Proactive Control in University Students with Varying ADHD Symptom Levels

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Abstract

Attention Deficit/Hyperactivity Disorder (ADHD) has been associated with poor cognitive control mechanisms. This study uses the dual mechanism framework of cognitive control to investigate proactive control. Recent research suggests that specifically, proactive cognitive control is impaired in people with ADHD. This implies people with ADHD have poorer preparatory mechanisms. This paper uses a dimensional structure for ADHD conceptualising it as a spectrum of symptoms rather than using a binary categorical structure. The aim of this study is to contribute to the research on the functioning of proactive control in ADHD, and to investigate whether it is impaired in university students with varying levels of ADHD. The test materials included in this study are the task switching online task and the CAARS online questionnaire. First year psychology students completed the Task Switching task and were assessed for their level of ADHD symptoms on The Conners' Adult ADHD Rating Scale (CAARS) questionnaire. The task switching task uses three cue levels before the task. The cues levels are alerting, informative and no cue. Alerting cues are used to conceptualise reactive cognitive control while controlling for the effect of increased vigilance. Informative cues are used to conceptualise proactive cognitive control. We expected reaction times to be faster for informative trials compared to alerting trials. This hypothesis was confirmed by analysis. To verify if proactive control is poorer for higher levels of ADHD, we tested if the difference between alerting and informative cue levels is related to the level of ADHD symptoms. The results found no significant impairment in proactive control for higher levels of ADHD symptoms. In conclusion, this study failed to find support for the idea that proactive control in impaired in ADHD, but this result remains inconclusive due to several limitations.

Keywords: Proactive cognitive control, ADHD, dual mechanisms framework

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ADHD and University Students

Attention Deficit/Hyperactivity Disorder (ADHD) is a prevalent neurodevelopmental disorder with symptoms of inattention and/or impulsiveness or hyperactivity, the worldwide prevalence of ADHD is between five and seven percent (Drescher, 2021). It is a chronic disorder however, there is less information available about adult ADHD compared to children with ADHD (Shen et al., 2020; Weyandt, 2006). Longitudinal research indicates that children diagnosed with ADHD often continue to display symptoms into adulthood (Weyandt et al, 2006). University students with ADHD are more likely to suffer from depression and tend to perform more poorly academically compared to those without ADHD (Weyandt et al, 2006). This is especially true when they have not received an early diagnosis. People suffering from ADHD also have higher rates of suicide which may reflect a failure to manage the emotional and social problems that can incur as a result of the disorder (Furczyk et al, 2014). Findings suggest that university students with ADHD are at a higher risk of academic and psychological difficulties (Weyandt et al, 2006). All of this highlights the importance of conducting more research aimed at understanding adult students with ADHD and improving their outcomes. This study uses an adult population of first year university students.

It has been frequently reported in the literature that ADHD involves an impairment of cognitive control, this is true for children as well as adults with ADHD. Cognitive control is defined as “the ability to regulate thoughts and actions in accordance with internally represented behavioural goals” (Braver, 2012). Research implies that impaired cognitive control contributes to the behavioural problems that are characteristic of ADHD such as

impulsiveness and hyperactivity (King et al, 2007). Cognitive control is conceptualised into two forms according to the dual mechanisms of cognitive control, these are proactive and reactive control. The central hypothesis of the dual mechanisms framework is that cognitive control operates in terms of these two distinct pathways.

Proactive control is a preparatory process for cognitively challenging events. It is activation and maintenance of goal-specific information. It also primes the attentional and response system for action (Sidlauskaite et al, 2020). In contrast, reactive control involves immediate responses to an event. It involves, "transient goal-relevant information upon the detection of interference and its resolution". As the names suggest, proactive is about anticipatory control whereas reactive is about detection and resolution of conflict. In more contemporary research, proactive rather than reactive cognitive control is thought to be impaired in people with ADHD (Sidlauskaite et al, 2020; King et al, 2007).

Altered Cognitive Control in Adult ADHD

In a study conducted by Joseph A King and colleagues, the Task Switching Paradigm and Stroop test were used to investigate cognitive control in adults with a childhood diagnosis of ADHD (King et al, 2007). Their aim was to study two processes of cognitive control namely, interference control and task set coordination. Interference control was studied in both tasks. Preparatory mechanisms, as well as task-set updating or maintaining, was investigated further in the task-switching task. They found abnormal processing of task-irrelevant stimuli in ADHD group performance on both tasks. Furthermore, performance on switch vs repeat trials depended on experimental manipulations (cue informativeness). They also concluded that error rates were generally higher and accuracy was generally lower in the ADHD group with the exception of the Stroop task error rates. Conclusively, this study found evidence for inefficient cognitive control in the clinical group. The dual mechanisms framework of cognitive control

was not used to conceptualise cognitive control however, the preparatory mechanisms that were studied using the task switching task are similar to the concept of proactive control. Proactive control also relates to "top-down" thinking. This study could imply proactive cognitive control is impaired in people with ADHD as it found evidence for altered preparatory processes in ADHD. However, the authors note that is remains inconclusive whether the inefficient cognitive control observed was due to "top-down failure or bottom-up engagement thereof" (King et al, 2007).

In another study conducted by Sidlauskaite and colleagues, evidence was found for impaired proactive control in individuals with a diagnosis of ADHD (Sidlauskaite, 2020). This study is similar in design to the previous study but uses the dual mechanisms framework outlined by Braver to conceptualise the findings and formulate the hypotheses. Like in the experiment by King and colleagues, a cued task switching task is also used. A trend towards slower responding was found in the ADHD group. Their analysis suggests preparatory proactive control is impaired. The evidence for this comes from poorer use of informative cues (Sidlauskaite et al, 2020). Both forms of cognitive control have their respective advantages and limitations. Considering this, optimal cognitive control probably involves a combination of both (Braver, 2012). Thus, according to an informed opinion piece by Braver, both systems may be active at the same time with a bias for one depending on the task. Both studies mentioned can indicate a problem with proactive control in the ADHD population with the latter stating this as its main conclusion.

Conversely, some studies have found a deficit in reactive control rather than proactive control (van Hulst et al, 2018). Van Hulst and colleagues used a modified stop signal task to differentiate reactive and proactive inhibition. Inhibition is a highly relevant for aspect of cognitive control and it is attenuated in those with ADHD (van Hulst, 2028). Their aim was to find out whether the attenuated inhibition was due to a deficit in "outright stopping

(reactive inhibition" or "anticipatory response slowing (proactive inhibition)" or both. Their results found a deficit in reactive inhibition in those with ADHD. They found no impairment in proactive inhibition in those with ADHD or autism. This contradicts the conclusion that only proactive control is impaired in ADHD. The task switching task (used in the previously mentioned studies) does not directly measure inhibition control so perhaps a deficit in reactive inhibitory control would not be noticeable on this task. This study was also conducted with children as the participants whereas the other two used adults.

Aim of the study

The aim of this experimental study is to contribute to the research describing the role of proactive control in ADHD. Previous studies have mostly focused on childhood ADHD, this study also contributes to research on adult ADHD. There is research to show altered preparatory processes in ADHD however, the role of proactive control has not yet been studied extensively (King et al, 2007; Sidlauskaite et al, 2020). The task-switching task will be used to measure the concept of proactive control. The task switching task uses three cue levels to observe cognitive control mechanisms (proactive or reactive). Cues are used to set expectations of responses on the next task trial. The three cue conditions are informative, alerting and no cue. Informative cues provide useful information to correctly respond to the upcoming trial. Alerting cues do not provide information but they do increase vigilance. Alerting cues are used to control for the effects of increased vigilance. Finally, the no cue condition does not give any information or provide a warning. This study aims to replicate the finding that informative cued trials on the Task Switching task will be significantly faster than alerting (non-informative) cued trials. This is generally found to be true regardless of an ADHD diagnosis. Our first research question is based on the previous proactive control research conducted on a clinical ADHD sample. The question is, 'is there a difference in

reaction times between alerting and informative trials on the task-switching task? If so, is this difference related to ADHD symptom level?'. The difference between informative and alerting trials is hypothesised to be smaller for people with higher levels of ADHD. In other words, compared to people with lower ADHD levels, people with higher ADHD levels fail to respond faster on trials wherein they receive cued information that will help them with the upcoming trial. If this finding is successfully replicated, it supports the conclusion of Sidlauskaite and colleagues that proactive control is impaired for those with symptoms of ADHD. However, our study is performed on a non-clinical sample with a group of people possessing a range of symptoms. Non-clinical samples have not been addressed in previous research on this topic so a well founded expectation cannot be made. It is also important to see how reaction times compare in general between higher and lower levels of ADHD to ensure that people with higher levels of ADHD do not only respond faster/slower overall.

The goal of this study is to research proactive cognitive control and to see if it is altered in those with higher levels of ADHD. The reaction times on the informative trials reflect how well participants have used helpful preparatory information, hence they are a good measure of proactive control. However, it is unclear how much a warning to prepare with no further information would accelerate reaction times (alerting cues). Therefore, we check if there is a difference between mean reaction times on the alerting and informative trials. Next, we verify if proactive control is different in those with higher levels of ADHD. This is achieved by observing if the difference in alerting and informative cues is related to ADHD index scores.

Hypothesis one is that reaction times will be faster on informative trials. This has generally been true for studies using the task switching paradigm (Braver, 2012). Theoretically it makes sense for people to be faster when they have been able to prepare and

know what to expect. Hypothesis two reflects the idea that proactive control is impaired with higher levels of ADHD.

Research question

Is there a difference in reaction times between alerting and informative trials on the task-switching task? If so, is this difference related to ADHD symptom level?

Hypotheses

Hypothesis 1

Reaction times will be faster on informative trials compared to alerting trials.

Hypothesis 2

The difference of reaction times between alerting and informative cues will be related to ADHD level. Specifically, the difference is expected to be smaller for higher levels of ADHD.

Methods

Participants

The participants were first-year university students recruited voluntarily from an online platform called the SONA system which was developed for the University of Groningen. The mean age was 19.87 (*sd* = 2.13). Participants received academic credits for their participation. In our study, there were 50 participants with varying levels of ADHD symptoms. There were 19 males, 30 females and one unspecified. Each participant completed The Conners' Adult ADHD Rating Scale (CAARS) questionnaire to assess their level of

symptoms and was given an index score based on this. They also completed the Task Switching task. Two of the participants did not fill in the CAARS questionnaire and were, therefore, not used in the analysis for the first hypothesis. The majority of the participants did not have a diagnosis of ADHD and their symptoms were not high enough to merit a diagnosis. However, two of the participants did report having a diagnosis of ADHD during the experiment. Another reported a diagnosis of "minor ADHD".

Materials

Task switching task

The task-switching task was run on a software called OpenSesame. Participants completed the task online. The task measures set-shifting and cognitive control. Three cue conditions allow for the manipulation of cognitive control mechanisms. The three cue conditions are no cue, informative cue and alerting cue. These different types of cues allow proactive and reactive control to be studied distinctly. The informative cues encourage the engagement of proactive cognitive control. The no cue condition forces the use of reactive cognitive control, and the alerting cue does the same but controls for vigilance. The Task switching paradigms demonstrate moderate to good test-retest reliability (r = .62 to .82) (Sicard et al., 2020).

In total, there were 378 trials with 110 of those in the medium speed condition. A cue was presented at the beginning of each trial followed by the task. The cue was either informative, alerting or not present. In the informative cue condition, a word indicated what participants should respond to on the upcoming task (*shape, colour*). Namely, the shape or

colour of the target stimulus presented in the task. In the alerting cue condition, four hashtags were shown (####). In the no-cue condition, only a black screen was shown.
Following the cue, the target stimulus is presented along with the word "shape" or "colour" above it. The stimulus appears in a certain shape (*circle* or *triangle*) and colour (*yellow* or *blue*) on a black background. The word above the stimulus indicates whether participants should respond to the shape (*m= triangle, z= circle*) or the colour (*m=blue, z=yellow*) of the stimulus. There were three speed conditions that varied how long a black screen was presented after responding (fast, medium, and slow). However, this analysis used only the medium condition in which a black screen was presented for 3000ms. The medium condition is considered the "typical" condition that is neither too fast nor slow.

Response times and accuracy were measured. Responses longer than two seconds were recorded as errors. The task included mixed and unmixed blocks that determined the order of trials. Unmixed blocks consisted of the same type of task repeated for each trial (*shape* or *colour*) with only one switch in between. On the other hand, mixed blocks contained a randomised order of trials. In mixed blocks participants had to either switch or repeat the same task (*shape, colour*), this is referred to as set-shifting. We used the data from the mixed block in the analysis so the participant cannot predict whether the upcoming trial will be about colour or shape. Set shifting was controlled for in the analysis as participants are slower on switch trials compared to repeat trials. In this study, the reaction times for alerting and informative trials in the medium speed condition were used in the analysis.

The task switching task was chosen as it allows for the measurement of different cognitive control mechanisms. Specifically, the reaction times on informative cues relate to the efficiency of proactive control. If a participant responds relatively quickly on trials with informative cues compared to trials when there is no information beforehand, it is implied they are using proactive control to effectively prepare for the task. Furthermore, if a

participant receives no cue and responds quickly and correctly to the task, they are making effective use of reactive control. The alerting cues warn the participants to prepare but do not provide any useful information for the upcoming task. They require reactive control on the task but perhaps some preparatory mechanisms are still used. Alerting cues make it possible to control for increased vigilance.

CAARS questionnaire

The CAARS questionnaire assessed participants' level of ADHD symptoms. It demonstrated high internal consistency (Cronbach's α = .88 to .91), high test-retest domain reliability (r = .80 to .91) as well as high criterion validity (Erhardt et al, 1999). The diagnostic sensitivity of the test was 82%, diagnostic specificity of 87%, and overall correct classification rate of 85% which shows its strength as a diagnostic tool (Erhardt et al., 1999). It includes 66 items, which are made up of four subsections of ADHD symptoms and three subscales based on ADHD symptomatology of the Diagnostic and Statistical Manual of Mental Disorders (4th ed.; DSM-IV; American Psychiatric Association, 1994). In this study, the level of ADHD symptoms was measured based on this questionnaire. Participants were given a total score based on a sum of points of a four point Likert scale (0 = not at all/never to 3 = very much/frequently). Higher scores represent higher levels of ADHD.

Procedure

The study was approved by the Ethical Committee of Psychology of the University of Groningen. Due to ongoing external limitations, the study was fully conducted online. First, participants gave informed consent for participating. Then, the participants that decided to participate in the study, were asked to fill in two questionnaires: the CAARS and the Weiss Functional Impairment Rating Scale (WFIRS). They were also asked to indicate if they had

any of the following disorders: ADHD, ADD, depressive disorder, anxiety disorder, stress, dyslexia or motor disorder and if they had it during childhood or adulthood. Furthermore, they were also asked about their age, gender and any use of medication. After filling out the questionnaires, they had to perform two online reaction time tasks: the task switching paradigm and the Stroop task. The order of these two was randomized. For each task (condition), participants first did several practice trials before starting the actual task. The participants were given the opportunity to take two 5-minute breaks to separate conditions within each task. If chosen to take these breaks, each task would have taken 44 minutes (either the Stroop task or the task-switching task). Due to the length of the experiment, the study was divided into two sessions. The WFIRS and Stroop task were part of a bigger study and will not be used in this specific study. After filling out the questionnaires, the participants were given a debriefing sheet regarding the true intentions of the study as well as emotional support.

Data Analysis

The data analysis was performed using SPSS. Assumptions of analysis of covariance (ANCOVA) were tested. The assumptions were all sufficiently met. The significance of the different analyses was tested by using a significance level of $\alpha = .05$. Effect sizes were measured using partial eta squared. Homogeneity of variance was not relevant to test because there were no between-subject factors. The same is true for sphericity. The within-subject factors were task (two levels, colour and shape), cue (two levels, alerting and informative) and set shifting (repeat, switch). Set shifting determines if the next task trial (colour, shape) will be the same as the previous (repeat) or different (switch). Set shifting may also influence reaction time (Luna-Rodriguez et al, 2018).

When looking at the frequency of reaction times in the medium condition of the task switching task one participant was clearly an outlier taking four seconds to respond compared to the average of less than one second. This participant was not excluded from the analysis despite being a significant outlier because it was speculated this participant may have responded much slower as a result of boredom or distraction relevant to higher levels of ADHD. It was verified that this outlier does have high levels of ADHD and therefore is relevant to the analysis. The ADHD index of this participant was 71 (a score over 65 is considered at risk of ADHD).

Hypothesis One

To test the hypothesis that reaction times will be faster on informative trials compared to alerting trials we will conduct an ANCOVA analysis between the alerting and informative cues as a within-subjects variable and ADHD scores as a covariate variable. We will check for the main effect of cue on reaction time. First, the assumptions of ANCOVA were verified. Namely, the normality and homogeneity of variance of the data.

Hypothesis Two

We will test if the difference between alerting and informative trials is affected by ADHD scores. It is hypothesised that ADHD affects reaction times on informative trials as this involves the engagement of proactive cognitive control.

Results

The mean reaction times for the alerting and informative cues in the medium condition of the Task Switching task were (m=1027.467) milliseconds and (m=791.793) milliseconds respectively. These results are an average of the shape and colour conditions as well as switch and repeat. Only the medium condition was used for calculations as this is the

condition participants were given a reasonable amount of time to complete the task in. The mean index score on the CAARS across all participants was 49.27 (*SD* = 10.03) and specifically 48.10 (*SD* = 9.41) for females and 51.28 (*SD* = 11.01) for males. Values of 50 indicate the average with a standard deviation of 10 on this test (Ghassemi et al, 2010). A visual analysis as well as statistical analysis of the ADHD score distribution (Figure A) confirmed the CAARS data to be normally distributed ($p = 0.62$).

Table A

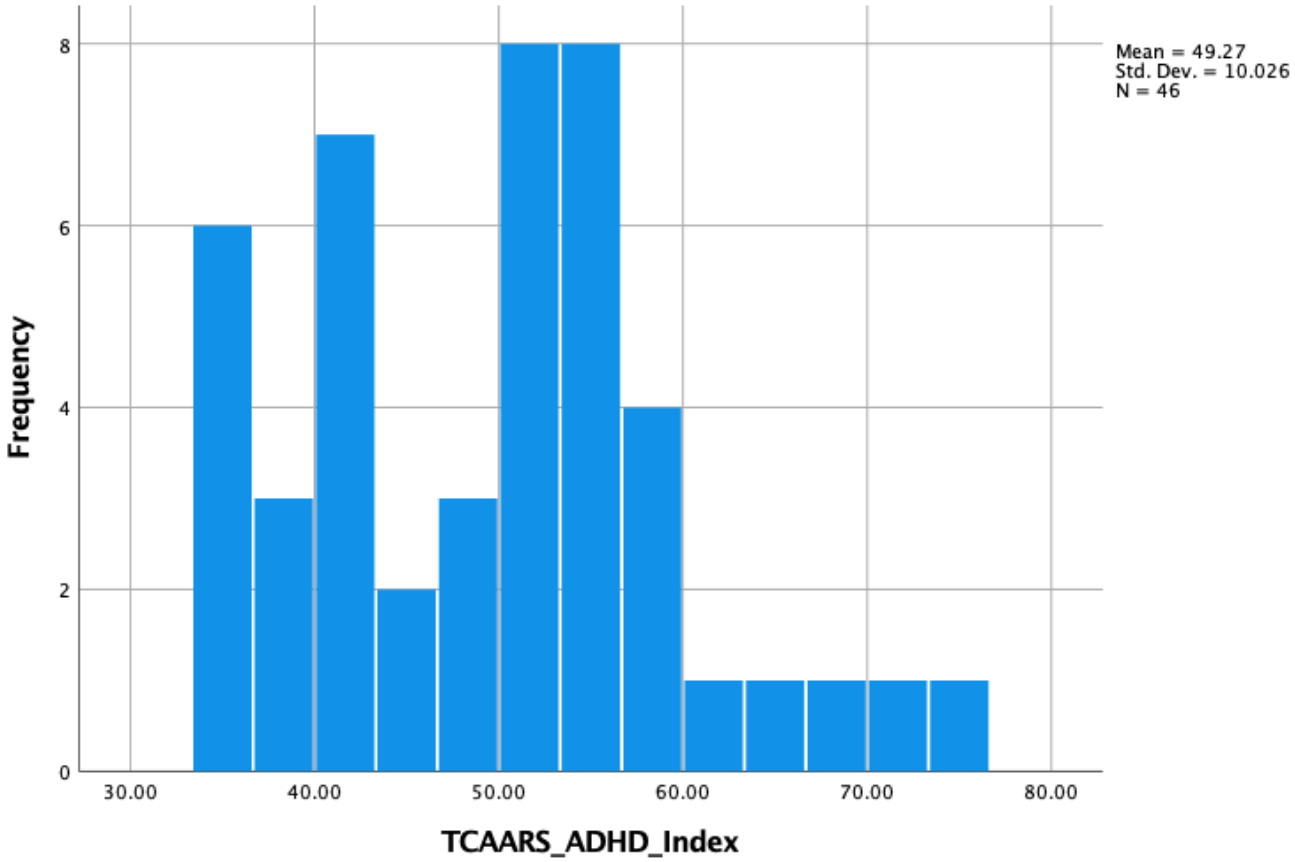
Descriptive statistics for the task switching task

Cue type	Mean	Standard deviation	Number
Alerting cues	1027.467ms	332.9321ms	49
Informative cues	791.793ms	274.9142ms	49

Note. The average of the colour, shape, switch and repeat trials was taken for the mean results.

Figure A

Frequency table of CAARS scores



Note. The average score is typically 50 in a random sample.

The check for normality of the task switching data showed significant results on Task Switching reaction times in the medium condition, colour, mixed block for alerting switch and repeat trials. It was also significant for the Task switching medium mix, shape, informative switch condition at the 5% significance level. Given that the majority of the variables are normal it can be assumed that the data are suitable for ANOVA analysis and those that do not meet the assumption would most likely be normal if we had a larger sample size, furthermore one participant that scored highly on the CAARS was an outlier that took much longer to respond on certain trials. The first and second hypotheses were tested using an ANCOVA. Results showed that the main effect of cue was significant ($p < 0.01$) (F=95.37) when ADHD was not included as a covariate and non-significant when it was (p =

0.107), (F=2.713). The second hypothesis, that ADHD affects reaction time was not significant. The interaction effect of cue level and ADHD scores was (a = 0.882) (F= 0.022).

Discussion

Our outcomes did not match the existing literature on proactive control (Sidlauskaite, 2020; King et al, 2007). We did not find evidence for proactive control impairment among students with higher levels of ADHD. Our evidence for this comes from the insignificant interaction effect of cue and ADHD symptom level on reaction time in the ANOVA with ADHD as covariate. However this does not necessarily imply that proactive control is not different among people with ADHD. Our study had low power and used a non-clinical sample. It is possible that the ADHD scores of our participants were not high enough to yield significant results.

It seems logical that proactive control would be favoured when advance information has been provided for a task which is the case on informative trials of the Task Switching task. People with ADHD suffer from executive dysregulation which makes preparatory tasks more difficult, thus one might expect proactive cognitive control to be impaired in a similar way (Grane, 2016).

Online testing is also a relevant source of variation. It introduces variation in wifi speed, browser used, screen size, device speed and external surroundings.

Hypothesis 1

Reaction times of informative cues were indeed faster than those for the alerting cues. This means that vigilance alone did not account for all of the increase in speed from the no cue condition. This shows a clear difference in reaction times across the three types of cues. The task switching experiment was designed to require different types of cognitive control

across the three types of cues. The fact that each cue had significantly different mean reaction times supports the idea that each has different cognitive demands.

Hypothesis 2

The second hypothesis was that the difference between informative and alerting cues would be related to the scores on the CAARS. This was not the case; however, this result remains inconclusive due to several limitations. This means we did not find support for the idea that proactive cognitive control is altered in those with higher levels of ADHD.

The current findings bring up more questions than it answered about how cognitive control is affected in ADHD. It is still probable that proactive control is somehow affected in ADHD and this study failed to find significant results due to the small sample size and non-clinical population. Furthermore, most studies on this topic have focused on clinically diagnosed children. It is not yet clear how it is affected dimensionally across a range of symptom levels. It is also not clear how it is affected across the lifespan. Perhaps elements of cognitive control improve naturally over time or people can develop strategies to improve. It would be wise to replicate this study with more of the limitations accounted for before drawing the conclusion that proactive control is not impaired in ADHD.

Limitations

Our research was limited due to a low sample size of 50 participants. This meant that the power for testing specific hypotheses was very low. The observed power for the first hypothesis was 0.364 and 0.052 for the second. With low power it is difficult to make concrete conclusions about results. Significant outcomes may not reflect a true effect and insignificant outcomes may have been significant if power was higher.

Furthermore our sample consisted of first year psychology students. It is likely inaccurate to generalise these results to all university students. Students that are further along in their

studies may have lower ADHD symptoms or have learned effective ways to cope with them in order to progress academically.

In addition, we used self report measures (CAARS) to assess ADHD. This is vulnerable to over or underestimation from students. It is also possible that comorbidities play a role, this was not considered in this research. ADHD is highly comorbid with depression and anxiety (Furczyk, 2014). Comorbities could potentially interfere with self reporting or reaction times.

Future research and conclusion

Future research will benefit from a higher sample size to conduct a higher powered investigation into proactive control in university students with ADHD symptomatology. Future studies could use both clinical and non-clinical populations to conduct research. Using a dimensional approach to ADHD requires a large number of participants that have a sufficient range of ADHD symptoms. Furthermore, all tests should be conducted in the same area on the same device. This will prevent participants from listening to music or being distracted during the task. Future studies could also include more aspects of proactive and reactive control such as inhibition. This creates a more nuanced picture of cognitive control and allows us to see what specific aspects are impaired or not. The conclusion of this research is that we did not find evidence for impaired proactive control in university students with higher levels of ADHD. However more research is needed to confirm this.

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Appendix

Table 1

Tests of ANCOVA Assumptions

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
TS_RT_MediumMix_colour_alerting_re	.248	46	<.001	.516	46	<.001
TS_RT_MediumMix_colour_alerting_sw	.174	46	.001	.912	46	.002
TS_RT_MediumMix_colour_informative_re	.116	46	.147	.956	46	.081
TS_RT_MediumMix_colour_informative_sw	.112	46	.188	.964	46	.160
TS_RT_MediumMix_shape_alerting_re	.126	46	.067	.961	46	.129
TS_RT_MediumMix_shape_alerting_sw	.088	46	.200*	.977	46	.493
TS_RT_MediumMix_shape_informative_re	.107	46	.200*	.960	46	.117
TS_RT_MediumMix_shape_informative_sw	.136	46	.033	.945	46	.031
TCAARS_ADHD_Index	.094	46	.200*	.963	46	.150
TCAARS_DSM_Total	.094	46	.200*	.963	46	.150

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

Table 2

Tests of Within-Subjects Effects

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
Task	Sphericity Assumed	9157.104	1	9157.104	.133	.717	.003	.133	.065
	Greenhouse-Geisser	9157.104	1.000	9157.104	.133	.717	.003	.133	.065
	Huynh-Feldt	9157.104	1.000	9157.104	.133	.717	.003	.133	.065
	Lower-bound	9157.104	1.000	9157.104	.133	.717	.003	.133	.065
Error(Task)	Sphericity Assumed	3312545.06	48	69011.355					
	Greenhouse-Geisser	3312545.06	48.000	69011.355					
	Huynh-Feldt	3312545.06	48.000	69011.355					
	Lower-bound	3312545.06	48.000	69011.355					
Cue	Sphericity Assumed	5443166.30	1	5443166.30	95.374	<.001	.665	95.374	1.000
	Greenhouse-Geisser	5443166.30	1.000	5443166.30	95.374	<.001	.665	95.374	1.000
	Huynh-Feldt	5443166.30	1.000	5443166.30	95.374	<.001	.665	95.374	1.000
	Lower-bound	5443166.30	1.000	5443166.30	95.374	<.001	.665	95.374	1.000
Error(Cue)	Sphericity Assumed	2739438.20	48	57071.629					
	Greenhouse-Geisser	2739438.20	48.000	57071.629					
	Huynh-Feldt	2739438.20	48.000	57071.629					
	Lower-bound	2739438.20	48.000	57071.629					
SetShift	Sphericity Assumed	57875.796	1	57875.796	1.379	.246	.028	1.379	.210
	Greenhouse-Geisser	57875.796	1.000	57875.796	1.379	.246	.028	1.379	.210
	Huynh-Feldt	57875.796	1.000	57875.796	1.379	.246	.028	1.379	.210
	Lower-bound	57875.796	1.000	57875.796	1.379	.246	.028	1.379	.210
Error(SetShift)	Sphericity Assumed	2014861.35	48	41976.278					
	Greenhouse-Geisser	2014861.35	48.000	41976.278					
	Huynh-Feldt	2014861.35	48.000	41976.278					
	Lower-bound	2014861.35	48.000	41976.278					
Task * Cue	Sphericity Assumed	50661.538	1	50661.538	.747	.392	.015	.747	.135
	Greenhouse-Geisser	50661.538	1.000	50661.538	.747	.392	.015	.747	.135
	Huynh-Feldt	50661.538	1.000	50661.538	.747	.392	.015	.747	.135
	Lower-bound	50661.538	1.000	50661.538	.747	.392	.015	.747	.135
Error(Task*Cue)	Sphericity Assumed	3255272.95	48	67818.186					
	Greenhouse-Geisser	3255272.95	48.000	67818.186					
	Huynh-Feldt	3255272.95	48.000	67818.186					
	Lower-bound	3255272.95	48.000	67818.186					
Task * SetShift	Sphericity Assumed	122962.656	1	122962.656	2.530	.118	.050	2.530	.344
	Greenhouse-Geisser	122962.656	1.000	122962.656	2.530	.118	.050	2.530	.344
	Huynh-Feldt	122962.656	1.000	122962.656	2.530	.118	.050	2.530	.344
	Lower-bound	122962.656	1.000	122962.656	2.530	.118	.050	2.530	.344
Error(Task*SetShift)	Sphericity Assumed	2332546.84	48	48594.726					
	Greenhouse-Geisser	2332546.84	48.000	48594.726					
	Huynh-Feldt	2332546.84	48.000	48594.726					
	Lower-bound	2332546.84	48.000	48594.726					
Cue * SetShift	Sphericity Assumed	18875.135	1	18875.135	.293	.591	.006	.293	.083
	Greenhouse-Geisser	18875.135	1.000	18875.135	.293	.591	.006	.293	.083
	Huynh-Feldt	18875.135	1.000	18875.135	.293	.591	.006	.293	.083
	Lower-bound	18875.135	1.000	18875.135	.293	.591	.006	.293	.083
Error(Cue*SetShift)	Sphericity Assumed	3091066.44	48	64397.218					
	Greenhouse-Geisser	3091066.44	48.000	64397.218					
	Huynh-Feldt	3091066.44	48.000	64397.218					
	Lower-bound	3091066.44	48.000	64397.218					
Task * Cue * SetShift	Sphericity Assumed	20036.588	1	20036.588	.366	.548	.008	.366	.091
	Greenhouse-Geisser	20036.588	1.000	20036.588	.366	.548	.008	.366	.091
	Huynh-Feldt	20036.588	1.000	20036.588	.366	.548	.008	.366	.091
	Lower-bound	20036.588	1.000	20036.588	.366	.548	.008	.366	.091
Error(Task*Cue*SetShift)	Sphericity Assumed	2628842.41	48	54767.550					
	Greenhouse-Geisser	2628842.41	48.000	54767.550					
	Huynh-Feldt	2628842.41	48.000	54767.550					
	Lower-bound	2628842.41	48.000	54767.550					

a. Computed using alpha = .05

Table 3

Multivariate tests

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Noncent. Parameter	Observed Power[a]
task	Sphericity Assumed	116584.081	1	116584.081	1.641	.207	1.641	.241
	Greenhouse-Geisser	116584.081	1.000	116584.081	1.641	.207	1.641	.241
	Huynh-Feldt	116584.081	1.000	116584.081	1.641	.207	1.641	.241
	Lower-bound	116584.081	1.000	116584.081	1.641	.207	1.641	.241
task * TCAARS_DSM_Total	Sphericity Assumed	139905.465	1	139905.465	1.970	.168	1.970	.279
	Greenhouse-Geisser	139905.465	1.000	139905.465	1.970	.168	1.970	.279
	Huynh-Feldt	139905.465	1.000	139905.465	1.970	.168	1.970	.279
	Lower-bound	139905.465	1.000	139905.465	1.970	.168	1.970	.279
Error(task)	Sphericity Assumed	3125573.14	44	71035.753				
	Greenhouse-Geisser	3125573.14	44.000	71035.753				
	Huynh-Feldt	3125573.14	44.000	71035.753				
	Lower-bound	3125573.14	44.000	71035.753				
cue	Sphericity Assumed	158319.878	1	158319.878	2.713	.107	2.713	.364
	Greenhouse-Geisser	158319.878	1.000	158319.878	2.713	.107	2.713	.364
	Huynh-Feldt	158319.878	1.000	158319.878	2.713	.107	2.713	.364
	Lower-bound	158319.878	1.000	158319.878	2.713	.107	2.713	.364
cue * TCAARS_DSM_Total	Sphericity Assumed	1307.815	1	1307.815	.022	.882	.022	.052
	Greenhouse-Geisser	1307.815	1.000	1307.815	.022	.882	.022	.052
	Huynh-Feldt	1307.815	1.000	1307.815	.022	.882	.022	.052
	Lower-bound	1307.815	1.000	1307.815	.022	.882	.022	.052
Error(cue)	Sphericity Assumed	2568040.72	44	58364.562				
	Greenhouse-Geisser	2568040.72	44.000	58364.562				
	Huynh-Feldt	2568040.72	44.000	58364.562				
	Lower-bound	2568040.72	44.000	58364.562				
set_sh	Sphericity Assumed	185074.710	1	185074.710	4.601	.038	4.601	.555
	Greenhouse-Geisser	185074.710	1.000	185074.710	4.601	.038	4.601	.555
	Huynh-Feldt	185074.710	1.000	185074.710	4.601	.038	4.601	.555
	Lower-bound	185074.710	1.000	185074.710	4.601	.038	4.601	.555
set_sh * TCAARS_DSM_Total	Sphericity Assumed	232276.887	1	232276.887	5.775	.021	5.775	.652
	Greenhouse-Geisser	232276.887	1.000	232276.887	5.775	.021	5.775	.652
	Huynh-Feldt	232276.887	1.000	232276.887	5.775	.021	5.775	.652
	Lower-bound	232276.887	1.000	232276.887	5.775	.021	5.775	.652
Error(set_sh)	Sphericity Assumed	1769814.86	44	40223.065				
	Greenhouse-Geisser	1769814.86	44.000	40223.065				
	Huynh-Feldt	1769814.86	44.000	40223.065				
	Lower-bound	1769814.86	44.000	40223.065				
task * cue	Sphericity Assumed	152152.816	1	152152.816	2.217	.144	2.217	.308
	Greenhouse-Geisser	152152.816	1.000	152152.816	2.217	.144	2.217	.308
	Huynh-Feldt	152152.816	1.000	152152.816	2.217	.144	2.217	.308
	Lower-bound	152152.816	1.000	152152.816	2.217	.144	2.217	.308
task * cue * TCAARS_DSM_Total	Sphericity Assumed	133020.245	1	133020.245	1.938	.171	1.938	.275
	Greenhouse-Geisser	133020.245	1.000	133020.245	1.938	.171	1.938	.275
	Huynh-Feldt	133020.245	1.000	133020.245	1.938	.171	1.938	.275
	Lower-bound	133020.245	1.000	133020.245	1.938	.171	1.938	.275
Error(task*cue)	Sphericity Assumed	3019846.72	44	68632.880				
	Greenhouse-Geisser	3019846.72	44.000	68632.880				
	Huynh-Feldt	3019846.72	44.000	68632.880				
	Lower-bound	3019846.72	44.000	68632.880				
task * set_sh	Sphericity Assumed	8218.517	1	8218.517	.163	.688	.163	.068
	Greenhouse-Geisser	8218.517	1.000	8218.517	.163	.688	.163	.068
	Huynh-Feldt	8218.517	1.000	8218.517	.163	.688	.163	.068
	Lower-bound	8218.517	1.000	8218.517	.163	.688	.163	.068
task * set_sh * TCAARS_DSM_Total	Sphericity Assumed	545.401	1	545.401	.011	.918	.011	.051
	Greenhouse-Geisser	545.401	1.000	545.401	.011	.918	.011	.051
	Huynh-Feldt	545.401	1.000	545.401	.011	.918	.011	.051
	Lower-bound	545.401	1.000	545.401	.011	.918	.011	.051
Error(task*set_sh)	Sphericity Assumed	2215354.81	44	50348.973				
	Greenhouse-Geisser	2215354.81	44.000	50348.973				
	Huynh-Feldt	2215354.81	44.000	50348.973				
	Lower-bound	2215354.81	44.000	50348.973				
cue * set_sh	Sphericity Assumed	82764.429	1	82764.429	1.250	.270	1.250	.194
	Greenhouse-Geisser	82764.429	1.000	82764.429	1.250	.270	1.250	.194
	Huynh-Feldt	82764.429	1.000	82764.429	1.250	.270	1.250	.194
	Lower-bound	82764.429	1.000	82764.429	1.250	.270	1.250	.194
cue * set_sh * TCAARS_DSM_Total	Sphericity Assumed	105251.616	1	105251.616	1.590	.214	1.590	.234
	Greenhouse-Geisser	105251.616	1.000	105251.616	1.590	.214	1.590	.234
	Huynh-Feldt	105251.616	1.000	105251.616	1.590	.214	1.590	.234
	Lower-bound	105251.616	1.000	105251.616	1.590	.214	1.590	.234
Error(cue*set_sh)	Sphericity Assumed	2913216.47	44	66209.465				
	Greenhouse-Geisser	2913216.47	44.000	66209.465				
	Huynh-Feldt	2913216.47	44.000	66209.465				
	Lower-bound	2913216.47	44.000	66209.465				
task * cue * set_sh	Sphericity Assumed	79538.815	1	79538.815	1.454	.234	1.454	.218
	Greenhouse-Geisser	79538.815	1.000	79538.815	1.454	.234	1.454	.218
	Huynh-Feldt	79538.815	1.000	79538.815	1.454	.234	1.454	.218
	Lower-bound	79538.815	1.000	79538.815	1.454	.234	1.454	.218
task * cue * set_sh * TCAARS_DSM_Total	Sphericity Assumed	74632.432	1	74632.432	1.364	.249	1.364	.208
	Greenhouse-Geisser	74632.432	1.000	74632.432	1.364	.249	1.364	.208
	Huynh-Feldt	74632.432	1.000	74632.432	1.364	.249	1.364	.208
	Lower-bound	74632.432	1.000	74632.432	1.364	.249	1.364	.208
Error(task*cue*set_sh)	Sphericity Assumed	2407328.21	44	54712.005				
	Greenhouse-Geisser	2407328.21	44.000	54712.005				
	Huynh-Feldt	2407328.21	44.000	54712.005				
	Lower-bound	2407328.21	44.000	54712.005				

a. Computed using alpha = .05

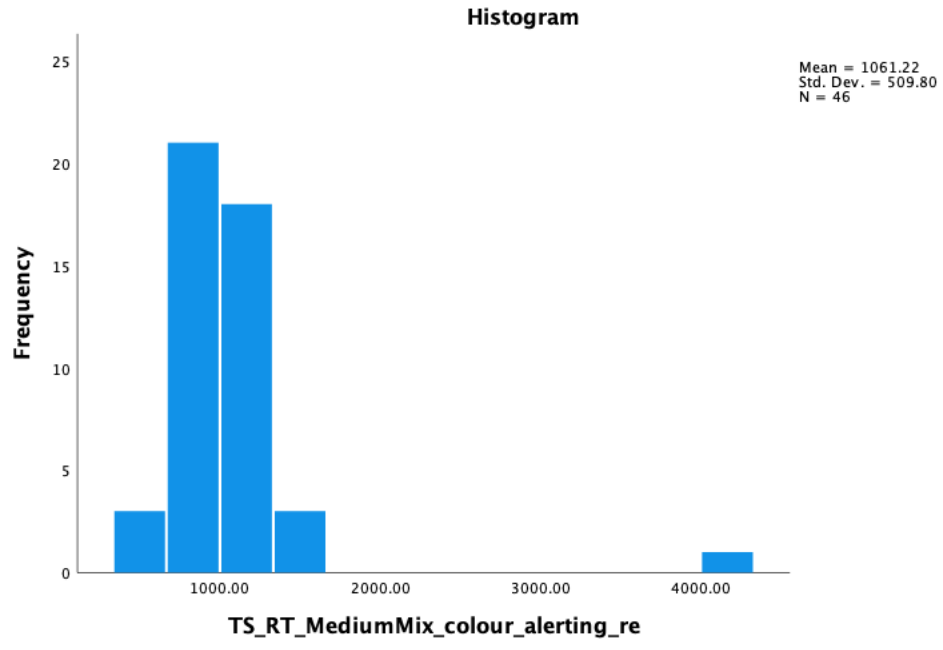
Table 4

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
TS_RT_MediumMix_colour_alerting_sw	49	543.00	1639.75	991.2806	261.80741
TS_RT_MediumMix_colour_alerting_re	49	548.71	4133.00	1050.5837	497.32464
TS_RT_MediumMix_colour_informative_re	49	344.00	1673.75	838.0663	293.92044
TS_RT_MediumMix_colour_informative_sw	49	351.50	1361.33	777.9220	254.44354
TS_RT_MediumMix_shape_alerting_re	49	433.50	1708.00	1042.5306	329.18364
TS_RT_MediumMix_shape_alerting_sw	49	567.67	1521.56	1025.4741	243.41326
TS_RT_MediumMix_shape_informative_re	49	332.50	1457.17	755.9424	263.55759
TS_RT_MediumMix_shape_informative_sw	49	364.75	1552.75	795.2398	287.73511
Valid N (listwise)	49				

Figure 1

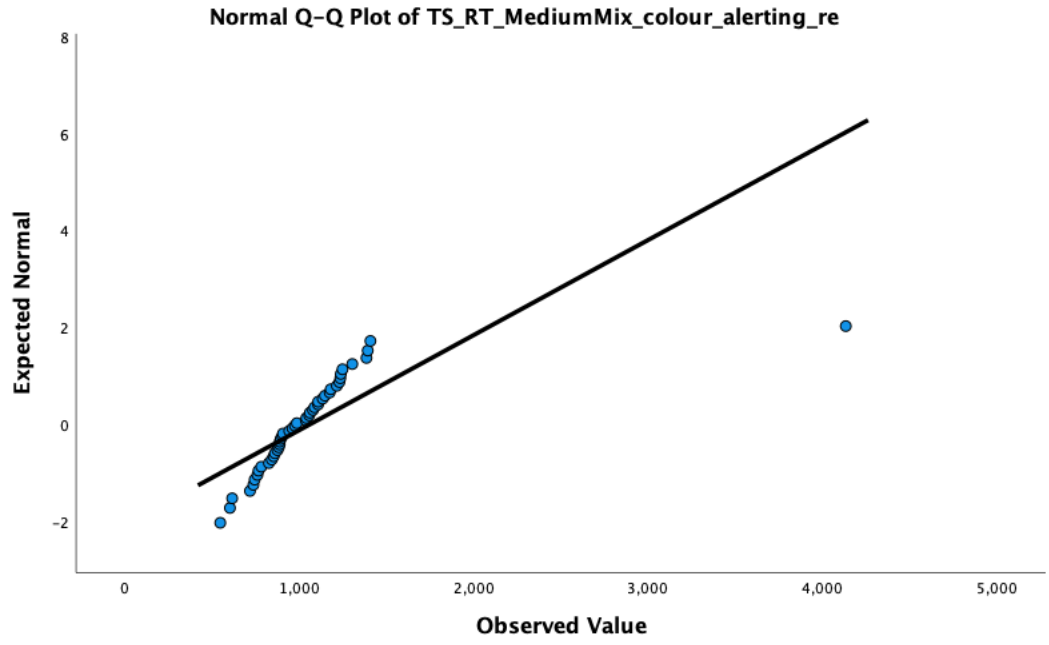
Normal plots for alerting and informative cues used in testing the first hypothesis



Note: This shows the frequency of reaction times in the medium mixed colour alerting condition with a visible outlier. This participant had high levels of ADHD symptoms.

Figure 2

Normal plot for medium colour alerting condition.



Note: This plot was significantly not normally distributed however, the outlier was left in the analysis because of their high ADHD levels being the suspected reason for the longer reaction time.