Multiple Object Tracking Ability, Working Memory Capacity and Individual Predictors of Complex Task Performance

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Abstract

The ability to efficiently attend to multiple objects in the environment is important in everyday tasks and various occupations. Given research demonstrates individuals differ in their capacity to carry out this ability, multiple object tracking (MOT) tasks were designed to measure this ability. Limited research has investigated the predictive utility of a MOT task called NeuroTracker on complex task performance. The present study sought to extend this research by examining whether NeuroTracker was more predictive of participants' performance on a simulated air traffic control (ATC) task than two working memory tests. The influence of other individual differences (age, gender and action video game experience) on task performance was also examined. Forty-seven participants (males = 38, females = 9) with a mean age of 28.7 years (SD = 9.10) completed the Randot Stereo Test, NeuroTracker, Corsi Block Tapping Task, OSPAN, ATC simulation, and a questionnaire. Regression analyses revealed NeuroTracker was predictive of four out of five ATC performance measures, making it more predictive than the working memory tests. Additionally, action video game experience was partially associated with ATC task performance, whereas no such effects were observed for age or gender. The study provides empirical support for the predictive utility of NeuroTracker.

Declaration

This thesis contains no material which has been accepted for the award of any other degree of diploma in any University, and, to the best of my knowledge, this thesis contains no material previously published except where due reference is made. I give permission for the digital version of this thesis to be made available on the web, via the University of Adelaide's digital thesis repository, the Library Search and through web search engines, unless permission has been granted by the School to restrict access for a period of time.

30/09/2019

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CHAPTER 1

Introduction

1.1 Overview

The ability to attend to and track multiple objects as they move around the environment is vital for everyday activities such as driving or playing sports (Crowe, Howard, Attwood, & Kent, 2019), and is especially important for certain occupations. It is for this reason the multiple object tracking (MOT) task was developed by Pylyshyn and Storm in 1988. The MOT task is a type of visual attention task which targets the key cognitive functions of working memory, information processing speed, and three domains of attention (sustained, selective and divided) (Allen, McGeorge, Pearson, & Milne, 2006; Doran & Hoffman, 2010; Harenberg et al., 2016; Lapierre, Price, Cropper, & Howe, 2017). This task involves tracking and identifying target stimuli as they move around in space amongst similar looking distractor stimuli (Arend & Zimmer, 2012). Previous research has identified two cognitive functions that are particularly important for MOT performance. The first is selective visual attention, in which processing resources are selectively allocated to certain stimuli over others (Richard & Anne, 2000). Selective attention is vital to MOT task performance as it plays the important role of filtering out information to ensure visual attention is directed towards target stimuli and away from distractor stimuli (Arend & Zimmer, 2012). The second cognitive function vital to MOT performance is working memory (Drew, Horowitz, Wolfe, & Vogel, 2011; Vandierendonck, Kemps, Fastame, & Szmalec, 2004). Working memory has been proposed to temporarily store the location of each tracked object in memory as they move around using active rehearsal mechanisms (Lapierre, Price, Cropper, & Howe, 2017). Additionally, working memory has also been suggested to play a vital role in the focusing, dividing and switching of attentional resources (Allen et al., 2006).

While working memory and attentional resources are important for MOT, both multiple resource theory (Wickens, 2002) and information processing theory (Miller, 1994) state that people have a finite capacity for each of these functions and that these capacities vary across individuals. Therefore, it stands to reason that some individuals would be more suited to highly demanding occupations in which multi-tasking and tracking of multiple objects are commonplace. One such demanding occupation is air traffic control (ATC). Air traffic controllers are responsible for performing the following duties for multiple aircraft at any one time: providing clearance for the use of runways; granting permission to take off and land; and providing navigational guidance in the air and on the ground to ensure no aircraft collisions occur (Ackerman & Kanfer, 1993). Given the complexity and importance of ATC, research has been devoted to identifying cognitive and non-cognitive predictors of ATC performance.

To date, no studies to the author's knowledge have investigated whether MOT ability is a predictor of ATC task performance. This gap in the research will therefore be addressed by the current study using a MOT task called NeuroTracker. The aim of this exploratory study is to determine whether NeuroTracker performance is predictive of participants' performance on a simulated ATC task. Additionally, other non-cognitive factors will also be explored for their predictive utility.

1.2 Air Traffic Control (ATC) Simulation Task

Simulated ATC tasks have been used within psychological research to study the influence of cognitive factors on ATC performance (Fothergill, Loft, & Neal, 2009; Loft, Hill, Neal, Humphreys, & Yeo, 2004). These simulated ATC tasks require participants to monitor multiple aircraft within a designated sector to ensure they are free from collision risks, as well as accept and handoff aircraft as they enter and exit the allocated sector. Research has demonstrated that both attentional resources and working memory are highly predictive of the number of conflicts correctly identified in ATC tasks (Redick et al., 2016). A study by Bender et al. (2017) further examined the predictive utility of working memory and attention on ATC task performance by identifying tests most predictive of ATC performance. They observed that the Corsi Block Tapping task (a measure of working memory) and the Automated Operation Span task (a measure of sustained attention and working memory) were both positively correlated with participants' response times to accepting and handing off aircraft, as well as their response times to detecting conflicts. Taken together, these studies provide empirical support for the contribution that working memory and attention make to simulated ATC task performance.

1.3 Predictive Utility of NeuroTracker

Today numerous versions of Plyshyn and Storm's (1988) MOT task exist. One such version, called NeuroTracker, has been used to study MOT ability in athlete (Faubert, 2013) and military populations (Vartanian, Coady, & Blackler, 2016). While to date NeuroTracker has largely been used by researchers to train cognitive skills, a limited number of studies have also examined whether it is a predictor of complex task performance in real-world settings. One such study was conducted by Mangine et al. (2014) who used NeuroTracker to predict 12 professional basketball players' court performance. The results of this study suggested NeuroTracker performance was a likely predictor of better game play, as determined by greater assists, turnovers and steals of the ball. These performance gains were possibly due to an increased efficiency in the ability to respond to various stimuli on the court. Another study conducted by Harenberg et al. (2016) found NeuroTracker scores significantly predicted performance on a simulated surgical task in a sample of 29 medical students. An additional study which more recently demonstrated a positive association between MOT ability and task performance was conducted by Woods-Fry et al. (2017). In their study, 30 elderly participants were tested on NeuroTracker and two driving simulator scenarios. Better NeuroTracker performance was significantly associated with fewer crashes and lane deviations for one of the scenarios, but not the other.

While these three studies all show promise for the predictive utility of NeuroTracker, one study did not find such an association. Tran and Gallagher Poehls (2018) examined the relationship between NeuroTracker scores and academic performance (measured using grade point average scores) for 45 American college students. This lack of an association could have been due to the dependent variable examined. It could be argued that grade point average scores do not directly measure cognitive abilities, such as attention, like the other studies previously mentioned could. Additionally, the lack of variability in grade point average scores in the sample could have also contributed to the lack of a significant finding.

Overall, these studies suggest that NeuroTracker shows promise for predicting complex task performance, especially where there is a strong requirement for sustained attention. However, given that so far only limited research has investigated the predictive utility of NeuroTracker, compounded by the relatively small sample sizes utilised in these studies, further research is warranted.

1.4 Multi-tasking

A common aspect of complex task performance such as ATC is the need to perform two or more independent tasks simultaneously; a skill commonly known as multi-tasking (Sanbonmatsu, Strayer, Medeiros-Ward, & Watson, 2013). Although research suggests no one can multi-task without some form of performance deficits, better working memory capacity and attentional resources have been associated with better multi-tasking ability (Bernhardt et al., 2016; Nelson et al., 2016; Redick et al., 2016). Working memory has been identified as important for successful multi-tasking due to its capacity to actively maintain the numerous task goals required to guide behaviour, as well as its role in directing attention towards relevant stimuli (Redick et al., 2016). Similarly, attention has been shown to predict multi-tasking ability due to the important influence it has over actively directing attention towards information and stimuli relevant to one task, while simultaneously ignoring information and stimuli not relevant to the current task (Sanbonmatsu et al., 2013). Collectively these studies provide support for the important role working memory and attention play in both MOT and ATC task performance.

1.5 Relationship Between MOT Ability and ATC Task Performance

According to Harenberg et al. (2016), NeuroTracker measures the cognitive functions of sustained attention, selective attention, divided attention, working memory and information processing speed. By contrast, discrete measures of working memory, such as those used in studies by Reddick et al. (2016) and Bender et al. (2018), primarily assess visuospatial working memory capacity. Previous research suggests selective attention, sustained attention, working memory, spatial ability, and information processing speed are key cognitive attributes for both air traffic controllers and effective performance on simulated ATC tasks (Ackerman & Kanfer, 1993; Fox, 2014; Langr, Kalvoda, & Pokorný, 2015; Trites, 1965). As NeuroTracker measures a range of cognitive functions relevant to ATC, it is reasonable to expect NeuroTracker to be a better predictor of ATC performance than working memory tests alone. Given no previous studies have tested this assumption, it will be a novel focus in the current study.

The ability of NeuroTracker to predict ATC task performance above and beyond working memory tests is further supported by research suggesting multi-tasking is one of the top ten crucial skills required by air traffic controllers. It could also be argued that effective multi-tasking would be vital to participants' performance on the ATC simulation task, given the need to switch between accept, handoff and conflict tasks. As multi-tasking is known to involve both attentional resources and working memory ability (Redick et al., 2016), once again NeuroTracker would be expected to be able to better predict participants' performance on the ATC task. It is therefore believed that MOT ability will be a better predictor of ATC task performance than discrete measures of working memory capacity, given the greater similarity between cognitive functions used in the two tasks. A comparison of the different cognitive functions involved in NeuroTracker, the ATC simulation task and two tests of working memory (Corsi Block Tapping Task and Automated Operation Span Task) can be found in Table 1.

Table 1.

Comparison of key cognitive functions involved in the four tasks

Task	**Selective Attention**	**Sustained Attention**	**Divided Attention**	**Attention Inhibition**	**Visual Working Memory**	**Information Processing Speed**	**Other**
MOT	X	X	X	X	X	X	
Corsi		X		X	X	X	
OSPAN		X		X	X	X	Basic Maths
ATC	X	X	X	X	X	X	Simple Rules

Note. Corsi = Corsi Block Tapping Task, OSPAN = Automated Operation Span Task.

1.6 Other Individual Differences

Research has found other individual difference factors, including age, gender, stereopsis and action video game experience, are associated with MOT ability. The following sections provide a brief summary of findings from this research.

1.6.1 Age. It is well established that human cognitive functioning declines with biological age. Memory and information processing speed particularly start declining from around the age of 45 and onwards (Deary et al., 2009). Of relevance to the current study, research has found elderly participants tend to perform poorer on MOT tasks than younger participants (Plourde, Corbeil, & Faubert, 2017) and in the ATC industry (Becker & Milke, 1998). For this reason, it is important to consider the potential effects of age whenever assessing individual performance on cognitive tests.

1.6.2 Gender. Previous research has identified gender to be a potential influencer of cognitive performance, particularly multi-tasking and spatial abilities (Mantyla, 2013). While some research suggests that males tend to have faster visual tracking speeds on MOT tasks compared with females (Tran & Gallagher Poehls, 2018), other research has found no such gender differences (Redick et al, 2016). Similarly, mixed results have been observed for the tendency of males to outperform females on tests of multi-tasking (Hambrick, Oswald, Darowski, Rench, & Brou, 2010; Mantyla, 2013; Redick et al., 2016; Todorov, Missier, Konke, & Mantyla, 2013). This therefore suggests that the relationship between gender and complex task performance is not straightforward and warrants further research.

1.6.3 Action video game experience. Research has shown that experience with action video games is linked to enhanced perceptual-cognitive skills. Green and Bevalier (2003) found that video game playing (defined as playing three to four times per week over a six-month period) was associated with higher levels of selective visual attention when compared with non-video game playing. Subsequent research has found that action video game players perform better on MOT tasks, as evidenced by their ability to track an average of approximately two or more objects compared to non-video game players (Green & Bevalier, 2006). Additionally, those with greater gaming experience outperform those with little to no action video game experience on tests of multi-tasking (Chiappe, Conger, Liao, Caldwell, & Vu, 2013; Hambrick et al., 2010). These findings therefore suggest the importance of examining the influence of prior action video game experience when assessing individual performance on complex tasks, such as ATC.

1.6.4 Stereopsis. Stereopsis, or binocular vision, is the perception of depth that is produced by the brain from visual stimuli input received from both eyes (Plourde et al., 2017). Previous research has found that MOT ability is influenced by individual differences in stereopsis, especially in those aged 65 and above when stereopsis has been found to deteriorate (Plourde et al., 2017). Consequently, when investigating MOT ability, it is important to first screen participants' stereopsis to ensure those with any deficits are excluded from participation.

1.7 The Current Study

The primary aim of this exploratory study is to investigate the predictive utility of individual differences (both cognitive and non-cognitive) on complex task performance using a simulated ATC task. The current study presents an opportunity to expand on the so far limited research examining the ability of NeuroTracker to predict real-world task performance. As working memory has also been found to significantly predict ATC task performance, two working memory tests will also be examined, and their predictive utility compared with that of NeuroTracker. In addition, the influence of participants' gender, age, and action video game experience on ATC and MOT performance will also be examined. The continued research into this area is justified by the need to ensure screening tools used for recruitment purposes can appropriately identify candidates who meet a standard of cognitive functioning. This is vital in certain occupations involving high cognitive load, such as ATC, where mistakes can lead to disastrous consequences.

1.7.1 Study aims and hypotheses. The current study has three aims. The first aim is to explore the relationship between MOT ability (as measured by NeuroTracker) and ATC task performance. The second aim is to examine the influence of age, gender, and action video game experience on MOT and ATC task performance. The final aim is to investigate whether MOT ability is a better predictor of ATC task performance than the two working memory tests. Consistent with these aims, the following hypotheses will be examined:

Hypothesis 1: Better MOT ability (i.e. faster visual tracking speeds) will be associated with better ATC task performance (i.e. faster response times and fewer errors).

Hypothesis 2: Action video game experience will be positively associated with MOT ability and ATC task performance.

Hypothesis 3: Age will be negatively associated with MOT ability and ATC task performance.

Hypothesis 4: Males will display better MOT ability and ATC task performance than females.

Hypothesis 5: MOT ability will be a better predictor of ATC task performance than discrete measures of working memory capacity.

CHAPTER 2

Method

2.1 Study Design and Approval

The study employed a within-subjects design. A priori power analyses were conducted using G*Power to determine an appropriate sample size. Results from these analyses identified an estimated sample size of 42 for correlational analyses (alpha = .05, effect size = .50, power = .95), and 40 for regression analyses (alpha = .05, effect size = .50, power = .95). The study received ethics approval from the University of Adelaide School of Psychology Human Research Ethics Committee (see Appendix A) prior to data collection. Written informed consent was obtained from all participants via signed consent forms. Participants did not receive any payment or credit for their time.

2.2 Participants

Forty-seven participants (males = 38, females = 9) comprised of civilian (n = 15) and military personnel (n = 32) took part in the study. Participants were aged between 20 and 55 (*M* = 28.7, *SD* = 9.1) and were all in good health at the time of the study. The inclusion criteria for participation included having normal or corrected-to-normal vision, normal stereo vision, being at least 18 years of age, no colour blindness, no epilepsy and no cognitive impairments. Participants were recruited via email (see Appendix B), as well as through the researcher's personal and professional contacts. One participant was excluded from the sample due to incomplete participation, resulting in a final sample size of 46 participants.

2.3 Apparatus and Materials

2.2.1 Randot Stereo Test (Designs for Vision, Australia). The Randot Stereo Test is a test of depth perception and stereo vision. For this test, participants are required to wear stereo glasses and hold a test booklet approximately 40 cm away from their eyes. In part one of the test, participants are shown three rows consisting of five cartoon animals and must name the animal from each row that appears to be closer to the participant than the others. For part two of the test, participants are shown two blocks of four squares. In the first block of squares, participants are required to point to the square that contains no shape. Next, they must name the shapes in the remaining three squares. Participants are lastly required to repeat this procedure for the second block of four squares. If participants correctly identify the right animals and shapes, as well as correctly point out the blank square, they are concluded as having normal stereo vision. The test took approximately one minute to administer. All 46 participants were determined as having normal stereo vision.

2.2.2 NeuroTracker (Cognisens Athletics, Inc, Montreal, Quebec, Canada). NeuroTracker is a MOT task that measures visual working memory, information processing speed, and sustained, selective, divided and inhibited attention, (Harenberg et al., 2016; Vartanian et al., 2016). NeuroTracker is a licensed software that can be purchased through Cognisens. Before participants begin testing, they first watch a brief 30 second video demonstrating how the task works and what they will be required to do. This video was part of the NeuroTracker software. To complete the task, participants are required to track target objects while ignoring distractor objects. To begin with, participants are presented with eight yellow balls, four of which are briefly illuminated in orange to signal the balls participants need to track. Next, all eight balls return to their original yellow colour and move around the screen for eight seconds. As the balls move around, participants track the four target balls, while ignoring the four distractor balls. Once all eight balls have stopped moving, participants select the four balls they believe are the targets using either a keyboard or a mouse. If the participant correctly identifies all four target balls, then the speed of the next trial increases. If the participant does not correctly identify all four target balls, then the speed of the subsequent trial decreases. Each phase of the task is demonstrated in Figure 1. Participants are required to complete three sessions of 20 trials, as is consistent with Harenberg et al.'s (2016) study. In contrast to previous studies which used the 3-D version of NeuroTracker to predict complex task performance (Harenberg et al., 2016; Mangine et al., 2014; Woods-Fry et al., 2017), this study used a 2-D version. Each session took between six to eight minutes to complete, with total testing taking approximately 24 minutes. The dependent variable was the average visual tracking speed across the three sessions (i.e. 60 trials).

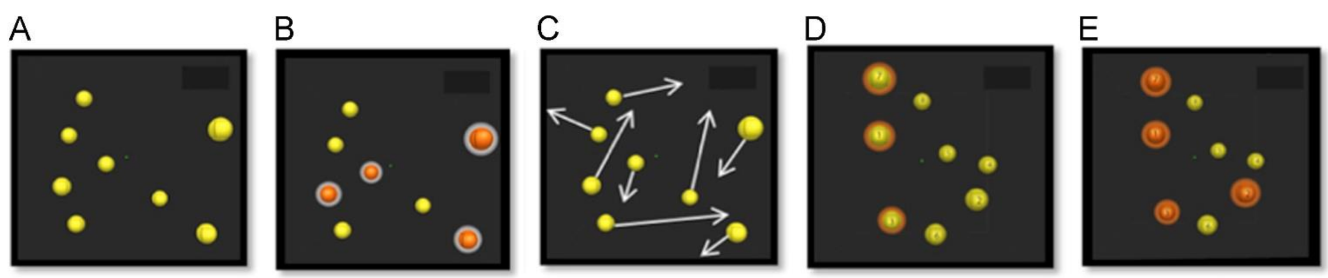


Figure 1. Illustration of the different phases of the NeuroTracker task; the four orange balls represent the target objects to be tracked while the four yellow balls represent the distractor objects (Image source: Harenberg et al., 2016).

2.2.3 Corsi Block Tapping Task (Corsi, 1972). The Corsi Block Tapping Task (commonly referred to as Corsi) is a widely used measure of visuospatial working memory span within clinical and experimental contexts (Claessen,Van Der Ham, & Van Zandvoort, 2015). The test was downloaded from the Millisecond Test Library and ran through Inquisit 5 Lab for Windows. For this task, participants are presented with a screen consisting of nine blue squares that light up individually in yellow in a predetermined sequence ranging from two to nine squares (see Figure 2 for a screenshot). Beginning with a sequence length of two squares, participants are required to correctly recall the presented sequence across two trials by clicking on the squares with their mouse. If participants correctly recall the presented sequence across both trials, then the sequence length for the next two trials increases by one. If participants incorrectly recall the presented sequence in both trials, then the test immediately ceases. Participants are required to complete the task twice in order for a more reliable measure of performance to be gained, given the lack of a practice opportunity. Total testing time took approximately 10 minutes. The dependent variable was the average length of the last correctly recalled sequence across the two trials (maximum possible score = 9).

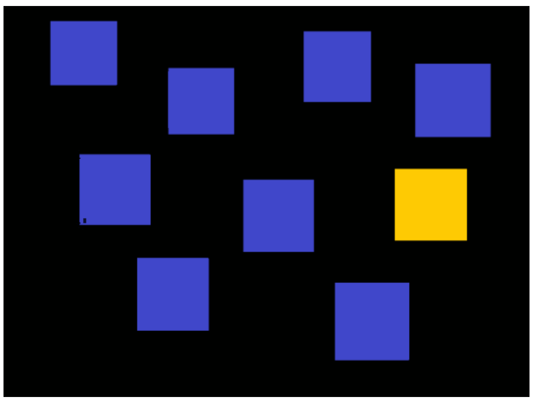


Figure 2. Screenshot of the Corsi Block Tapping Task

2.2.4 Automated Operation Span Task (Redick et al., 2012). The Automated Operation Span (OSPAN) Task is a measure of working memory capacity that has been shown to have strong validity (Unsworth, Heitz, Schrock, & Engle, 2005). In this task, participants are required to remember a sequence of letters while simultaneously solving some simple mathematical problems. The task consists of three practice phases and one testing phase. For the first practice phase, participants memorise and recall a sequence of letters, while in the second practice phase they solve some simple mathematical equations by indicating whether a provided solution is true or false. The final practice phase involves simultaneously memorising and recalling letter sequences while solving a mathematical equation in between the presentation of each letter to be memorised. For the testing phase, participants are again required to simultaneously recall letter sequences while solving mathematical equations. The testing phase involves a total of 15 trials consisting of three trials of each sequence length ranging from three to seven letters. An illustration of the four key tasks involved in this testing phase is shown in Figure 3. Total testing time was approximately 16 minutes. The dependent variable was the total number of letters recalled in the correct order (maximum possible score = 75).

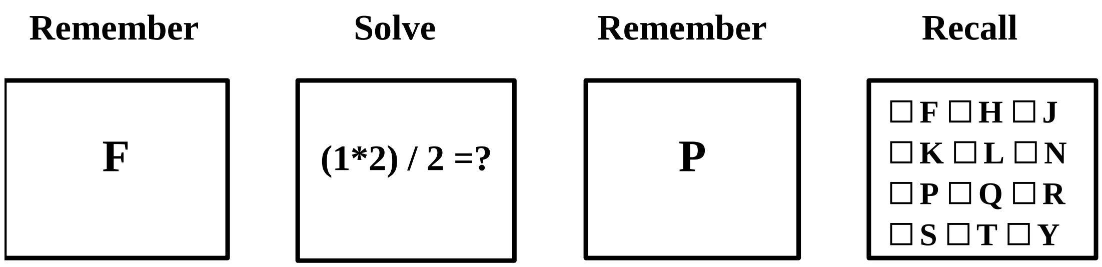


Figure 3. *Illustration of the four tasks involved in the testing phase of the OSPAN task*

2.2.5 Air Traffic Control (ATC) Lab (Fothergill, Loft & Neal, 2009). The ATC-Lab is a software program that provides a low fidelity simulation of ATC. The software has been used extensively in previous research and was obtained by the author by contacting one of the developers directly. In the task participants have three main responsibilities: (1) accept all approaching aircraft entering their sector, (2) hand-off all departing aircraft leaving their sector, and (3) correct for any conflicts between aircraft. In order to detect conflicts, participants are required to observe the direction aircraft are travelling in, as well as the flight levels they are travelling on. If they discover two aircraft travelling at the same altitude whose paths will intercept without intervention, they are required to increase the altitude of one of the aircraft. Participants are responsible for observing between eight to 12 aircraft at any one time. The total testing time was approximately 30 minutes. The original dependent variables examined for this task included: acceptance response time, acceptance accuracy, handoff response time, handoff accuracy, conflict response time, conflict accuracy, and number of false alarms due to incorrectly detecting a conflict. Correlational analyses, however, demonstrated a very strong relationship between acceptance and handoff response times (r = .83, p <.001) and acceptance and handoff accuracy (r = .79, p <.001). Due to these high correlations, as well as the large similarities between the two tasks, these four variables were collapsed into two variables. Accordingly, acceptance and handoff response times were collapsed into a combined response time score and acceptance and handoff accuracy scores were collapsed into a combined accuracy score. Collapsing these variables therefore meant that performance on the ATC task was instead measured using the following five variables: response time (measured in seconds), response accuracy (maximum possible score = 93), conflict time (measured in seconds), conflict accuracy (maximum possible score = 10) and conflict false alarms (measured as a number).

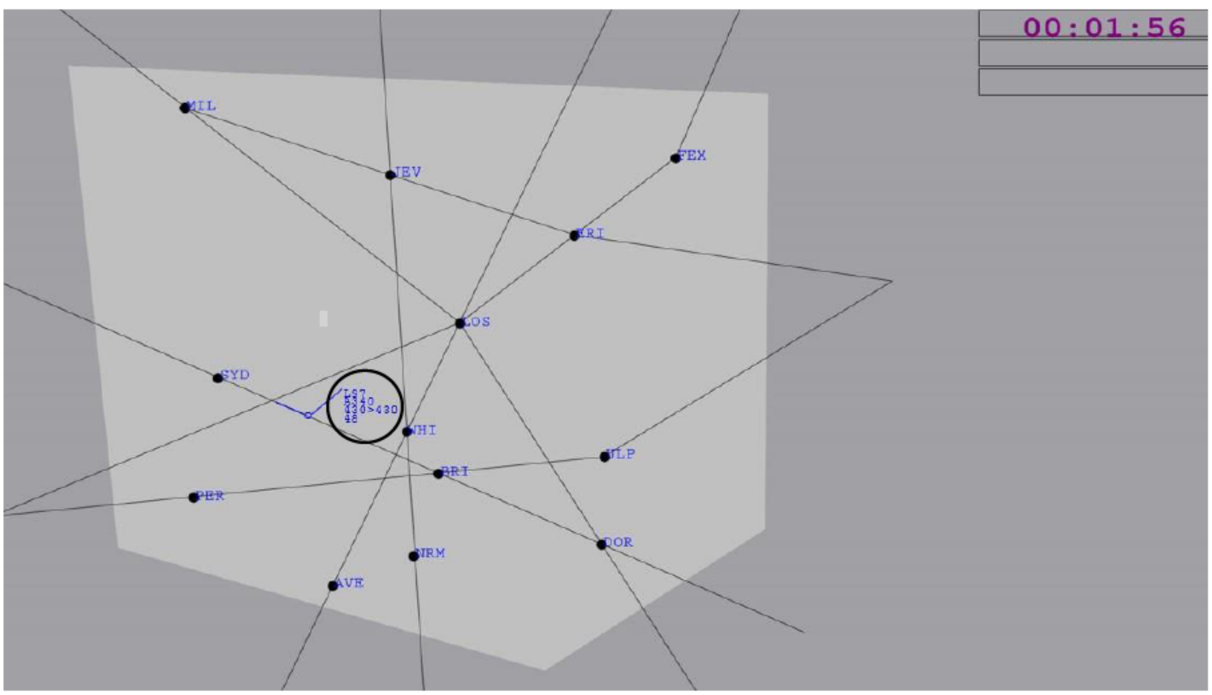


Figure 4. *Screenshot of the ATC-Lab task: the middle light grey area represents the sector under participants control, the lines running through the map represent flight paths aircraft would travel on and the aircraft is circled in black (Image source: Fothergill et al., 2009).*

2.2.6 Questionnaire. A paper-based questionnaire was administered to capture participants' age, gender and action video game experience (see Appendix C). All action video game experience questions were adapted from Green and Bevalier's (2003) study.

2.3 Procedure

All testing was conducted in a quiet location under the guidance and supervision of the student researcher. Upon arrival at the test location, participants were briefed on the study requirements, given a copy of the study information sheet and signed a consent form. Participants were seated for the full duration of testing which ran for approximately two hours. For the four computer-based cognitive tests, participants used either a tablet (ASUS Transformer Mini T102HA, 10.1" touchscreen, 4GB RAM), a laptop (Lenovo Notebook V110, 15.6", 8GB RAM or Acer Spin SP513-51, 13.3", 8GB RAM) or desktop computer (Dell Intel Core i7-6700, 16GB RAM with a Dell 22" monitor). All computer devices met minimum recommended specifications for use with Inquisit and NeuroTracker software.

The order of test administration was the same for all participants: Questionnaire, Randot Stereo Test, NeuroTracker, Corsi, OSPAN, and the ATC task. All participants were provided with a 15-minute rest break between the OSPAN and ATC tasks.

For the ATC task, participants first read an information sheet (see Appendix D) instructing them on how to complete the task. Additionally, they were given an instruction sheet outlining all the computer keys (see Appendix E) needed to complete the task. Next, participants' understanding of the task was tested via six PowerPoint quiz questions and a five-minute practice scenario. Participants were informed that they could ask as many questions as they liked and that their results from these two practice exercises would not count towards their performance. Once participants felt confident in their understanding of the task, they completed the final testing scenario. Immediately following the completion of each of the study's four tasks, participants were provided with brief feedback on their performance via each of the tests.

While all participants completed each of the tests individually, 30 of the military participants completed the tests in a group setting. This was due to having access to only four NeuroTracker licences, as well as the limited time available for accessing the military personnel who took part in the study. These factors meant that testing of these 30 military participants was conducted over two consecutive days, rather than a single test session of two hours.

The procedure for this group testing is described as follows. On day one, participants first completed the questionnaire before being assigned into groups of three to four and allocated to different time slots throughout the day. At their allocated time, participants arrived at the test location and completed the Randot Stereo Test and NeuroTracker task. On the second day of testing, participants completed all remaining tasks in a group setting on individual computers. Consistent with those who were tested individually, participants next completed the Corsi and OSPAN tasks. Following the completion of these two working memory tasks, participants were given a 15-minute break. After the break, participants completed the ATC task. However, instead of only being given an instruction sheet to read as those tested individually, these participants were additionally shown a 20-minute narrated PowerPoint presentation. This PowerPoint presentation provided the same information as the ATC written instruction sheets, only in more detail. This was done to compensate for the decreased opportunities participants in the group setting had to ask questions compared to those who were tested individually. Participants were seated in blocks of eight, with four on each row and dividers in between. The student researcher and three research assistants oversaw the test administration for the group of 30 military participants.

CHAPTER 3

Results

3.1 Preliminary Analyses

Data was analysed using SPSS Statistics® Version 25. Prior to analyses being conducted, all data was screened for missing values and outliers. The following data was identified as being affected due to computer or user errors: three OSPAN scores, all acceptance and handoff related data for one participant, and all ATC scores for one participant. While these ATC scores were subsequently removed, the three OSPAN scores were replaced with mean scores in order to maximise the power of regression analyses. The following outliers were identified using the outlier labelling rule: one OSPAN score, two acceptance response time scores, two handoff response time scores and nine conflict false alarm scores. Based on Tabachnick, Fidell and Ullman's (2007) recommendations on how to treat outliers, the OSPAN, acceptance response time and handoff response time scores were all changed to one unit smaller than the next most extreme score for that variable. The nine false alarm outliers were further screened for extreme values using Z-scores of four and above. This analysis identified two extreme scores which were deleted. Additionally, all conflict scores (both response time and accuracy scores) for the two participants belonging to these extreme false alarm scores were also deleted. This was due to the assumption that these two participants were likely using divergent strategies from other participants for monitoring potential conflicts, as evidenced by their extreme false alarm scores, very fast response times and high accuracy scores. As these two participants' acceptance and handoff scores were not significantly faster than the average, it was assumed they did not use a divergent strategy for the acceptance and handoff tasks; as such these scores were not removed.

An independent samples t-test and Mann-Whitney U test was next conducted to ensure there were no significant performance differences between those tested individually and those tested as a group. No significant differences in NeuroTracker, OSPAN, Corsi, or ATC scores were observed (all *p* values ranged from .079 to .838). As such the two groups were treated as a single group for further analyses. Output from these analyses can be viewed in Appendix F.

Finally, all variables were checked for normality via visual inspections of histograms and the Kolmogorov-Smirnov goodness-of-fit test. Only response time and conflict time were identified as being normally distributed. Therefore, analyses on all remaining variables were conducted using non-parametric tests.

3.2 Sample Characteristics and Descriptive Statistics

Of the 46 participants that completed testing, 80% (n = 37) were male and 65% (n = 30) reported playing action video games within the last six months. Additionally, given that the mean age of participants was 28.70 years, it meant that the sample was skewed relatively young. Descriptive statistics for participants' age and performance on each of the four tasks are presented in Table 2. Of note, participants actioned 99.60% of all aircraft that needed to be accepted and handed off in the ATC task, with a mean number of 92.66 out of 93 aircraft identified. For the conflict task, participants accurately identified 84.40% of conflicts between aircraft, with a mean score of 8.44 out of 10 conflicts detected. Lastly, although participants had much slower response times when detecting conflicts than they did for accepting and handing off aircraft, this was likely due to the nature of the differing tasks rather than a reflection of their performance. Participants received visual cues when aircraft required accepting or handing off (i.e. they flashed orange or blue), thus enabling a quicker response from participants. For the conflict task, however, there were no such visual cues. Additionally, it took longer to identify and respond to conflicts given it was impossible to tell with any certainty whether two aircraft would conflict with one another until they were closer together. Overall, while participants performed close to ceiling on accuracy measures of the ATC task, there was great variability in their response times.

Table 2

Descriptive statistics for age and test variables

Variable	Mean	SD	Min	Max	*n*
Age	28.70	9.10	20	55	46
NeuroTracker	1.19	.41	.53	1.93	46
Corsi	6.38	.94	5	9	46
OSPAN	57.20	11.46	27	72	43
Response time (s)	2.91	.89	1.45	4.63	44
Response accuracy	92.66	.96	89	93	44
Conflict time (s)	102.82	38.21	18.90	163.80	43
Conflict accuracy	8.44	2.39	1	10	43
Conflict false alarms	4.65	4.56	0	18	43

Note. Maximum Corsi scores equaled 9, maximum OSPAN scores equaled 75, maximum response accuracy scores equaled 93 and maximum handoff accuracy scores equaled 10

3.3 Correlational Analyses

In order to tests for hypotheses one through four, correlation analyses were conducted. The inter-correlation matrix for all variables is shown in Table 3. With regards to hypothesis one, results showed a significant and moderate negative correlation between NeuroTracker scores and both response time (r = -.36, p = .017) and conflict false alarms (r = -.39, p = .010). This meant that higher NeuroTracker scores were associated with faster response times for accepting and

Table 3

Correlation coefficients for all variables

Scale	1	2	3	4	5	6	7	8	9	10
1. NeuroTracker										
2. Corsi	.41**									
3. OSPAN	.50**	.26								
4. Response time	-.36*	-.25	-.18							
5. Response accuracy	.28	.39**	.09	-.49**						
6. Conflict time	-.16	-.44**	-.22	.41**	-.47**					
7. Conflict accuracy	.27	.38*	.16	-.56**	.54**	.67**				
8. Conflict false alarms	-.39*	-.02	-.16	.23	-.07	-.38*	-.01			
9. Age	.08	-.03	.15	.05	.02	.10	.01	-.18		
10. Gender	-.10	-.12	.04	.14	.05	.22	-.08	-.05	.18	
11. Action video games	-.12	-.11	.05	.53**	.03	.17	-.06	-.00	.31*	.33*

Note. Spearman's was used to examine all variables except for Response Time and Conflict Time which was examined using Pearson's, gender: 1= male 2 = female, action video game experience (AVG): 1 = yes, 2 = no, * p < .05, * *p < .01

handing off aircraft and fewer errors when identifying conflicts between aircraft. The correlations between NeuroTracker scores and the other three ATC measures, however, were not significant ($p > .050$).

For the two working memory tests, significant correlations were observed for performance on both the ATC and NeuroTracker tasks. Specifically, Corsi scores were significantly correlated with NeuroTracker scores ($r = .41$, $p = .005$) and with three of the ATC performance measures; a moderate to strong negative relationship with conflict time ($r = .44$, $p = .003$); a moderate positive relationship with response accuracy ($r = .39$, $p = .009$); and a moderate positive relationship with conflict accuracy ($r = .38$, $p = .013$). OSPAN scores in contrast were positively and significantly correlated with NeuroTracker scores ($r = p <.001$), but not with any of the measures of ATC task performance.

With regards to action video game experience, there was a significant, moderate negative correlation with ATC task performance for response time ($r = .31$, $p <.001$). This meant that playing action video games within the last 6 months was associated with faster response times for accepting and handing off aircraft. Action video game experience, however, was not significantly correlated with NeuroTracker scores. Neither age nor gender was significantly correlated with any of the ATC measures or with NeuroTracker performance (all $p > .050$).

3.4 Regression Analyses

In order to test hypothesis five, the following analyses were used: hierarchical multiple linear regression to examine response time and conflict time; binary logistic model to examine response accuracy and conflict accuracy; and negative binominal model to examine conflict false alarms. For all analyses, the predictor variables were entered in the following steps: action video game experience and gender at step one to control for their effects on ATC task performance;

NeuroTracker at step two to determine its unique effect on performance; and Corsi and OSPAN at step three to determine their unique effect on ATC task performance, as well as any subsequent changes in NeuroTracker's effects. Gender was excluded from all regression analyses due to the sample containing few females who reported playing action video games (n = 3), thus making it practically impossible to separate the effects of gender and gaming experience on ATC task performance.

Before either of the hierarchical multiple regressions were run for response time and conflict time, they were first checked to ensure all necessary assumptions were met. For both variables, the assumptions of linearity, multivariate normality, multicollinearity and homoscedasticity were confirmed as being met. Both regressions were run using the enter method in the three steps discussed above. The results of these analyses can be seen in Table 4. The first hierarchical multiple regression analysis examined response time as the dependent variable. Step one of the regression model significantly predicted a total of 23% of variance, $F(2,41) = 6.08$, $p = .005$, with action video game experience being a significant predictor of acceptance and handoff response times. Adding NeuroTracker into the model at step two explained an additional 11% of variance, and this change in R^2 to .34 was significant, $F(1, 40) = 6.87$, $p = .012$. At this step, both action video game experience and NeuroTracker were significant predictors of acceptance and handoff response times. Finally, adding Corsi and OSPAN into the model only explained an additional 1% of variance and this change in R^2 to .35 was not significant, $F(2,38) = .34$, $p = .715$, but the overall regression model was, $F(5,38) = 4.15$, $p = .004$. Step three accounted for a total of 35% of variance in response time, with only action video game experience remaining a significant predictor. It is important to note, however, that while NeuroTracker was not significant in step three of the model, it was approaching

Table 4

Hierarchical multiple linear regression analyses for response time and conflict time

Variable	*β*	*t*	*p*	95% CI	sr^2	R^2	ΔR^2
						.23	.23
Response time							
Step 1							
Constant	16.87	3.85	<.001	8.02, 25.73			
Age	.02	.13	.894	-.28, .32	.00		
AVG	8.53	3.05	.004	2.88, 14.19	.18		
Step 2						.34	.11
Constant	26.41	4.82	<.001	15.33, 37.49			
Age	.03	.24	.810	.24, .31	.00		
AVG	7.67	2.90	.006	2.33, 13.00	.17		
NeuroTracker	-7.40	-2.62	.012	-13.1, -1.70	.15		
Step 3						.35	.01
Constant	30.63	2.86	.007	8.95, 52.32			
Age	-.00	-.00	.998	-.30, .30	.00		
AVG	7.76	2.86	.007	2.26, 13.26	.18		
NeuroTracker	-7.09	-1.94	.060	-14.47, .30	.09		
Corsi	-1.11	-.73	.472	-4.19, 1.98	.01		
OSPAN	.06	.48	.637	-.18, .30	.01		
Conflict time						.04	.04
Step 1							
Constant	.75	3.51	.001	.32, 1.18			
Age	.01	.80	.428	-.01, .02	.02		
AVG	.08	.62	.537	-.19, .36	.01		
Step 2						.06	.02
Constant	.90	3.21	.003	.33, 1.47			
Age	.01	.82	.416	-.01, .02	.02		
AVG	.07	.54	.591	-.20, .35	.01		
NeuroTracker	-.12	-.84	.409	-.42, .17	.02		
Step 3						.14	.08
Constant	1.79	3.27	.002	.68, 2.90			
Age	.00	.27	.788	-.01, .02	.00		
AVG	.11	.82	.420	-.16, .38	.02		
NeuroTracker	.06	.32	.751	-.30, .41	.00		
Corsi	-.12	-1.58	.123	-.27, .03	.06		
OSPAN	-.01	-.85	.403	-.02, .01	.02		

Note. Action video game (AVG): 1 = yes, 2 = no significance (*p* = .060). From these results, it can be concluded that gaming experience was a significant predictor of response time. Additionally, higher NeuroTracker scores appeared to be a better predictor of faster response times, likely more so than either Corsi or OSPAN.

The second hierarchical multiple regression examined conflict response time as the dependent variable. Step one resulted in an insignificant model, $F(2,40) = .92$, $p = .406$. Neither adding NeuroTracker in step two, $F(3, 39) = .84$, $p = .479$, or Cosi and OSPAN in step three, $F(5,37) = 1.24$, $p = .309$, resulted in a significant regression model. Additionally, none of the predictor variables significantly predicted conflict response time at any step of the model. It can therefore be concluded that conflict response time was not able to be predicted.

The remaining three ATC scores were examined using a binary logistic model and a negative binomial model. The results of these analyses can be viewed in Table 5. The first binary logistic model used response accuracy as the dependent variable. Step one resulted in a non-significant model, $X^2(2, n = 44) = 2.37$, $p = .305$; Nagelkerke $R^2 = .06$. At this step, neither action video game experience nor age significantly predicted response accuracy. NeuroTracker became a significant predictor when it was added at step two, and resulted in a significant model, $X^2(3, n = 44) = 20.93$, $p < .001$; Nagelkerke $R^2 = .45$. This addition of NeuroTracker at step two resulted in a substantial improvement in model fit compared to step one. Lastly, step three also resulted in a significant model, $X^2(5, n = 44) = 26.77$, $p < .001$, as well as a further improvement in model fit; Nagelkerke $R^2 = .54$. Both NeuroTracker and Corsi were significant predictors at this step. From these results, it can be concluded that better performance on NeuroTracker and Corsi predicted greater accuracy of accepting and handing off aircraft.

The second binary logistic model examined conflict accuracy as the dependent variable. Step one of the regression was not significant, $X^2(2, n = 43) = 3.37$, $p = .185$,

Table 5

Binary logistic and negative binominal model results for response accuracy, conflict accuracy and conflict false alarms

Variable	X^2 (df)	Log Likelihood	Nagelkerke R^2	Coefficient Estimates	Standard Error	Odds Ratio	95% CI for Odds Ratio
Response accuracy Model 1	2.37(2)	-38.65	.06				
Intercept				7.51	1.41	1861.77	116.86, 29662.47
AVG				-.94	.74	.39	.09-1.67
Age				-.04	.03	.96	.90-1.02
Model 2	20.93**(3)	-29.37	.45				
Intercept				5.37	2.00	215.18	4.28, 10826.20
AVG				-1.77	1.03	.17	.02-1.27
Age				-.08	.04	.93	.86-1.01
NeuroTracker				3.86*	1.16	47.41	4.90-459.16
Model 3	26.77**(5)	-26.45	.54				
Intercept				.42	3.40	1.52	.00, 1155.50
AVG				-2.03	1.31	.13	.01-1.72
Age				-.05	.05	.96	.87-1.05
NeuroTracker				3.27*	1.28	26.26	2.13-324.58
Corsi				1.17*	.52	3.23	1.16-8.97
OSPAN				-.04	.03	.96	.91-1.02
Conflict accuracy Model 1	3.37(2)	-106.73	.08				
Intercept				2.71	.62	15.00	4.49, 50.10
AVG				-.27	.32	.76	.40-1.44
Age				-.03	.02	.97	.94-1.00
Model 2	34.31**(3)	-91.26	.55				
Intercept				.82	.76	2.28	.52, 10.02
AVG				-.52	.36	.59	.29-1.21
Age				-.04*	.02	.96	.93-1.00
NeuroTracker				2.18**	.44	8.83	3.72-20.92

Variable	X^2 (df)	Log Likelihood	Nagelkerke R^2	Coefficient Estimates	Standard Error	Odds Ratio	95% CI for Odds Ratio
Model 3	46.82**(5)	-85.00	.67				
Intercept				-3.57	1.66	.03	.00, .73
AVG				-.39	.38	.68	.32-1.42
Age				-.01	.02	.99	.96-1.03
NeuroTracker				1.83**	.49	6.23	2.37-16.38
Corsi				.78*	.23	2.18	1.38-3.45
OSPAN				-.02	.01	.98	.96-1.01
Conflict false alarms Model 1	1.67(2)	-112.58	.04				
Intercept				2.37	.69	10.70	2.77, 41.38
AVG				-.20	.37	.82	.40-1.70
Age				-.03	.02	.98	.94-1.01
Model 2	8.87*(3)	-108.99	.19				
Intercept				3.52	.82	33.82	6.73, 169.88
AVG				-.02	.38	.98	.47-2.05
Age				-.02	.02	.98	.94-1.02
NeuroTracker				-1.29*	.48	.28	.11-.70
Model 3	9.37(5)	-108.73	.20				
Intercept				2.55	1.78	12.80	.39, 422.15
AVG				-.01	.38	.99	.47-2.08
Age				-.02	.02	.98	.94-1.02
NeuroTracker				-1.54*	.60	.22	.07-.69
Corsi				.09	.23	1.09	.69-1.72
OSPAN				.01	.02	1.01	.97-1.05

Note. action video game experience (AVG): 1 = yes, 2 = no, * p <.050, ** p <.001

Nagelkerke R^2 =.08, with neither action video game experience nor age significantly predicting conflict accuracy. The addition of NeuroTracker in step two did however result in a significant model, $X^2(3, n = 43) = 34.31$, p <.001, Nagelkerke R^2 = .55, with NeuroTracker being a significant predictor of conflict accuracy. Finally Corsi and OSPAN were added at step three, $X^2(5, n = 43) = 46.82$, $p < .001$, and resulted in an improved model fit; Nagelkerke $R^2 = .67$. At step three, both NeuroTracker and Corsi were significant predictors. It can be concluded that better performance on both NeuroTracker and Corsi tasks was predictive of greater accuracy in correctly identifying aircraft requiring conflict resolution.

Finally, a negative binomial model was used to examine conflict false alarms. Step one of the model resulted in no significant predictors or a significant model, $X^2(2, n = 43) = 1.67$, $p = .433$; Nagelkerke $R^2 = .04$. NeuroTracker was a significant predictor in step two and its addition resulted in a significant model, $X^2(3, n = 43) = 8.87$, $p = .031$; Nagelkerke $R^2 = .19$. Lastly, the addition of Corsi and OSPAN into step three resulted in a non-significant model, $X^2(5, n = 43) = 9.37$, $p = .095$; Nagelkerke $R^2 = .20$. These results therefore indicate that NeuroTracker performance was predictive of making fewer false alarms when detecting conflicts.

3.5 Additional Analyses

To further examine hypotheses two and four, any significant differences in mean NeuroTracker scores were calculated using Mann-Whitney U Tests. First examining gender, mean scores showed that males had slightly higher NeuroTracker scores ($M = 1.21$) than females ($M = 1.11$), however this difference was not significant, $U = 143.50$, $p = .524$. While those who played action video games within the past six months did have slightly higher mean NeuroTracker scores ($M = 1.22$) than those who did not play ($M = 1.12$), once again this difference was not significant, $U = 204.50$, $p = .413$. Therefore, it can be concluded that it is unlikely either gender or action video game experience contributed to NeuroTracker performance.

CHAPTER 4

Discussion

4.1 Overview

The present study sought to examine the predictive utility of both cognitive and non-cognitive factors on complex task performance. More specifically, it aimed to investigate whether performance on a MOT task called NeuroTracker would be predictive of performance on a simulated ATC task. Given that working memory is known to be a strong predictor of both ATC and MOT task performance, two discrete measures of working memory were also included to compare their predictive utility with that of NeuroTracker. In addition to these cognitive factors, gender, age and action video game experience were also examined for their influence on MOT and ATC task performance. Results showed that while NeuroTracker was only correlated with two performance measures for the ATC task, regression analyses found NeuroTracker to be predictive of four measures. In contrast for the two working memory tests, Corsi was predictive of two performance measures, while OSPAN was predictive of none. Lastly, action video game experience was partially associated with ATC performance but not MOT performance, while both age and gender were not associated with performance on either of the two tests. These results will be discussed in greater detail in the following sections, as well as the limitations and implications of the current study.

4.2 Summary of Findings

4.2.1 MOT ability and ATC task performance. The first aim of the study was to explore the relationship between performance on the MOT task NeuroTracker, and performance on the ATC task. It was hypothesised that MOT performance would be correlated with ATC task performance. Results revealed that only two out of five measures of ATC task performance (response time and conflict false alarms) were correlated with NeuroTracker performance. Therefore, hypothesis one was only partially supported. As previous studies have found moderate to high correlations between MOT performance and complex task performance (Mangine et al., 2014; Woods-Fry et al., 2017), this finding was only partially consistent with these studies.

A possible explanation as to why NeuroTracker was only correlated with two performance measures of the ATC task is due to fundamental differences between the key tasks involved in the ATC simulation. Specifically, participants were responsible for two main tasks: (1) accepting and handing off aircraft approaching or leaving the sector, and (2) monitoring all aircraft within the sector for potential conflicts. For the first task, accepting and handing off aircraft, participants received visual cues (i.e. aircraft flashing in blue or orange) as to when this task had to be actioned. For the conflict task, however, participants received no such visual cues until after the time to action the task had passed.

Due to these differences in the two main tasks, it is possible that they required different cognitive functions to perform them. Given that visual cues were available for accept and handoff tasks, the most likely cognitive function underpinning these tasks was attention. In contrast for the conflict task which did not have any visual cues, working memory may have played a greater role. Working memory was potentially more likely to contribute to participants' performance on the conflict task due to the need to remember the different flight levels and orientations of the numerous aircraft, while simultaneously accepting and handing off aircraft as required. This could then potentially explain why NeuroTracker, which was primarily designed to measure and train different aspects of attention, was correlated with accept and handoff response times, but not conflict response times. The finding that the working memory test Corsi was only significantly correlated with conflict response time and conflict accuracy, also supports this explanation that the accept-handoff and conflict tasks required different cognitive functions. Another potential explanation for why NeuroTracker was not correlated with the conflicts tasks is that unlike the accept-handoff tasks, the conflict task required an aspect of decision making. For the conflict task, participants were required to decide whether two aircraft were likely to be in conflict in the future, whereas no such decision making was required for the accept and handoff tasks. As NeuroTracker also largely lacks decision making, it is likely MOT tasks are not able to capture this. Unfortunately, no explanation could be found for why NeuroTracker was correlated with conflict false alarms, but not accept and handoff response accuracy.

4.2.2 Action video game experience, age and gender. The second aim of the study was to examine the influence of action video game experience, age and gender on ATC and MOT task performance. To explore this aim, three hypotheses were examined. The first hypothesis stated that playing action video games within the past six months would be positively associated with MOT and ATC task performance. Correlational analyses found that action video game experience was not correlated with NeuroTracker performance, but it was correlated with response time on the ATC task. Similarly, regression analyses showed NeuroTracker was predictive of participants' response time for accepting and handing off aircraft in the ATC task. Lastly, a Mann-Whitney U test observed no significant performance differences between action video game players and non-action video game players on any aspects of the ATC task. These results taken together suggest that playing action video games within the past six months was not associated with MOT performance, but it was associated with faster response times for accepting and handing off aircraft in the ATC task. Hypothesis two was therefore only partially supported.

Action video game experience not being associated with MOT performance was unexpected given previous research has indicated that regular game players tend to have better selective attention and visual attention (Dye, Green, & Bavelier, 2009; Green & Bavelier, 2003; Green and Bavelier, 2006). Given how important both aspects of attention are to MOT performance, it would be expected that action video game players would therefore perform better on MOT tasks. While these previous studies classified action video game players as those who had played an average of three to four days a week in the past six months, the current study used a classification of any game play within the past six months regardless of frequency. This divergence from previously used classifications could potentially explain why the current study did not find an association between action video game experience and MOT ability. Additionally, the relatively low frequency of female's who had reported playing action video games also likely contributed to this finding.

While the lack of association between action video game experience and MOT performance was unexpected, an association with ATC performance was expected. This was due to research which suggested that those with greater experience playing video games are better multi-taskers, something that would have been essential for effective performance on the ATC task (Chiappe et al., 2013; Hambrick et al., 2010). What was surprising, however, was that action video game experience was only associated with one out of five measures of ATC performance. As previously mentioned, action video game experience has been primarily associated with increased attentional resources. So, it is possible that previous gaming experience made participants quicker at responding to the flashing of aircraft requiring acceptance and hand off but not to conflicting aircraft which had no such visual cues to trigger a response.

The second hypothesis related to this aim predicted that males would perform better than females on the MOT and ATC tasks. Results, however, demonstrated no significant association between gender and performance on either of the MOT or ATC task and as such hypothesis four was not supported. Although males had slightly higher NeuroTracker scores than females, the difference in scores was not statistically significant. However, given that there were very few females in the sample who reported playing action video games, this meant that the discrete effects of gender and gaming experience on ATC and MOT performance could not be reliably determined. This would be especially likely given that one plausible explanation for the tendency of males to outperform females on tests of multi-tasking is their propensity to have significantly more action video game experience than females (Hambrick et al., 2010).

The final hypothesis related to aim two predicted that age would be negatively associated with MOT and ATC task performance. As with gender, results demonstrated that age too was not associated with either MOT or ATC task performance, meaning hypothesis four was not supported. This lack of an association once again could have been influenced by a lack of a diverse sample. Research demonstrates that the speed at which individuals can process information begins to slow down from the age of 30, with certain mental functions such as memory, executive functioning and reasoning beginning to decline from 45 (Deary et al., 2009). The current study, however, only contained 10 participants over the age of 30 and only four aged 45 and above, which is possibly why these affects may not have been found.

4.2.3 Predictive utility of NeuroTracker. The final aim of this study was to determine whether MOT ability was more predictive of ATC task performance than either of the two working memory tests. It was hypothesised that NeuroTracker would be more predictive. Regression analyses revealed that having higher NeuroTracker scores was predictive of greater accuracy at identifying aircraft requiring acceptance and handing off, greater accuracy at correctly identifying all conflicts between aircraft, and less false alarms due to incorrectly identifying a conflict between aircraft. Regression analyses also indicated NeuroTracker was a significant predictor of accept and handoff response time after controlling for the effects of gender and age, and remained close to statistical significance after accounting for the influence of Corsi and OSPAN. In contrast for the two working memory tests, OSPAN was not predictive of any ATC task performance measures and Corsi was only predictive of two performance measures; response accuracy and conflict accuracy. Based on these findings, NeuroTracker scores were predictive of more aspects of ATC task performance than either of the two working memory tests, thus supporting hypothesis five.

NeuroTracker was expected to be more predictive than either of the working memory tests given that the study by Bender et al. (2017) demonstrated both attention and working memory was predictive of participants' performance on the ATC task. Furthermore, because NeuroTracker captures a greater diversity of cognitive functions than tests of working memory alone, it would be able to better predict complex task performance. The greater predictive utility of NeuroTracker is further supported by research which shows that effective multi-tasking, which would have been vital to successful MOT performance, is heavily influenced by both working memory capacity and attention (Sanbonmatsu et al., 2013).

4.3 Strengths and Limitations

The present study had a couple of notable strengths. The first was the use of a standardised protocol when administering the tests. All participants were administered the tests in the same order under the direct supervision of the student researcher, while using consistent instructions. Although this ensured consistency between participants, it could be argued that randomising the test order would have helped to minimise potential fatigue effects or motivational losses experienced in the final ATC task. However, as the mean response time and conflict time scores in this study were slightly quicker than those in the ATC study conducted by

Bender et al., (2018), this suggests that possible fatigue effects associated with the current study schedule are unlikely to have been a factor. A second strength of the study was that it used the largest sample size compared to the three previous NeuroTracker studies which also found an association between MOT and complex task performance (Mangine et al., 2014; Harenberg et al., 2016; Woods-Fry et al., 2017). Additionally, post-hoc power analyses using G*Power revealed that the study's sample size was well powered at .95 (effect size = .30, alpha = .05, sample size = 45). As such, the current study provides further weight to the significant effects observed in these previous studies.

Despite the strengths of the study, there were also some limitations worth mentioning. The first and most significant limitation was the use of convenience sampling, which resulted in a skewed sample comprised largely of young male military personnel. This not only limits the generalisability of the findings, but also limited the ability to assess the influence of gender, age, and action video game experience on ATC task performance.

Another major limitation of this study was the large percentage of variance in ATC performance that was unexplained. Regression analyses were only able to explain between approximately 19% and 67% of variance for four of the ATC performance measures, while no variance was significantly predicted for conflict response time. Additionally, given that the Nagelkerke R^2 statistic used in the binary logistic and negative binomial models is only an approximate measure, these estimates may have been even lower. This therefore suggests that there are other factors likely contributing to participants' performance on the ATC task that were not captured by this study. While there was still a large percentage of variance unexplained, findings of this study are an improvement on the study by Harenberg et al. (2016) which only predicted between 28% and 29% of variance in task performance. Even so, more research will need to be conducted before tools such as NeuroTracker could be reliably used to screen personnel for jobs involving complex tasks.

Another potential limitation of the study was the fact that some participants were tested as a group over two consecutive days, while others were tested individually over two hours. However, given that independent samples t-test and Mann-Whitney U analyses found no significant performance differences between the two groups, this suggests that performance of either group was not unduly affected. Additionally, the use of different computer devices used to test participants may have also affected results, although all devices did meet the minimum performance specifications required. A final consideration worth mentioning is the use of NeuroTracker in 2-D mode rather than 3-D mode. While this may not have been a limitation *per se*, it does make it harder to compare these results with previous studies which used the 3-D version of NeuroTracker.

4.4 Implications for Future Research

In light of the study's limitations, recommendations are outlined for future research to address them. The first recommendation would be to replicate the study with a more representative sample. Accordingly, this would require utilising a roughly equal number of male and female participants, and to recruit participants with a wide range of action video game experience. In doing so, this would allow the use of criteria set by Green and Bavelier (2003) for classifying action video game experience. Finally, in order to gain a better understanding of the effect age has on both MOT and complex task performance, future research should target a broader range of age groups. Given research by Deary et al. (2009) on declines in cognitive functioning with age, the following age groups could be utilised: 18 to 29 when little to no declines in cognition are known to occur; 30 to 44 when information processing is known to slow; and 45 to 65 when various cognitive functions start declining.

Another suggestion would be to increase the complexity of the ATC task in order to better generate a more realistic simulation of the job demands for air traffic controllers, and to reduce the likelihood of performance ceiling effects. This could be achieved by turning off the flashing of aircraft requiring acceptance and handoff, as well as adding in competing distractors such as ambient noise and secondary tasks to increase the cognitive load on participants' attention and working memory. In addition, using a sample of novice and experienced air traffic controllers and comparing their ability on NeuroTracker and the ATC task would also be worthwhile.

Finally, as there was still a significant amount of unexplained variance in ATC task performance, this suggests that NeuroTracker and the two working memory tests did not tap into all of the cognitive components of the ATC task. Accordingly, utilising a greater battery of cognitive tests in addition to NeuroTracker could overcome this limitation. Using NeuroTracker in 3-D mode in future studies could also potentially result in further improvement in its predictive utility. Lastly, it could also be helpful for future studies to examine a greater number of personal characteristics, such as motivation and personality factors.

4.5 Conclusion

The current study has extended previous research exploring the predictive utility of NeuroTracker by investigating its relationship with complex task performance on a simulated ATC task. Overall the findings were generally consistent with previous NeuroTracker research, given that regression analyses showed NeuroTracker performance was predictive of four performance measures on the ATC task. A novel contribution of this study was the finding that NeuroTracker explained a greater proportion of ATC performance variance than discrete measures of working memory. In contrast to previous research, however, no strong effects were observed for gender, age and action video game experience on either MOT or ATC task performance. This lack of an effect, however, was likely due to methodological limitations associated with using a convenience sample. Overall, as this is still a relatively under-studied area of research, further investigation into the predictive utility of NeuroTracker and other individual factors of complex task performance is warranted. Ultimately it is hoped that this study will garner increased research into the ability of NeuroTracker and other individual factors to predict complex task performance. More effective screening tools for occupations in which multiple object tracking or multi-tasking is vital, particularly in jobs such as ATC which involves public safety.

References

Ackerman, P., & Kanfer, R. (1993). Integrating laboratory and field study for improving selection: Development of a battery for predicting air traffic controller success. *Journal of Applied Psychology, 78*(3), 413-432.

Allen, R., McGeorge, P., Pearson, D. G., & Milne, A. (2006). Multiple-target tracking: A role for working memory? *Quarterly Journal of Experimental Psychology, 59*(6), 1101-1116.

Arend, A. M., & Zimmer, H. D. (2012). Successful training of filtering mechanisms in multiple object tracking does not transfer to filtering mechanisms in a visual working memory task: Behavioral and electrophysiological evidence. *Neuropsychologia, 50*(10), 2379-2388.

Becker, J. T., & Milke, R. M. (1998). Cognition and aging in a complex work environment: relationships with performance among air traffic control specialists. *Aviation, space, and environmental medicine*, *69*(10), 944-951.

Bender, A., Loft, S., Lipp, O., Bowden, V., Whitney S., & Visser, T. (2018). *Situation Awareness Mediates the Relationship between Working Memory Ability and Performance on the Air Traffic Control Task.* Presentation to Defence Human Sciences Symposium 2018. Perth, Western Australia.

Bernhardt, K. A., Salomon, K. A., Ferraro, F. R., Crockett, R. J., Terrell, H. K., Petros, T., & Vacek, J. J. (2016). Individual differences in dynamic multitasking performance. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting, 60*(1), 1255-1259.

Chiappe, D., Conger, M., Liao, J., Caldwell, J. L., & Vu, K.-P. L. (2013). Improving multi-tasking ability through action videogames. *Applied Ergonomics, 44*(2), 278-284.

Claessen, M. H., Van Der Ham, I. J., & Van Zandvoort, M. J. (2015). Computerization of the standard Corsi block-tapping task affects its underlying cognitive concepts: A pilot study. *Applied Neuropsychology: Adult*, *22*(3), 180-188.

Crowe, E. M., Howard, C. J., Attwood, A. S., & Kent, C. (2019). Goal-directed unequal attention allocation during multiple object tracking. *Attention, Perception, & Psychophysics*, *81*(5), 1312-1326.

Deary, I. J., Corley, J., Gow, A. J., Harris, S. E., Houlihan, L. M., Marioni, R. E., ... & Starr, J. M. (2009). Age-associated cognitive decline. *British medical bulletin*, *92*(1), 135-152.

Doran, M., & Hoffman, J. (2010). The role of visual attention in multiple object tracking: Evidence from ERPs. *Attention, Perception, & Psychophysics, 72*(1), 33-52.

Drew, T., Horowitz, T., Wolfe, J., & Vogel, E. (2011). Delineating the neural signatures of tracking spatial position and working memory during attentive tracking. *The Journal of Neuroscience: The Official Journal of the Society for Neuroscience, 31*(2), 659- 668

Dye, M. W., Green, C. S., & Bavelier, D. (2009). The development of attention skills in action video game players. *Neuropsychologia*, *47*(8-9), 1780-1789.

Faubert, J. (2013). Professional athletes have extraordinary skills for rapidly learning complex and neutral dynamic visual scenes. *Scientific reports*, *3*, 1154.

Fothergill, S., Loft, S., & Neal, A. (2009). ATC-lab advanced: An air traffic control simulator with realism and control. *Behavior research methods*, *41*(1), 118-127.

Fox, K. D. (2014). *Prediction of Air Traffic Controller Trainee Selection and Training Success Using Cognitive Ability and Biodata.* (Unpublished doctoral dissertation). Walden University, Minneapolis, Minnesota.

Green, C. S., & Bavelier, D. (2003). Action video game modifies visual selective attention. *Nature*, *423*(6939), 534.

Green, C. S., & Bavelier, D. (2006). Enumeration versus multiple object tracking: The case of action video game players. *Cognition*, *101*(1), 217-245.

Hambrick, D. Z., Oswald, F. L., Darowski, E. S., Rench, T. A., & Brou, R. (2010). Predictors of multitasking performance in a synthetic work paradigm. *Applied Cognitive Psychology, 24*(8), 1149-1167.

Harenberg, S., McCaffrey, R., Butz, M., Post, D., Howlett, J., Dorsch, K. D., & Lyster, K. (2016). Can multiple object tracking predict laparoscopic surgical skills? *Journal of surgical education*, *73*(3), 386-390.

Lapierre, M. D., Price, N. S. C., Cropper, S. J., & Howe, P. D. L. (2017). Shared processing in multiple object tracking and visual working memory in the absence of response order and task order confounds. *PLoS ONE, 12*(4).

Langr, D., Kalvoda, V., & Pokorný, V. (2015). Testing aptitudes as part of the selection process of air traffic controllers by the Czech Armed Forces. *Advances in Military Technology*, *10*(2).

Loft, S., Hill, A., Neal, A., Humphreys, M., & Yeo, G. (2004). ATC-lab: An air traffic control simulator for the laboratory. *Behavior Research Methods, Instruments, & Computers*, *36*(2), 331-338.

Mangine, G. T., Hoffman, J. R., Wells, A. J., Gonzalez, A. M., Rogowski, J. P., Townsend, J. R., ... & Fragala, M. S. (2014). Visual tracking speed is related to basketball-specific measures of performance in NBA players. *The Journal of Strength & Conditioning Research*, *28*(9), 2406-2414.

Mantyla, T. (2013). Gender differences in multitasking reflect spatial ability. *Psychological science*, *24*(4), 514-520.

Miller, G.A. (1994). The magical number seven, plus or minus two: some limits on our capacity for processing information. *Psychological Review, 101* (2), 343–52.

Nelson, J., McKinley, R. A., Phillips, C., McIntire, L., Goodyear, C., Kreiner, A., & Monforton, L., (2016). The effects of transcranial direct current stimulation (tDCS) on multi-tasking throughput capacity. *Frontiers in Human Neuroscience, 10,* 589.

Plourde, M., Corbeil, M. E., & Faubert, J. (2017). Effect of age and stereopsis on a multiple-object tracking task. *PloS one*, *12*(12), e0188373.

Pylyshyn, Z. W., & Storm, R. W. (1988). Tracking multiple independent targets: Evidence for a parallel tracking mechanism. *Spatial vision*, *3*(3), 179-197

Redick, T., Shipstead, Z., Meier, M., Montroy, J., Hicks, K., Unsworth, N., . . . Engle, R. (2016). Cognitive predictors of a common multitasking ability: Contributions from working memory, attention control, and fluid intelligence. *Journal of Experimental Psychology: General, 145*(11), 1473-1492.

Richard, W. P., & Anne, S. M. (2000). Attention and Multitasking. In *Modeling Human and Organizational Behavior: Application to Military Simulations* (pp. 112- 128). Washington, DC: The National Academies Press.

Sanbonmatsu, D. M., Strayer, D. L., Medeiros-Ward, N., & Watson, J. M. (2013). Who multi-tasks and why? Multi-tasking ability, perceived multi-tasking ability, impulsivity, and sensation seeking. *PLoS ONE, 8*(1), 1-8.

Tabachnick, B. G., Fidell, L. S., & Ullman, J. B. (2007). *Using multivariate statistics* (Vol. 5). Boston, MA: Pearson.

Todorov, I., Missier, F., Konke, L., & Mantyla, T. (2015). Deadlines in space: Selective effects of coordinate spatial processing in multitasking. *Memory & Cognition, 43*(8), 1216-1228.

Tran, J., & Gallagher Poehls, C. (2018). *NeuroTracker cognitive function and its relationship to GPA in college students.* (Honours thesis). Retrieved from https://digitalcommons.lmu.edu/honors-thesis/219

Trites, D. K. (1965). Problems in air traffic management. VI., Interaction of training-entry age with intellectual and personality characteristics of air traffic control specialists. *AEUROSPACE MEDICINE, 35*(12), 1184-1194.

Unsworth, N., Heitz, R. P., Schrock, J. C., & Engle, R. W. (2005). An automated version of the operation span task. *Behavior research methods*, *37*(3), 498-505.

Vandierendonck, A., Kemps, E., Fastame, M. C., & Szmalec, A. (2004). Working memory components of the Corsi blocks task. *British Journal of Psychology, 95*(1), 57-79.

Vartanian, O., Coady, L., & Blackler, K. (2016). 3D multiple object tracking boosts working memory span: Implications for cognitive training in military populations. *Military Psychology*, *28*(5), 353-360.

Wickens, C. D. (2002). Multiple resources and performance prediction. *Theoretical issues in ergonomics science*, *3*(2), 159-177.

Woods-Fry, H., Deut, S., Collin, C. A., Gagnon, S., Faubert, J., Bédard, M., & Marshall, S. (2017). Three-dimensional multiple object tracking speed thresholds are associated with measures of simulated driving performance in older drivers. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting 61*(1), 42-45.

Appendix A: Ethics approval

THE UNIVERSITY OF ADELAIDE
AUSTRALIA

School of Psychology
University of Adelaide
North Terrace, Adelaide SA 5005
Ph. 61 8 8313 5693
Fax 61 8 8313 3770

School of Psychology: Human Research Ethics Subcommittee
Approval Sheet

Dear ANNA

The members of the subcommittee have considered your application:

Code Number: 19/40

Title: INDIVIDUAL PREDICTORS OF MULTI-TASKING PERFORMANCE ON A COMPLEX TASK

With [Student name, if applicable] PHIL TREMBLY

I am writing to confirm that approval has been granted for this project to proceed. Approval is granted to 12 months from the date specified below.

Yours sincerely,

[redacted]

Deputy Convenor, Human Research Ethics Subcommittee

Name: PAUL DELFABBRO

Date: 30/4/19

Phone Number: 8313 4936

Email: paul.delfabbro@adelaide.edu.au

Appendix B: Recruitment Email

Dear Staff

Are you interested in testing your cognitive abilities? Are you good at cognitively demanding tasks?

We are seeking volunteers to participate in a research study examining Cognitive Factors and Complex Task Performance.

Why is this study being conducted?

The study is being conducted as part of a larger research effort within DST Land Division's Cognition and Behaviour STC, which is investigating how individual characteristics influence performance on cognitively demanding tasks.

The aim of the study is to better understand how performance on complex tasks is influenced by individual differences in cognitive ability and experience.

What is involved in the study? Are there any risks?

The study will require participants to complete several computer-based tasks and a brief questionnaire. Participation will require a single session of about 2 hours.

The tests have been used in several studies with no adverse effects, but some people might experience minor discomfort from concentrating for long periods or completing cognitive tests.

Who is conducting the study? Has it been approved?

The study is being led by Amy Jarvis (Honours student) under the supervision of Mr Philip Temby (DST Land Division) and Dr Anna Ma-Wyatt (University of Adelaide).

The study has been reviewed and approved by the University of Adelaide Low Risk Research Ethics Committee.

When and where will the study be conducted?

The study will be conducted during July at the DST Edinburgh site in a quiet location in Building 75.

How can I participate or find out more information?

If you are interested in taking part, or would like more information, please reply to this email and one of the study team will get in contact with you.

Appendix C: Study Questionnaire

Participant Questionnaire

Name: ______________

Defence ID: ______________

What is your current age (in years): ______________

What is your gender?

- Male
- Female
- Prefer not to answer

In the past six months, have you ever played action video games? Please note action video games refer to games which are fast paced, require tracking multiple objects on screen and fast reaction times. Some examples include Call of Duty and Fortnite. Examples of non-action video games include Final Fantasy.

- Yes
- No

If you answered Yes, how often (on average) have you played action video games in the last six months?

- Daily
- Three to four times a week ('a few times a week')
- Once a week ('weekly')
- Once a month (monthly)
- Less than once a month

How long do you usually spend playing action video games during a single session?

- Less than 1 hour
- 1 -2 hours
- 3 - 4 hours
- 5 -6 hours
- 7 -8 hours
- More than 8 hours

Please provide the name of the game(s) you spend the most amount of time playing:

____

In the past six months, have you played any action sports? Action sports games include any games requiring fast reaction times and tracking multiple players and/or objects at the same time. Examples of actions sports games are soccer, football, hockey and tennis.

- Yes
- No

If you answered Yes, how often (on average) have you played action sports in the last six months?

- Daily
- Three to four times a week (‘a few times a week’)
- Once a week (‘weekly’)
- Once a month (monthly)
- Less than once a month

Please list the type of sport that you regularly play:

____

In the past six months, have you ever used brain training apps or games? Examples include Brain Age, Lumosity, My Brain Trainer, Elevate etc.

- Yes
- No

If you answered Yes, how often (on average) did you engage in brain training activities?

- Daily
- Three to four times a week (‘a few times a week’)
- Once a week (‘weekly’)
- Once a month (monthly)
- Less than once a month

How much time did you spend using the brain training app or game in a single session?

- 0-30 mins
- 30-60 mins
- 1-2 hours

- More than 2 hours

Please name the type of brain trainer game or app you used:

____

Do you wish to receive one of the following at the conclusion of this project?

- Your individual test results
- Results from the completed study

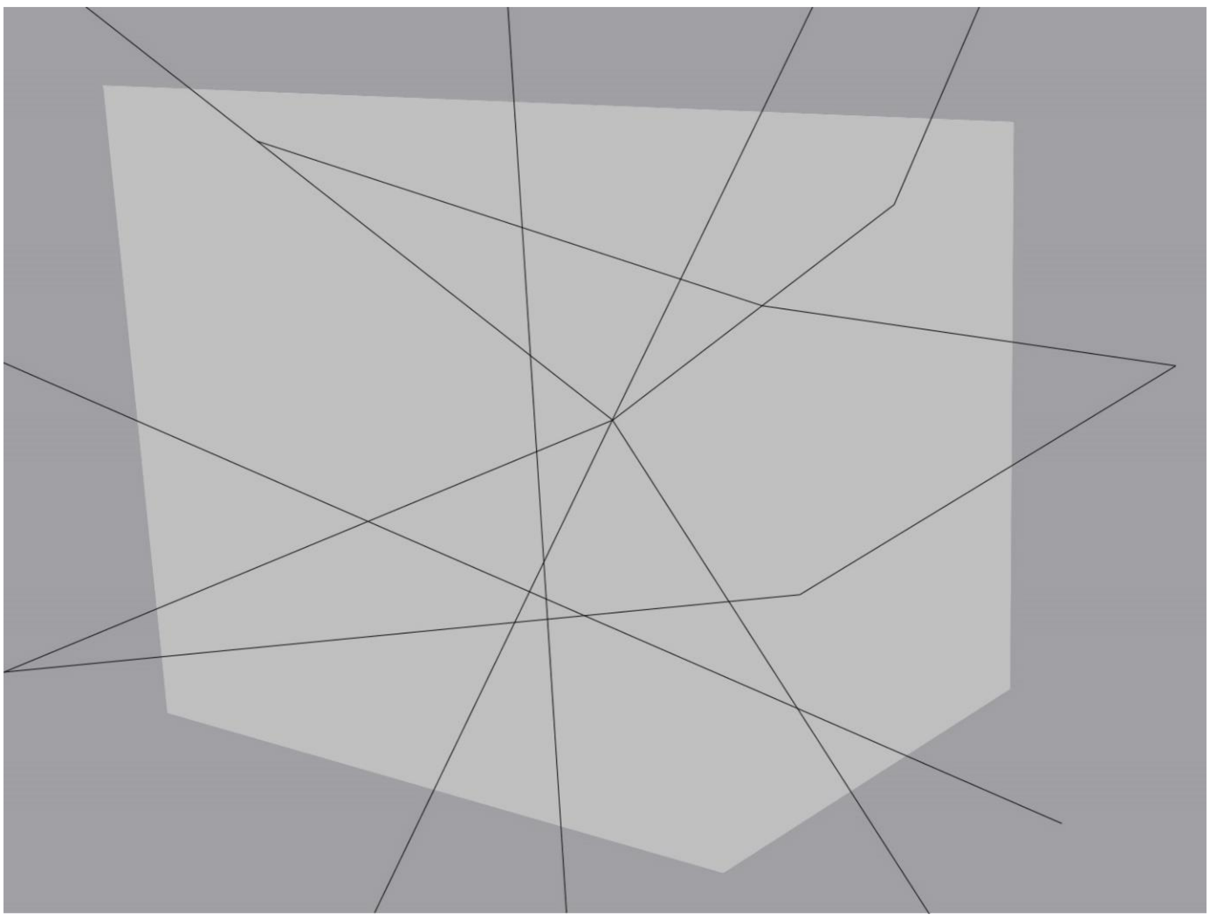
If you answered yes to either of the two options listed above, please provide your email address:

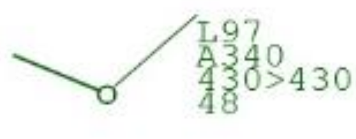
____

Appendix D: ATC Instruction sheet

Air traffic control simulation

Below is an example of what you will see during the air traffic control simulation. This is the sector map and will display numerous aircraft. The lines running through the map represent different flight paths. The middle light grey area represents the sector under your control while the dark grey area represents sectors outside of your control.





This is an example image of how the different aircraft will be displayed. The first number (L97) represents the flights call sign and will be unique to each individual flight. The second number (A340) represents the aircraft type and for the purposes of this task can be ignored. The third number (430>430) represents the aircraft's flight level. The first number is the airlines current flight level while the second number is the airlines cleared flight level. Finally, the fourth number (48) represents the aircraft's speed. The left-hand darker line represents the aircraft's projected direction. The longer this line is, the faster the aircraft is traveling. If any part of the aircraft's information is obscured by other aircraft, it can be rotated by double left-clicking on the middle circle.

You will have three main tasks during this simulation: accept all aircraft entering into the sector map; handoff all aircraft leaving the sector map; and detect and resolve any conflicts between aircraft.

Accepting aircraft

Your first task will be to accept all aircraft approaching your sector. In order to accept aircraft, you will need to patrol all aircraft approaching your sector, represented as the light grey area in the middle of the sector map. When any aircraft start **flashing blue**, you will have 20 seconds to accept the aircraft into your sector. To do this you will first need to press 'A' on the keyboard, and then click on the aircraft. If at any time you fail to accept incoming aircraft, you will hear a voice informing you of this.

Handoff aircraft

Your second task will be to handoff all aircraft leaving your sector. In order to handoff aircraft, you will need to patrol all aircraft approaching the edges of your sector. When any aircraft start

flashing orange, you will have 20 seconds to handoff the aircraft out of your sector. To do this you will need to press ‘H’ on the keyboard, and then click on the aircraft. If at any time you fail to handoff departing aircraft, you will hear a voice informing you of this.

<u>Detect and resolve conflict</u>

Your third and final task will be to monitor all aircraft within your sector to ensure no aircraft are at risk of crashing into one another. If two aircraft are both heading in the same trajectory, but are at different altitudes, they are not in conflict and no action needs to be taken. If two aircraft are heading in a different trajectory, (Note: the line to the left of the aircraft information shows which direction the aircraft is heading in) but are at the same altitude they are also not in conflict and no action needs to be taken. If two aircraft are both heading in the same trajectory, however, and are at the same altitude they are in conflict and you will need to resolve this.

You can resolve a conflict between two flights by a single left click where the flight’s altitude is listed (the third line of the aircraft information display). A textbox will then appear stating “select aircraft that will conflict with [flight callsign]”, and you will need to click on the other conflicting aircraft. If you accidently select the wrong aircraft, you can simply click on the correct aircraft and it should change. Once you are sure both aircraft have been correctly selected, click ‘Ok’ on the textbox and one of the two flights will change their altitude so that they are no longer in conflict. Please note, however, that it will take 20 seconds for an aircraft to change its altitude, so all conflicts need to be detected early. If at any time you fail to detect a conflict, you will hear a voice informing you of this. Also, if at any time you detect a conflict when none exists, you will hear a voice informing you of this.

<u>Note</u>

If at any time you want to clear a demand, just press the space bar. For example, if you accidently press A when you wanted to press H, press the space bar and this will clear the demand.

Appendix E: ATC Computer Control Sheet

Simulation Controls

Accept aircraft:

A + left click on the circle

Handoff aircraft:

H + left click on the circle

Re-orientate aircraft information:

Double left click on the circle

Resolve conflict:

Single left click where the altitude information is displayed for the first aircraft + single left click where the altitude information is displayed for the second aircraft + click 'Ok'

To **clear** any incorrect controls:

Space bar

Appendix F: Independent Samples T-Test and Mann-Whitney U Analyses

Independent samples t-test for conflict time and response time

		Levene's Test		t-test						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Diff	Std. Error	95% CI	
									Lower	Upper
ConflictTir	Equal variances assumed	0.354	0.555	1.801	41	0.079	21.1551	11.7445	-2.5634	44.8735
	Not assumed			1.87	35.343	0.07	21.1551	11.3128	-1.8031	44.1133
Response	Equal variances assumed	0.243	0.625	0.42	42	0.676	116.3975	277.0106	-442.632	675.4275
	Not assumed			0.431	36.859	0.669	116.3975	270.2864	-431.325	664.1204

Mann-Whitney U test for NeuroTracker, Corsi, OSPAN, response accuracy, conflict accuracy and false alarms.

Test Statistics[a]

	Average visual tracking speed	Corsi	OSPAN	ResponceAccuracy	ConflictAccuracy	FalseAlarms
Mann-Whitney U	237.500	206.000	217.000	221.000	185.000	153.500
Wilcoxon W	672.500	359.000	370.000	599.000	321.000	289.500
Z	-.205	-.948	-.673	-.344	-.828	-1.582
Asymp. Sig. (2-tailed)	.838	.343	.501	.731	.408	.114

a. Grouping Variable: Conditionno