handle the stressor more effectively than the control training. Consequently, the proactive group had reduced anxiety symptoms when faced with the stress-inducing task.

There was no treatment effect demonstrated by SCL, indicating that the effect might be mediated by the parasympathetic nervous system rather than the sympathetic nervous system.

According to the self-reported STICSA scores, the proactive condition felt marginally more cognitively anxious than the control condition immediately following the AX-CPT, suggesting that the task alone affects anxiety. This indicates the proactive condition's instructions were more difficult and required more attention, resulting in the brief higher anxiousness than the control condition. For example, the proactive condition had to say out loud "If X-target, " click "target" or "nontarget," and also think about whether they viewed an "A" or "non-A" during the probe timeframe. This may have stressed the proactive participants out at the time more than the control participants, as the controls only had to worry about clicking and were subsequently on "auto-pilot." However, the proactive condition's anxiolytic effect is present post-TSST. Coping with the TSST stressor was easier for the proactive condition, since they were coming from an AX-CPT version that was harder than the AX-CPT version that the controls were coming from. This is analogous to the

learning and performance research by Bjork and Bjork (2009) that examines how introducing desirable difficulties can enhance learning: completing a hard exam A before exam B will make exam B easier to deal with than if exam A were easy or not present at all.

The groups did differ post-AX-CPT in terms of self-reported anxiety as mentioned above, but they did not differ in terms of their HR and skin conductance. The lack of difference could be because the physiology measures were taken only on day four, at which point the participants had been well acquainted with the AX-CPT.

Broader Implications

As mentioned above, the current research alludes to the idea that effort is more important than success on the AX-CPT training to have the anxiolytic effect following the stressor. Also, it suggests that the effect of the training stretched over the entire longitudinal period, since the stressor was only induced on the final day of the study. This is promising, as it provides insight into potential treatment programs for anxiety. However, this should be considered carefully, as it is unclear whether the training was really effective as intended.

Rogers (2014) tested a one-time AX-CPT training and TSST task between proactive and reactive groups. Both groups consisted of attention demanding AX-CPT versions, resulting in no significant differences. The most prominent changes to the current study include the longitudinal nature, as well as using a control group instead of a reactive group to compare the proactive training to. The control group did not equip participants with any strategy to complete the AX-CPT, while the reactive group, used by Rogers (2014), equipped participants with a strategy that trained them to react only after seeing the probe, rather than prepare ahead to anticipate a “target” or “nontarget” in proactive training. Thus, it is unclear if the main effects in this study are due to the increased training period or the use of the control group in lieu of the reactive group.

Thus, we need to further delve into understanding what effect the training exactly had. For both proactive and control groups, anxiety significantly reduced between days one and three. After day three, the cognitive anxiety stabilizes. This suggests that the training did increase familiarity with the task, decreasing anxiety because they were more confident and familiar with it, doing it over and over again. However, when introduced with the novel TSST on day four, both groups are thrown for a loop, but the proactive condition can cope with it more effectively. Hence, we must not rule out a familiarity effect at work. By the time the participants come in for day four, they are very comfortable with the training. Even though the consent form informs them of additional tasks, they may still be caught off guard since this is a brand new task.

We must also question the nature of the training because it is unclear if participants were really trained or if they were using taxation as mental preparation. According to the data, the training showed trends in the right direction, but did not conclusively work since there were no significant differences in AX-CPT behavioral performance. Thus, it may be that the higher taxation the proactive condition experiences mentally prepares them better for the TSST stressor. As mentioned earlier, this is consistent with Bjork and Bjork (2009), as the harder first task makes the second task seem easier. However, it is important to realize that this effect may not be directly due to the training, but more so due to generally increased cognitive processing.

Despite the caveat discussed above, the current research provides insight into the relationship between anxiety and attentional control. Given that anxiolytic effect was present, the findings suggest that utilizing proactive control can prevent anxiety symptoms from exacerbating in the presence of a stressor. This allows patients suffering from anxiety to learn how to reduce their anxiety symptoms when presented with spontaneously stressful situations and also perform better on attention-demanding tasks. Anxiety often precedes social

problems or substance and alcohol abuse. As a result, treating anxiety can circumvent additional pathologies.

Braver (2012) developed the DMC, which explains how attention may affect anxiety via cognitive control. Anxiety is believed to increase the stimulus-driven attentional system and decrease the goal-directed attentional system. Thus, it explains the lack of proactive control in people suffering from anxiety. The DMC explains the flexible nature of cognitive control (Eysenck et al., 2007; Braver, 2012) and this study's findings demonstrate the causal relationship between anxiety and attentional control. Thus, changing cognitive control may be a first step in alleviating anxiety.

Strengths and Limitations of the Current Research

There are several strengths to this research that suggested a causal relationship between anxiety and attentional control. First, despite the aforementioned uncertainty of whether the training was effective, the longitudinal aspect of the study ensures that the training was not superficial. This improvement from Rogers' study (2014) confirms that the participants are being equipped with the proactive strategies and retaining these skills.

Additionally, the use of a control group allows us to draw more convincing conclusions that a proactive training, compared to no training, will prevent increased anxiety when exposed to stressors. This is more applicable to treatment programs since patients with anxiety often come from no training background, and thus can feel a difference when prepared with proactive methods. Additionally, in Rogers' study (2014) the difference between the proactive and reactive training was too small to verify that the proactive training was in fact making a difference.

Furthermore, using the TSST was important because it demonstrated how there were no differences in physiology following the AX-CPT, but differences emerged during the anxiety-provoking task. Since the focus of this study is anxiety patients' response to attention

demanding tasks, the TSST stressor was ideal to show the effect of the training on response to this task.

Administratively, participants performed the experiment in a highly controlled lab setting for days one and four. With random assignment to either proactive or control group, there was approximately an even number of males and females in each group, and experimenters were provided a script to eliminate potential experimenter's biases.

Despite the significant findings, there are some limitations to the current research. The power of the findings could be increased if the sample size were larger. There were more females and males overall and the sample was fairly homogenous given that most participants were Tufts University students. This limits the generalizabillity of the results to other populations.

There were some inconsistencies in how participants were run. Some participants were run exactly over four days, while others stretched over five or six days depending on scheduling conflicts and missed appointments. It is unlikely that this affected the results, but research in the future may control for this better. Stretching the training over five or six days may have been advantageous as there would have been more distributed learning, thereby increasing efficacy of the training. To support the idea of a "distributed practice effect," Cepeda, Coburn, Rohrer, Wixted, Mozer, and Pashler (2009) have done extensive research on how increasing a temporal lag between study sessions enhances performance on subsequent tests.

Another minor limitation was the lack of accuracy feedback provided to the participants during the AX-CPT task. The auditory "ding" informed participants to respond faster, however if participants were also notified of their accuracy, perhaps that may have increased their motivation to improve and attain a higher hit rate. This may have resulted in a

magnified effect of the proactive training, since all participants would have implemented the effort as well as been successful.

Additionally, participants completed days two and three of the study remotely. The controlled environment is not the same as the lab and thus these training sessions may not have had the same effect. It is difficult to tell whether the participants put in the same effort as they would have in the lab. For example, when the proactive condition is instructed to say aloud "If X, target," there is no way of ensuring they are actually doing so (and not saying it in their heads, not at all, or perhaps have music playing in the background). STICSA self-reported data indicates that anxiety was significantly reduced on day two. This could be because the task was familiar and/or because they were in the comfort of their own home that day.

Furthermore, a general limitation of using STICSA self-reported data is that it is not always reliable as participants may not be able to accurately determine how they feel. However, the physiology measures were consistent with the STICSA self-reported data, thereby reducing this potential weak point.

Lastly, participants in this current study were not selected on the basis of having been diagnosed with clinical anxiety. The participants only had to score above a median level of anxiety previously established on the prescreening survey. The manipulations for cognitive control may have had a larger impact on patients with clinical levels of anxiety (Braver et al., 2007).

Additional Directions for Future Research

This research was conducted in a lab setting and is thus not completely clinically applicable. Modifying the study to be more clinically suitable would improve upon the applicability to anxiety treatment programs. To start, using participants who are diagnosed with clinical anxiety would yield a better understanding of the efficacy of this paradigm in

patients. Furthermore, implementing the AX-CPT and proactive control skills acquisition would be more relevant to the real world if participants were not clicking in front of a screen, but actually practicing tasks that exercise realistic proactive control strategies. For example, someone experiencing relationship problems with a significant other may prepare before an anticipated fight how he or she would approach the argument. Similarly, if a student suffers from test anxiety, they may develop study habits that ease their nervousness prior to the day of the exam. This would extend beyond the AX-CPT and result in a more holistic acquisition of the necessary skills.

Another route would involve considering the subcategories of anxiety. Panic disorder and post-traumatic-stress-disorder are examples of variants of anxiety. Developing mechanisms that cater to these specific anxiety disorders may broaden the applicability and alleviate symptoms of more patients. For example, to investigate the effect of proactive training on panic disorder in particular, a task in which participants experience stressful situations with a confederate may be used in lieu of the TSST. Similarly, in the case of post-traumatic-stress-disorder, participants may be asked to recount their previous anxiety-inducing experience in lieu of the TSST. Such modifications can shine light on the boundaries of this methodology and in what circumstances it works.

Concluding Comments

To summarize, my goal was to determine if proactive training would reduce anxiety compared to a control training. The AX-CPT was used for the proactive versus control training and the TSST was used as the anxiety-inducing task. I found that there is an anxiolytic effect of proactive training in the presence of a stressor, evidenced by self-reported anxiety and HR. Effort in completing the AX-CPT trumped success, as the group as a whole showed an anxiolytic effect following the stressor, regardless of their performance on the previous AX-CPT task.

This novel causal relationship between attentional control and anxiety provides an understanding of another root cause of anxiety. It also provides insight into how modulating cognitive control can optimize anxiety treatment. Anxiety is one of the leading mental illnesses of the world, and the development of novel methods to decrease or prevent anxiety symptoms may better the lives of several people globally.

Table 1

Mean and Standard Deviations for STICSA cognitive and somatic scores at baseline and following the AX-CPT for days one through 4.

	Proactive		Control	
COGNITIVE	*M*	*SD*	*M*	*SD*
Pre-AX-CPT D1	20.83	5.98	17.76	5.96
Post-AX-CPT D1	18.97	7.48	17.03	4.96
Pre-AX-CPT D2	19.57	6.54	16.38	5.38
Post-AX-CPT D2	19.37	6.75	15.93	5.14
Pre-AX-CPT D3	18.40	6.97	15.83	5.11
Post-AX-CPT D3	18.27	7.08	15.86	5.24
Pre-AX-CPT D4	18.73	6.15	16.31	5.16
Post-AX-CPT D4	18.40	6.22	16.76	5.15
SOMATIC				
Pre-AX-CPT D1	15.07	3.79	14.41	4.50
Post-AX-CPT D1	16.90	6.35	16.83	4.61
Pre-AX-CPT D2	14.60	3.37	14.69	4.12
Post-AX-CPT D2	17.20	5.49	15.86	3.84
Pre-AX-CPT D3	14.43	4.42	13.83	3.74
Post-AX-CPT D3	15.77	3.92	15.24	4.36
Pre-AX-CPT D4	15.10	3.49	14.21	3.82
Post-AX-CPT D4	16.13	5.02	15.66	4.39

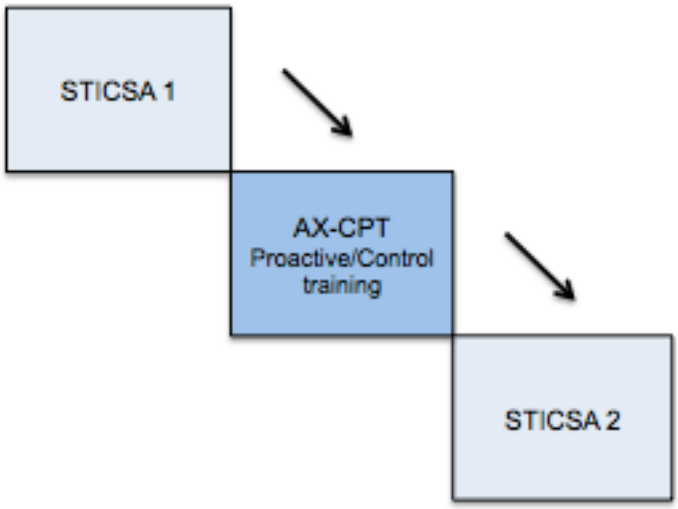

Figure 1. A flowchart explaining the experimental design for days one, two, and three. Participants signed the informed consent form and were asked to complete the self-report measures: STICSA and Mood Ratings. Participants were randomly assigned to the proactive or control condition and performed the AX-CPT. Then, participants completed the same self-report measures as before.

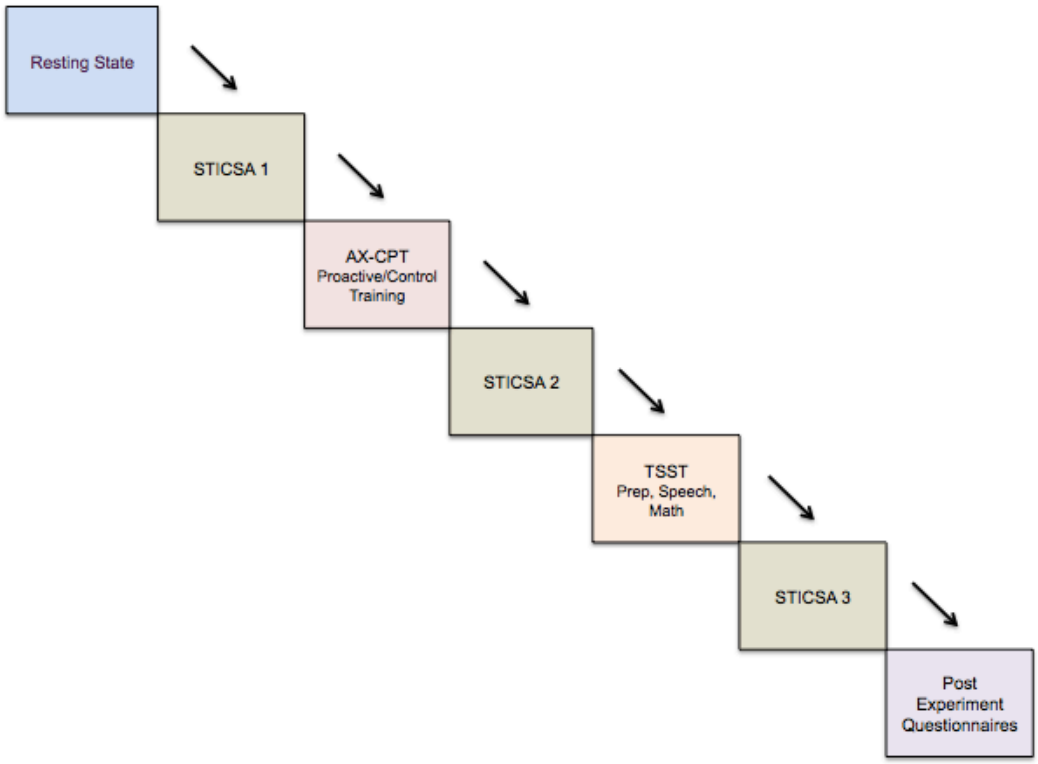

Figure 2. A flowchart explaining the experimental design for day four. Participants signed the informed consent form for the video component. While HR and SCL were recorded, participants were asked to sit silently and look at a fixation cross for two minutes. They were then asked to complete the self-report measures: STICSA and Mood Ratings. Participants performed the AX-CPT version consistent with their group assignment from day one while HR and SCL were recorded. Then, participants completed the same self-report measures as before. Participants were instructed to prepare for three minutes for a speech to last five minutes. Without notes, participants presented the speech and then were asked to complete a five-minute maths task (TSST). HR and SCL were recorded during the TSST as well. Participants completed the self-report measures one last time as well as post-experiment questionnaires. Following the conclusion of the experiment, participants watched a video clip to alleviate the TSST-induced stress.

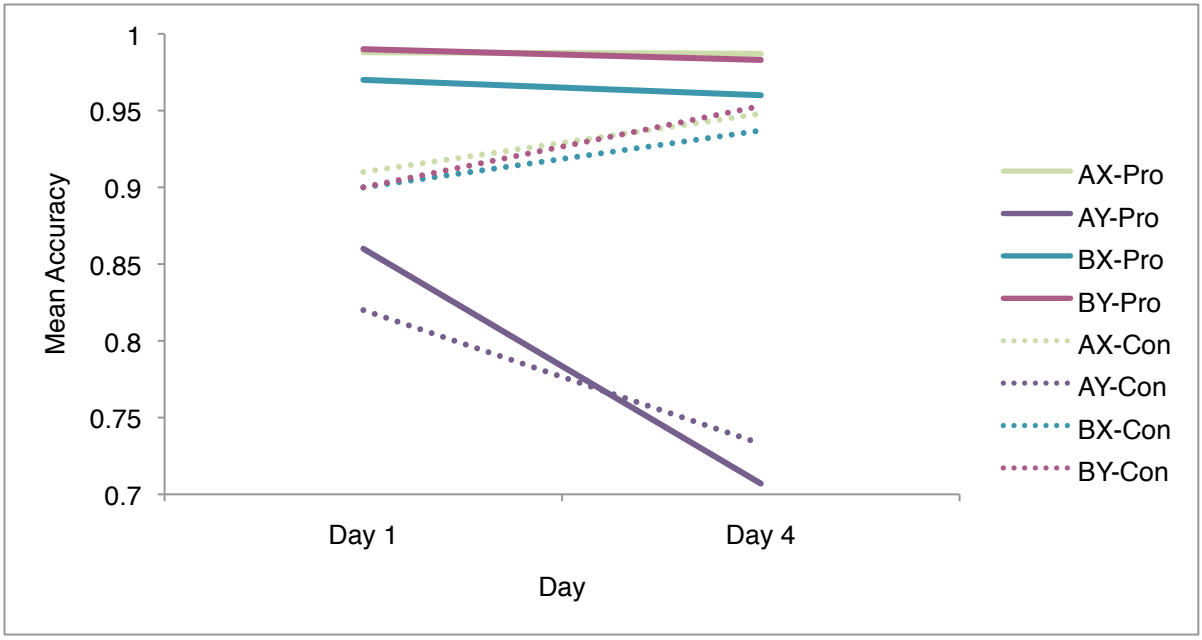

Figure 3. The figure above shows the significant differences in accuracy among the cue-probe trial type in the AX-CPT, but no significant differences between groups on days one and four. The error bars represent +/- 1 SE.

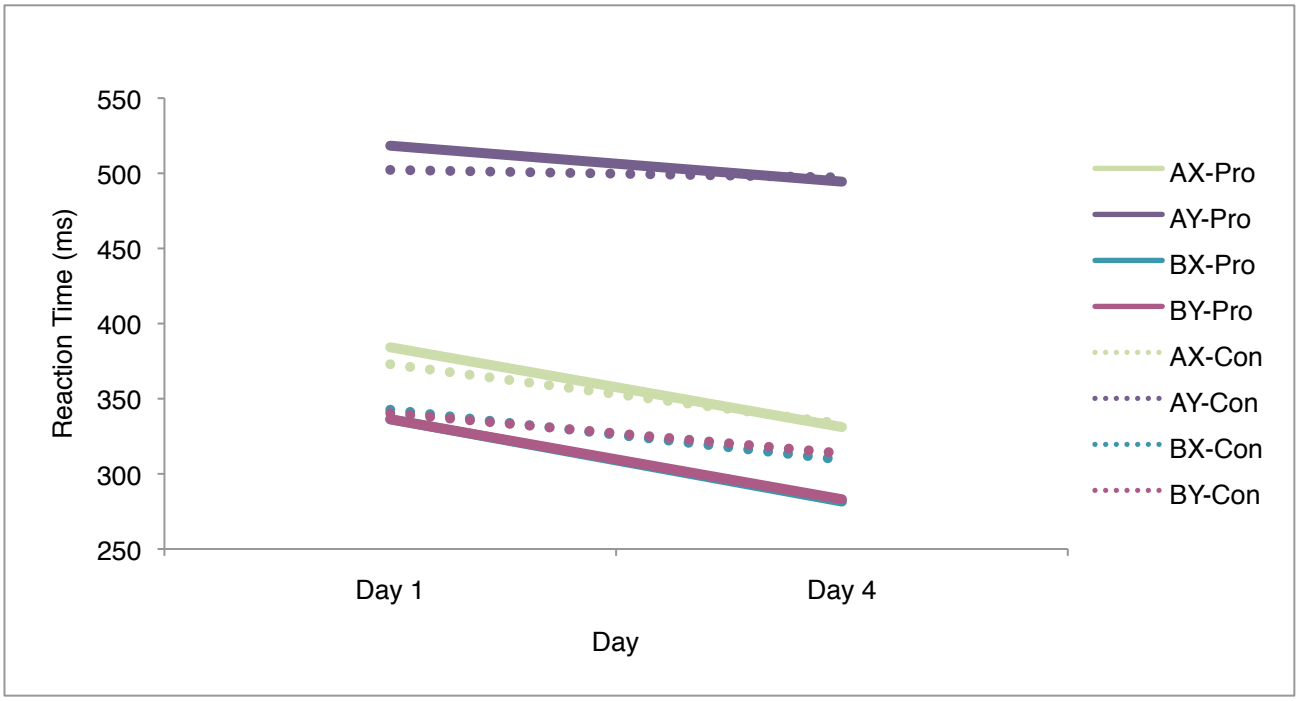

Figure 4. The figure above shows the significant differences in reaction time among the cue-probe trial type in the AX-CPT, but no significant differences between groups on days one and four. The error bars represent +/- 1 SE.

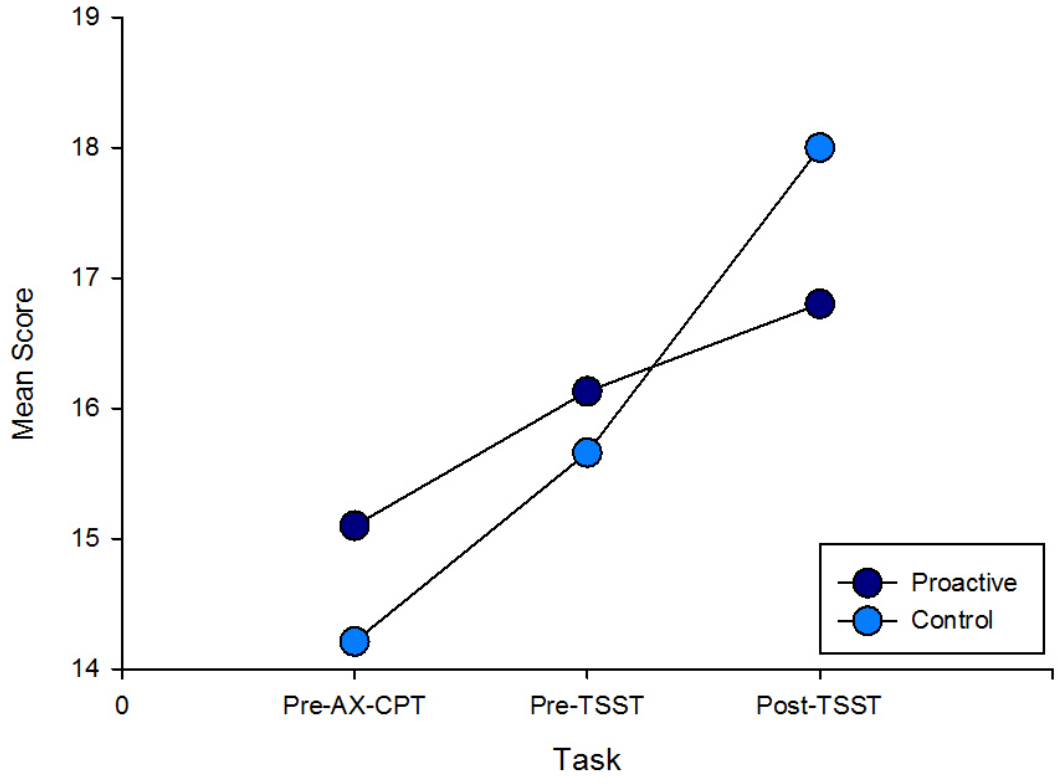

Figure 5. Mean STICSA somatic scores before the AX-CPT, before the TSST (which is after the AX-CPT), and following the TSST on day four. There was a larger increase in anxiety post-TSST for the control group than for the proactive group for somatic anxiety. The proactive group started with a slightly higher somatic anxiety score, as pre-TSST is just after the AX-CPT. Post-TSST, the control group had an overall higher mean somatic score than the proactive group, as expected.

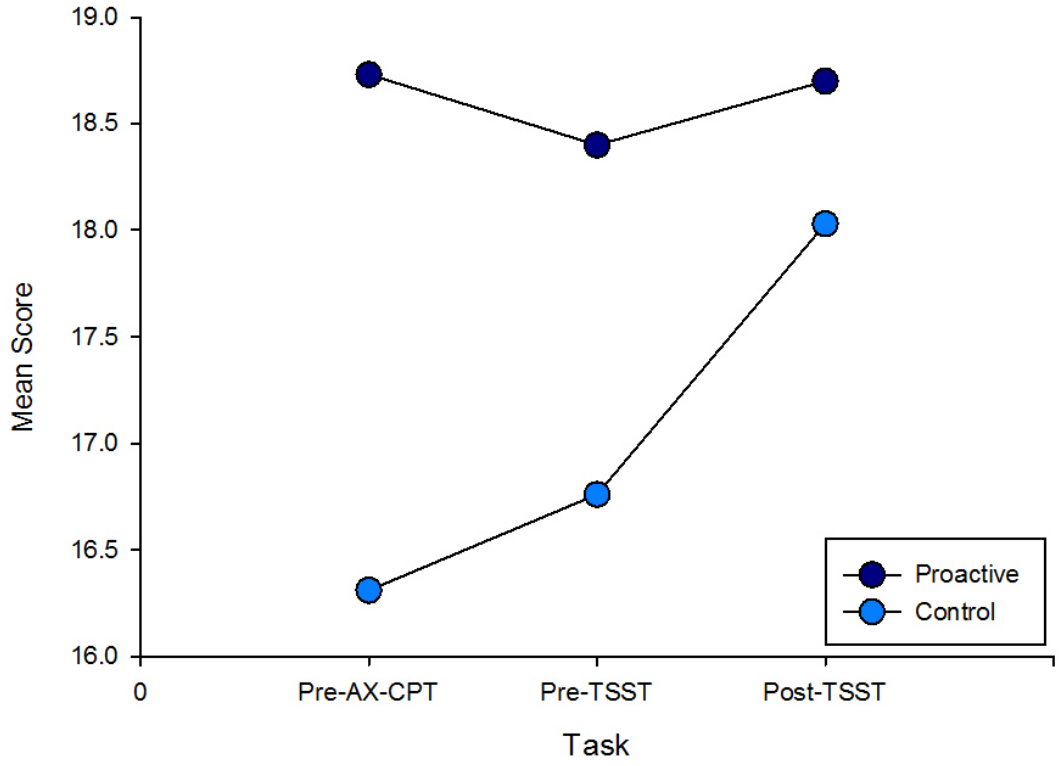

Figure 6. Mean cognitive STICSA scores before the AX-CPT, before the TSST (which is after the AX-CPT), and following the TSST on day four. The difference between pre-TSST and post-TSST in cognitive anxiety was greater for the control group than the proactive group, while the proactive group had a higher mean overall at pre-TSST.

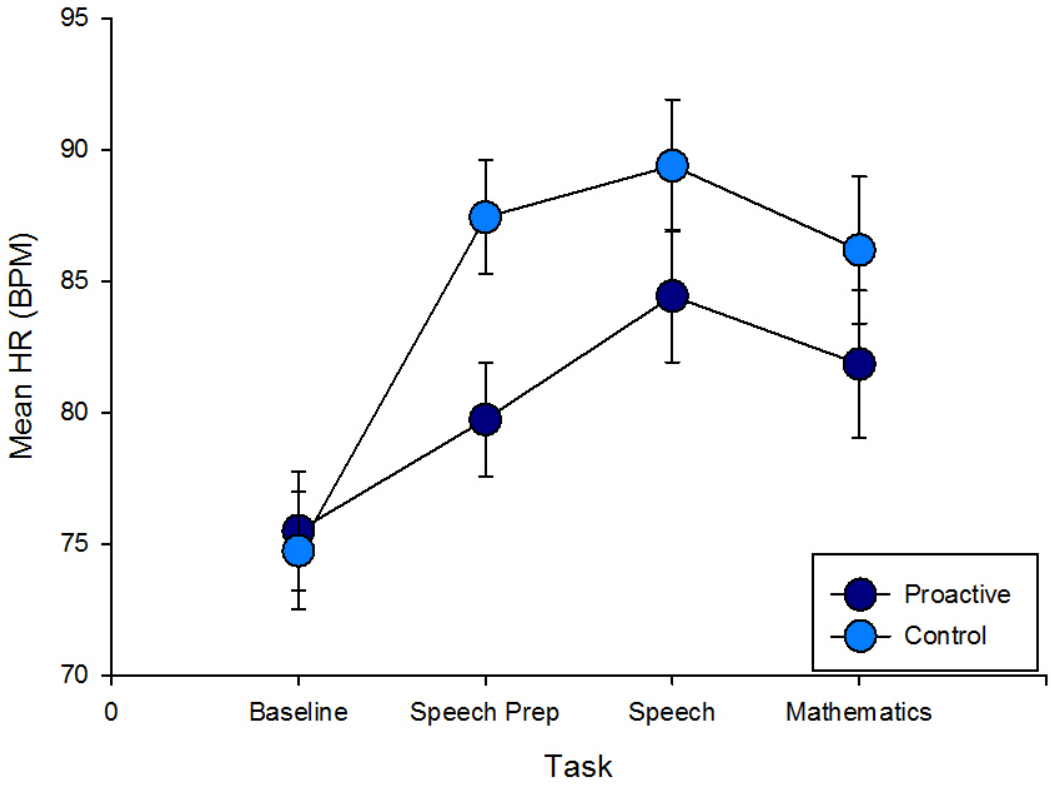

Figure 7. Change in HR as a function of task. The baseline shows no differences in HR between the two groups. This pattern continues between groups during the AX-CPT and was subsequently omitted from the graph. As soon as the TSST-induction begins, the HR for the control group is significantly greater than that of the proactive group, indicating that the proactive control resulted in an anxiolytic effect when introduced with a stressor. The error bars represent +/- 1 SE, $p = 0.031$.

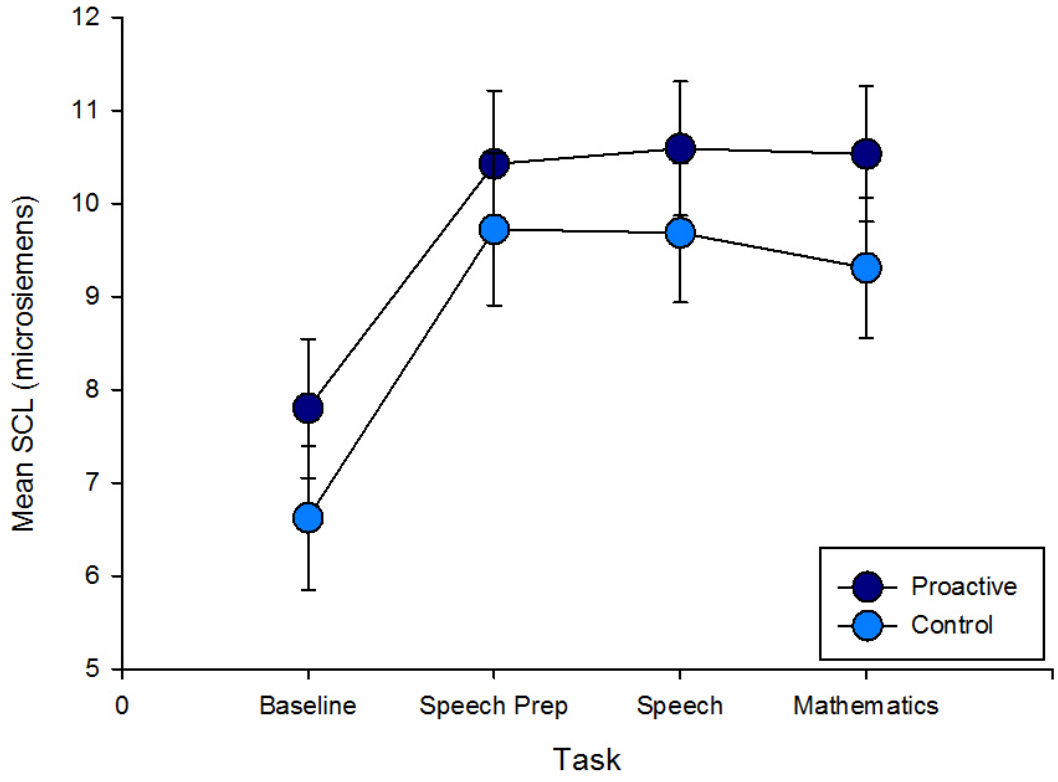

Figure 8. Change in SCL as a function of task. There was no significant differences between groups at any time point. The error bars represent +/- 1 SE.

Appendix A

State Trait Anxiety Inventory (STAI). The second primary self-report measure used was the state version of (Y-2) STAI, containing 20 items that measure trait anxiety asking participants to rate how they generally feel using a Likert scale ranging from 1 (*almost never*) to 4 (*almost always*). Ten of the 20 items are anxiety present (for example, "*I lack self-confidence*"), while the other ten are anxiety absent (for example, "*I am content*"). The anxiety absent items were reverse scored. STAI was used to assess participants' trait anxiety levels and see if the trait anxiety had an impact on the responses to training.

Anxiety Sensitivity Index – 3 (ASI-3). The third primary self-report measure used was ASI-3, containing 18 items to evaluate anxiety sensitivity (Taylor et al., 2007). Anxiety sensitivity is psychological arousal resulting from fear of a given situation thereby having negative consequences, which could include insanity or death. Reiss & McNally, the original creators of the ASI-3 scale in 1985, suggested that an increase in anxiety can result from anxiety sensitivity. Participants were asked to rate how they feel using a Likert scale (ranging from 1 (*very little*) to 5 (*very much*)) in a given situation, for example, "*I think it would be horrible for me to faint in public*." The ASI-3 scale provided insight into the cognitive control training in relation to anxiety sensitivity.

Attentional Control Scale (ACS). Attentional shifting, the ability to change from one task to another task, and attentional focus, the ability to focus despite distractions, were tested with the ACS 20-item scale developed by Derryberry & Reed (2002). Items exemplifying attentional shifting and focusing included, "*It takes me a while to get really involved in a new task*" and "*It's very hard for me to concentrate on a difficult task when there are noises around*," respectively. Participants rated how frequently each statement applied to them according to a Likert scale from 1 (*almost never)* to 4 (*almost always).* Given the high

reliability of the ACS measure (Cronbach's alpha = .88), it provides a measure to determine the effect of attentional control on the cognitive control training.

Emotion Regulation Strategies Questionnaire (ERS). The ERS questionnaire was developed by members of the Emotion, Brain, and Behavior Laboratory at Tufts University to assess how participants regulate emotions. There were 20-items in which participants had to rate how they react to a certain stressful situation ranging from 1 (*not at all)* to 9 (*quite a bit*). An example of an item from ERS includes, "*I attend to non-emotional aspects of the task."*

Difficulty, Success, and Effort (DSE). The DSE is a questionnaire developed by the members of the Emotion, Brain, and Behavior Laboratory at Tufts University that receives feedback from the participants on the level of difficulty, success, and effort applied that they experienced on the AX-CPT and TSST. The Likert scale ranged from 1 (*not at all)* to 10 (*extremely).*

Affective Style Questionnaire (ASQ). Hoffman and Kashdan developed the ASQ questionnaire containing 20-items that measure concealing (suppressing emotions), adjusting (balancing emotions), and tolerating (tolerating arousing emotions) within participants affective mode. Participants were asked to rate where they stand for each item according to a Likert scale ranging from 1 (*not true of me*) to 5 (*extremely true of me*). Examples of the concealing, adjusting, and tolerating items include, "*I often suppress my emotional reactions to things," "I am able to let go of feelings," "I can tolerate being upset,"* respectively.

Sleep Assessment. Participants were asked to complete a 10-item survey asking that aimed to evaluate their sleep the night before coming into the lab for day 4. Questions inquired the general quality of sleep, if they woke up in the middle of the night, and how many hours they slept total, for example.

Menstrual Cycle Assessment. Female participants were asked to complete an 8-item self-report that assessed typical qualities of their menstrual cycles, including the duration of their cycle, the nature of their last one, if they are consuming birth control or any other contraceptives, and if they ever experienced amenorrhea.

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