Number 3/2017
ISSN 2324-3635

OCCASIONAL & DISCUSSION PAPER SERIES

Thinking while standing: An exploratory study on the effect of standing on cognitive performance

L. L. M. Patston,
A. N. Henry,
M. McEwen,
J. Mannion, and
L. A. Ewens-Volynkina

ePress Unitec Institute of Technology

ePress Research with impact Unitec Institute of Technology

OCCASIONAL AND
DISCUSSION PAPER SERIES 3/2017

Thinking while standing: An exploratory study on the effect of standing on cognitive performance

By L. L. M. Patston, A. N. Henry, M. McEwen, J. Mannion, and L. A. Ewens-Volynkina

THIS PUBLICATION MAY BE CITED AS:

L. L. M. Patston, A. N. Henry, M. McEwen, J. Mannion, and L. A. Ewens-Volynkina (2017). Thinking while standing: An exploratory study on the effect of standing on cognitive performance. Unitec ePress Occasional and Discussion Paper Series (2017:3). Retrieved from http://www.unitec.ac.nz/epress

ABOUT THIS SERIES:

Unitec ePress periodically publishes occasional and discussion papers that discuss current and ongoing research authored by members of staff and their research associates. All papers are blind reviewed. For more papers in this series please visit: www.unitec.ac.nz/epress/index.php/category/publications/epress-series/discussion-and-occasional-papers/

Cover design by Penny Thomson

CONTACT:

epress@unitec.ac.nz
www.unitec.ac.nz/epress/
Unitec Institute of Technology
Private Bag 92025, Victoria Street West
Auckland 1142
New Zealand

ISSN 2324-3635

Thinking while standing: An exploratory study on the effect of standing on cognitive performance

Authors:
L. L. M. Patston
A. N. Henry
M. McEwen
J. Mannion
L. A. Ewens-Volynkina

ABSTRACT

Sedentary behaviour is extremely prevalent in Western societies and is significantly associated with an elevated risk of all-cause mortality that cannot be mitigated by physical activity. The introduction of standing desks into the workplace offers a solution to this inactivity, but there is limited investigation regarding the effects of standing on cognition, which is a major consideration in much office-based work. In this study we aimed to provide an exploratory investigation on the effect on cognitive performance of standing while working. We tested 30 office-based adults on a battery of 19 cognitive tasks (tapping five cognitive domains) in a randomised, repeated-measures crossover design study. Two conditions (standing versus sitting) were investigated over two 7.5-hour work days including morning, midday and afternoon sessions (Time of Day). Effects were analysed using multivariate two-way repeated-measures ANOVAs (Condition by Time of Day) for five cognitive domains. Overall, after correcting for multiple comparisons, there were no differences in performance between sitting and standing. At an uncorrected level, however, significant effects of Condition were found in three of the 19 tasks, with all demonstrating better performance while standing. Importantly, these results suggest that there is no detriment to cognitive performance through standing. They also provide an initial indication that there may be cognitive benefits of standing in the attention and working memory domains, which may be a promising avenue for future inquiry.

INTRODUCTION

Sedentary behaviour is a common occurrence in Western societies (World Health Organisation, 2010) and is significantly associated with an elevated risk of diabetes, obesity, cardiovascular disease and all-cause mortality (Biswas et al., 2015; Healy et al., 2008; Stamatakis, Hamer, & Dunstan, 2011; Wijndaele et al., 2009; Wilmot et al., 2012). Acute bouts of sedentary behaviour, such as during hospitalisation, have also been shown to induce health risks. Distinct health outcomes observed between sitting, physical activity and exercise suggest that sitting has an association with overall ill health and mortality that must be considered independently of other physical activity (Biswas et al., 2015; Katzmarzyk, Church, Craig, & Bouchard, 2009). Katzmarzyk et al., (2009) found that individuals with higher levels of sitting time had greater rates of mortality than individuals with lower levels of sitting time, independent of leisure-time physical activity. This suggests that compensation for time spent sitting cannot be achieved by meeting or even exceeding the current physical activity guidelines. Practically, therefore, it is sitting behaviour that we must reduce if health is to be improved.

In the United States it has been reported that people in fulltime work sit for an average of 9.2 hours per day during the week (van Uffelen et al., 2010) and, consequently, the workplace has been the focus for addressing sedentary behaviour. A number of studies have employed active work stations, such as treadmill desks (John, Bassett, Thompson, Fairbrother, & Baldwin, 2009; Koepp et al., 2013) and cycle desks (Straker, Levine, & Campbell, 2010) in what could be assumed to be an effective intervention at reducing sedentary behaviour. While sedentary time can be reduced and associated metabolic markers shown to improve when using these active desks, however, several complaints emerge. These include feasibility, in terms of equipment cost (Tudor-Locke et al., 2014), gait instability (Kline, Poggensee, & Ferris, 2014), reduced work performance (Koepp et al., 2013; Ben-Ner, Hamann, Koepp, Manohar, & Levine, 2014), psychological harm, and reports of physical discomfort and overriding fatigue after prolonged periods of use (Cifuentes, Qin, Fulmer, & Bello, 2015). A more promising intervention in the office work context may therefore be the standing desk, or sit-stand workstation. Standing desks became popular after a number of them were installed at the White House in the United States (Lebowitz, 2015) and these desks are increasingly available in the marketplace. To date, the majority of investigations on the use of standing desks have been in the areas of energy expenditure and activity (Benden, Blake, Wendel, & Huber, 2011; Gilson, Suppini, Ryde, Brown, & Brown, 2012; Reiff, Marlatt, & Dengel, 2012), acceptability (Grunseit, Chau, van der Ploeg, & Bauman, 2013; Hinckson et al., 2013), and metabolic biomarkers (Buckley, Mellor, Morris, & Joseph, 2014).

BACKGROUND

If standing desks are to be implemented in the workplace, however, it is important that the impact on cognition be considered, as cognitive performance is a pertinent aspect of many computer-based tasks. To date, a small body of research has investigated cognitive performance of participants while standing, but results have been mixed. Early studies used measures of transcription speed and accuracy (Ebara et al., 2008; Hedge, Jagdeo, Agarwal, & Rockey-Harris, 2005) or data entry speed and accuracy (Husemann, Von Mach, Borsotto, Zepf, & Scharnbacher, 2008) to investigate the effects of standing desks on work performance, finding no difference between sitting and standing conditions. Other studies, however, have used tests of cognitive performance that better represent the types of work that are expected in many office-based positions (i.e., higher-level cognitive functions).

For example, Schraefel, Kenneth and Andersen (2012) conducted a crossover study comparing sitting and standing work postures in a small sample of adult males (n=17). Their measures were based on a computerised neurocognitive vital signs battery that tested executive function, complex attention, cognitive flexibility, psychomotor speed, reaction time and processing speed. The results showed no difference in cognitive performance between sitting and standing, except for the task measuring complex attention, which showed participants' performance was superior when they were sitting (Schraefel et al., 2012). In a more recent investigation, Bantoft et al. (2015) conducted a randomised, counterbalanced study of 45 undergraduate students using cognitive performance measures based on the Wechsler Adult Intelligence Scale (WAIS-III; Wechsler, 1997a). Attention, processing speed, working memory, visual-motor speed and learning were measured while sitting, standing, and walking at a low intensity speed. Results revealed no significant changes to cognitive performance in any of the conditions (Bantoft et al., 2015). A limitation in both studies was the use of very short condition durations. Schraefel et al. (2012) required participants to spend only 30 minutes sitting and standing, while Bantoft et al. (2015) tested for one hour per week, over three weeks.

Russell et al. (2015) investigated cognitive performance while sitting and standing in a randomised controlled crossover trial of 36 university staff, all of whom were new to standing desks. This study improved on previous research by utilising a longitudinal design: participants spent one hour per day on four consecutive days in each condition (sitting and standing). On the first three days, participants performed their normal work duties, while on the fourth day participants underwent a cognitive test battery that included tests of selective and sustained attention, psychomotor processing speed, working memory and 'work performance' (a proofreading test). Results indicated that, although standing was associated with small improvements in performance on measures of attention and working memory, there were no significant differences between the sitting and standing conditions. It is possible, however, that despite the fact that standing was spread over a longer time period compared to previous research, the amount of time spent standing each day was still insufficient to induce statistically significant improvements in cognitive performance.

Finally, a longitudinal study of high school students by Mehta, Shortz and Benden (2015) assessed the effects of introducing standing desks into the classroom on executive functioning and working memory in a sample of 27 freshmen (New Zealand Year 9). After approximately 27.5 weeks of continual standing-desk use, students' performance was significantly improved on executive function tests assessing cognitive flexibility, inhibition and abstract reasoning. These results, strengthened by utilising a much longer intervention period than other research in this area, would seem to suggest that standing desks may promote enhanced executive functioning. However, the lack of a control comparison group is an important limitation in this study, given the age of the participants. Cognitive abilities, and particularly executive functions, continue to develop throughout the teenage years, alongside structural changes in the frontal cortex (Hooper, Luciana, Conklin, & Yarger, 2004; Luciana et al., 2005; Luna et al., 2004). It is therefore difficult to disentangle the effects attributable to the use of a standing desk from increases in cognitive performance associated with age.

In general, research investigating the effects on cognition of standing to work is still in its infancy. The current study aimed to add to this literature by making two methodological improvements. Firstly, considering that the use of a standing desk is intended for longer durations over the entire working day than have previously been assessed, we aimed to investigate cognitive performance in adults while either sitting or standing for a full 7.5-hour work day. On the basis of the majority of previous findings, we hypothesised that there would be no change in cognitive performance between sitting and standing. Secondly, we chose to conduct an exploratory study over a wide range of validated cognitive tasks, spanning five domains of cognition, to provide a more complete description of the effects of standing on cognitive abilities. Due to the elongated time frame required for testing (7.5 hours), we devised a large battery of tests that was repeated three times per testing day (morning, midday and afternoon sessions). We were also interested in exploring any effect these sessions had on task performance and the perceived level of fatigue participants experienced across the sessions.

METHODS

Participants

Thirty healthy volunteers (14 women and 16 men) aged between 20 and 49 years participated in both standing and sitting conditions in this crossover study. The order of conditions (sitting condition first or standing condition first) was selected by block randomisation (stratified by gender and age group: 18-25, 26-35, 36-50 years). The groups did not differ significantly for age, $t(28) = .58$, $p = .570$, or sex, $x2 = 0$, $p > .250$. See Table 1 for a full list of participant demographics.

Time	Testing Sessions	Day 1 Set of tasks used	Day 2 Set of tasks used
9:00 – 11:00 a.m.	**Morning testing session**	Set 1	Set 4
11:00 – 12:00 p.m.	Break 1		
12:00 – 2:00 p.m.	**Midday testing session**	Set 2	Set 5
2:00 – 2:30 p.m.	Break 2		
2:30 – 4:30 p.m.	**Afternoon testing session**	Set 3	Set 6

Figure 1. Outline of the testing day showing sessions, task sets and breaks.

Participants were recruited via word-of-mouth and whitecloud-solutions.com, an online website connecting researchers and volunteers. Participants were only included if they claimed to have full-time, desk-based study or work lifestyles and usually sat for extended periods as part of their normal working day, but no baseline data was collected for lifestyles or average number of hours normally spent sitting. Potential participants were excluded if they had any of the following: 1) musculoskeletal or other pathologies preventing or influencing their ability to stand for prolonged periods of time; 2) cognitive pathologies such as chronic fatigue or any previous serious head injuries that might have influenced their ability to perform cognitive tasks; 3) current usage of any medications which might have affected concentration and/or cognitive performance; 4) poor fluency in written or verbal English; or 5) clinically diagnosed colour blindness, due to some of the tasks relying on colour perception.

Ethics approval for this study was obtained from the Unitec Research Ethics Committee (2014-1085). Written informed consent was obtained from all participants prior to testing. The experiment was performed at the Unitec Institute of Technology, Auckland, New Zealand.

Prior to testing, participants were assessed to ensure they were comfortable in both their sitting and standing postures. Normal office desks and chairs were used for the sitting condition (adjusted accordingly) and wooden boxes were placed on these desks for use in the standing condition. Three different heights were available to suit the participant's height. Participants were able to assume the opposite posture briefly to alleviate discomfort as necessary. All participants successfully completed both testing days.

A cognitive battery of 19 different tasks was completed by each participant three times per testing day (morning, midday and afternoon sessions) separated by breaks in which they were encouraged to eat, drink and rest (Figure 1). Each participant was tested individually by a research assistant in a quiet testing room in the Department of Osteopathy, Unitec Institute of Technology, New Zealand. The battery took approximately 1 hour and 45 minutes to complete, but this could vary between participants and even within participants, across testing sessions. In order to combat the variation in time taken to complete each battery, participants who finished before break times were provided with tasks, such as data entry and proofreading (see Supplemental Material 1 for further information on these tasks), to ensure all participants worked for similar time durations.

Procedure

A counterbalanced, randomised, repeated-measures crossover design was used to examine the cognitive effects of working from a standing desk compared to working from a sitting desk. Each participant completed two full days of testing (see Figure 1), with at least one week between testing days. Wherever possible, participants were tested on the same day of the week to minimise any impact of weekday variation in factors such as tiredness, but this was not always practically possible, with only 63% of participants tested on the same day for both conditions. Participants were also asked to keep their internal environment as consistent as possible by consuming a similar diet (beverage and calorie intake), consuming a similar number of caffeinated drinks ($t(29) = .36$, $p = .722$), and to wear the same shoes on both testing days (90% of participants wore the same shoes for both conditions). Data was also collected for the number of standard alcoholic drinks consumed the night before testing ($z(30) = .75$, $p = .454$) and the number of hours slept the night before testing ($t(29) = .41$, $p = .682$). Table 2 shows data collected for each participant over both conditions.

Materials and measures

Nineteen tasks (Table 3) were adapted from recognised tests of cognition and were associated with five domains of cognition: 1) Processing Speed, 2) Executive Function, 3) Working Memory, 4) Perceptual Reasoning, and 5) Attention. Supplemental Material 2 provides detailed descriptions and the procedural administration of each task.

Due to the different nature (e.g., visual, auditory, etc.) of many of the tasks, sets were constructed via different methods. So while Trail Making items were mirror-reversed, items in Set 1 and 4 of Arithmetic were the same mathematical equations but with different numbers and nouns associated with each. For example, Item 1: Set 1 is a story that reads, "A man goes home to his three cats and gives each cat four biscuits. How many biscuits does he dish out?" (3 x 4 = 12), but for Item 1: Set 4, the story reads, "A girl comes home to her four rabbits and gives each rabbit five pieces of carrot. How many carrot pieces does she dish out?" (4 x 5 = 20).

Tasks of each domain were evenly distributed throughout each set and the task order was kept constant across each set (i.e., Trail Making was always the first task completed). Holding task position steady across each set meant less variation of fatigue within each task across sets. For example,

Number	Participant ID	Gender	Years of Age	Age Category	Group
1	001A	Female	22	Young	Sitting First
2	016S	Female	24	Young	Sitting First
3	010A	Male	22	Young	Sitting First
4	021I	Male	25	Young	Sitting First
5	026I	Male	23	Young	Sitting First
6	032S	Male	22	Young	Sitting First
7	002I	Female	29	Mid	Sitting First
8	012N	Female	32	Mid	Sitting First
9	027A	Male	28	Mid	Sitting FIrst
10	030H	Male	29	Mid	Sitting First
11	007A	Female	38	Older	Sitting First
12	012I	Female	36	Older	Sitting First
13	018H	Male	44	Older	Sitting First
14	020S	Male	38	Older	Sitting First
15	108S	Female	25	Young	Standing First
16	133N	Female	24	Young	Standing First
17	114I	Male	25	Young	Standing First
18	125S	Male	25	Young	Standing First
19	129N	Male	25	Young	Standing First
20	004N	Female	32	Mid	Standing First
21	105A	Female	26	Mid	Standing First
22	106A	Female	28	Mid	Standing First
23	115N	Female	27	Mid	Standing First
24	134N	Female	31	Mid	Standing First
25	122S	Male	33	Mid	Standing First
26	123H	Male	35	Mid	Standing First
27	131H	Male	28	Mid	Standing First
28	103I	Female	36	Older	Standing First
29	117H	Male	51	Older	Standing First
30	124H	Male	41	Older	Standing First

Table 1. Demographic characteristics of participants by group.

Trail Making (Task 1) was always conducted when participants were fresh, while Visual Reproduction (Task 19) was always conducted when participants were weary, but, importantly, this was constant across Conditions. Furthermore, the nature of the study meant it did not matter whether participants performed more poorly for Visual Reproduction than they did for Trail Making, because 1) we were not interested in participants' level of prowess for any individual task, and 2) we were not comparing performance between tasks (i.e., Participant 1 for Trail Making and Visual Reproduction), only across conditions for each task (i.e., Participant 1 for Trail Making in the sitting Condition and standing Condition, and Participant 1 for Visual Reproduction in the sitting Condition and standing Condition).

Participants were also asked to complete a fatigue Visual Analogue Scale (VAS) after every session. This required them to "Circle the level of fatigue or tiredness you are feeling right now," where zero represented no fatigue or tiredness at all and 10 represented the worst fatigue or tiredness imaginable. Fatigue data was collected to assess whether participants tired more easily in one condition over the other, and in anticipation that this data may be needed for use as a covariate should there be a significant difference in fatigue between conditions. Unfortunately, baseline fatigue was not collected.

Statistical analyses

Effects for all variables were analysed using multivariate two-way repeated-measures ANOVAs for each of the five domains. Condition (sitting and standing) and Time of Day (morning, midday and afternoon sessions) were used as within-subject factors. One participant demonstrated signs of stress during testing of some tasks in the Attention and Perceptual Reasoning Domains and was later identified as an outlier in several of those tasks. The participant was excluded from the analyses of those two domains. An additional participant was excluded from data analyses for the Attention Domain because he clearly misunderstood the task instructions for the CPT-AX and CPT-Inhibition tasks. This was evident by viewing the raw data, whereby most of the errors made were consistent with correct responses for the other task. Data and SPSS analyses are available at: https://osf.io/q4ehr/

RESULTS

The current study was exploratory in nature and included 19 different cognitive tasks over five different domains. When multivariate analyses were run at the domain level, none of the domains returned a significant effect for Condition. Similarly, when the individual tasks were inspected at the significance value of .003 (adjusted for multiple comparisons), none of the 19 showed a significant effect for Condition (see Table 4 for results at task level). Inspection of the variable Time of Day (Table 4) showed that nine of the 19 tasks had a significant main effect of Time of Day. For seven of these (Symbol Search, CPT-AX, CPT-Inhibition, Block Design, Stroop Effect (word naming), Trail Making and Visuospatial Search), performance improved throughout the day. Performance on the Visual Reproduction task worsened throughout the day and performance on the Figure Weights tasks peaked at midday but returned to morning levels in the afternoon.

For Fatigue, there was no main effect of Condition, $F(1,27) = 1.39$, $p = .249$, but there was a main effect of Time of Day, $F(2,54) = 25.60$, $p < .001$. Pairwise analyses revealed a significant increase in fatigue scores (greater perceived fatigue) between morning ($M = 3.55$, $SE = 0.29$) and midday ($M = 4.47$, $SE = 0.27$), p = .003, and between morning and afternoon ($M = 5.52$, $SE = 0.28$), $p < .001$, as well as between midday and afternoon, $p < .001$. Importantly, there was no interaction between Condition and Time of Day, $F(2,54) =$

Table 2
Matched variables. Red denotes a difference across conditions.
^ symbols represent discrepancies across conditions (2-hrs+ for Hours of Sleep).

Participant ID	Day of the Week Testing Occurred			Shoe Style on Testing Day		Number of Standard Alcoholic Drinks Previous Night (Category*)		Number of Caffeinated Drinks		Hours of Sleep Prior to Testing	
	Sitting	Standing		Sitting	Standing	Sitting	Standing	Sitting	Standing	Sitting	Standing
001A	Mon	Mon		Flats^	Sneakers^	2^	3^	1.5^	2^	6	7
002I	Wed	Wed		Sneakers	Sneakers	1^	3^	3^	2^	5^	7^
004N	Fri^	Sun^		Comfortable	Comfortable	1	1	0	0	4^	7^
007A	Sun	Sun		Sneakers	Sneakers	1	1	3^	2^	6.5	8
010A	Sat	Sat		Sneakers	Sneakers	2	2	0^	1^	7	7
012I	Sun^	Mon^		Running	Running	1	1	2	2	5	5
013N	Sat	Sat		Sneakers	Sneakers	2	2	1.5^	1^	7	7
016S	Mon	Mon		Sneakers	Sneakers	1	1	0	0	8.5^	6.5^
018H	Sun	Sun		"Venice"	"Venice"	1	1	1	1	10	10
020S	Sat	Sat		Sports	Sports	3^	2^	1^	2^	7	7.5
021I	Sat	Sat		Trainers	Trainers	2^	1^	2	2	9	8
026I	Sat^	Sun^		Sneakers	Sneakers	2^	1^	3	3	8	7
027A	Fri^	Sun^		Trainers	Trainers	1^	2^	0^	1^	7.5^	9.5^
030H	Mon	Mon		Sports	Sports	1	1	3	3	5	5
032S	Sat	Sat		Sneakers	Sneakers	1	1	0	0	7	8
103I	Sat	Sat		Jandals	Jandals	1	1	0	0	6^	8^
105A	Mon	Mon		Sports	Sports	1	1	1	1	7^	9^
106A	Fri	Fri		Sneakers	Sneakers	1	1	2	2	7	7
108S	Sun^	Fri^		Jandals^	Sports^	3^	1^	1	1	8	8
114I	Sat	Sat		Sneakers^	Sandals^	1	1	0	0	12^	6^
115N	Mon	Mon		Sneakers	Sneakers	1	1	0	0	6.5	6
117H	Wed^	Fri^		Jandals	Jandals	2^	1^	0	0	6^	8^
122S	Wed^	Mon^		Trainers	Trainers	2	2	2	2	8	7
123H	Wed^	Thu^		Jandals	Jandals	2	2	2^	3^	8	8
124H	Mon^	Wed^		Flats	Flats	1	1	2^	1^	7	7
125S	Mon^	Wed^		Running	Running	1	1	0	0	8	7
129N	Sun	Sun		Sneakers	Sneakers	2	2	0	0	7	7
131H	Sun	Sun		Comfortable	Comfortable	1	1	2	2	8^	5^
133N	Thu^	Sat^		Sneakers	Sneakers	2^	1^	2	2	6	6.5
134N	Fri	Fri		Sneakers	Sneakers	1	1	0	0	5.5^	7.5^

*Alcoholic Drinks Categories:
1 = no drinks, 2 = 1-2 drinks, 3 = 3-4 drinks,
4 = 5-6 drinks, 5 = 7+ drinks

Cognitive Domain	Order	Task Name	Task Origin (adapted from)
Processing Speed	2 7 11 16	Symbol Search Cancellation Rapid Picture Naming Coding	WAIS-III – Wechsler (1997a) WAIS-III – Wechsler (1997a) Woodcock-Johnson III – Woodcock et al. (2001) WAIS-III – Wechsler (1997a)
Executive Function	1 6 10 15	Trail Making Stroop Effect Visuospatial Search Verbal Fluency	Partington and Leiter (1949) Stroop (1935) Patston and Tippett (2011) Pendleton (1982)
Working Memory	4 9 13 19	Spatial Span Letter-Number Sequencing Arithmetic Visual Reproduction	WMS-III – Wechsler (1997b) WAIS-III – Wechsler (1997a) WAIS-III – Wechsler (1997a) WMS-III – Wechsler (1997b)
Perceptual Reasoning	5 14 18	Figure Weights Matrix Reasoning Block Design	WAIS-III – Wechsler (1997a) WAIS-III – Wechsler (1997a) and Raven's Progressive Matrices – Raven et al. (1998) WAIS-III – Wechsler (1997a)
Attention	3 8 12 17	CPT-AX Figural Intersection CPT-Inhibition PASAT	Conners and Sitarenios (2011) Pascual-Leone and Baillargeon (1994) Conners and Sitarenios (2011) Gronwall and Sampson (1974)

Table 3: Cognitive domains and task information.

1.17, $p > .250$, suggesting participants were not differentially impacted by sitting and standing as the day progressed.

Of note, at an uncorrected significance level only two tasks returned a significant effect of Condition and another task showed a significant interaction between Condition and Time of Day.

First, in the Working Memory domain, the Spatial Span task (expressed as percent correct) showed a significant effect of Condition, $F(1,29) = 6.72$, $p = .015$, where performance while standing ($M = 84.89$, $SE = 1.86$) was better than performance while sitting ($M = 81.00$, $SE = 2.30$).

Second, in the Attention domain, the Figural Intersection task (expressed as percent correct) also showed a significant effect of Condition, $F(1,27) = 8.24$, $p = .008$. Again, performance while standing ($M = 91.79$, $SE = 1.62$) was better than performance while sitting ($M = 87.69$, $SE = 2.25$).

Third, also in the Attention domain, there was a significant interaction between Condition and Time of Day in the Continuous Performance (CPT)-Inhibition task, $F(2,54) = 4.11$, $p = .022$. The interaction indicated that in the standing condition only, reaction time was significantly faster in the afternoon than in the morning, $p < .001$ (Figure 3). The interaction also showed that in the afternoon the difference between sitting and standing was significant, $p = .050$, with faster reaction times seen in the standing condition.

The results of this large, exploratory study showed that, overall, there was no difference in performance between sitting and standing. However, in three instances findings were significant at the 0.05 level (i.e., not adjusted for multiple comparisons). As all three were in the same direction (in favour of the standing condition), this provides an initial indication that standing may confer a small cognitive benefit on tasks involving attention and working memory, a notion that should be pursued in further investigations.

Task	Variable	Significance Value of Main Effect of Condition	Significance Value of Main Effect of Time of Day	Significance Value of Interaction
Domain: Processing Speed				
Cancellation	Number Correct	0.375	0.008	0.837
Coding	Number Correct	0.091	0.773	0.496
Rapid Picture Naming	Total Time to Complete (s)	0.465	0.055	0.110
Symbol Search	Number Correct	0.922	< .001	0.958
Domain: Attention				
CPT-AX	Average RT (ms)	0.397	< .001	0.417
CPT-Inhibition	Average RT (ms)	0.446	< .001	0.022
Figural Intersection	Percentage Correct	0.008	0.030	0.324
PASAT	Percentage Correct	0.785	0.006	0.309
Domain: Working Memory				
Arithmetic	Percentage Correct	0.568	0.060	0.328
Letter-number Sequencing	Percentage Correct	0.135	0.017	0.591
Spatial Span	Percentage Correct	0.015	0.393	0.190
Visual Reproduction	Percentage Correct	0.802	< .001	0.625
Domain: Perceptual Reasoning				
Block Design	Average Time to Complete (s)	0.149	< .001	0.467
Figure Weights	Percentage Correct	0.946	< .001	0.956
Matrix Reasoning	Percentage Correct	0.952	0.049	0.533
Domain: Executive Functioning				
Stroop Effect	1. Word Naming – Number Correct	0.428	< .001	0.513
	2. Colour Naming – Number Correct	0.634	0.015	0.105
	3. Interference – Number Correct	0.692	0.029	0.741
Trail Making	Average Time to Complete (s)	0.639	< .001	0.646
Verbal Fluency	Number Correct	0.755	0.564	0.219
Visuospatial Search	Number Correct	0.945	< .001	0.706

Table 4: Results for each task by domain. p-values are bolded where significant at the 0.03 level of significance.

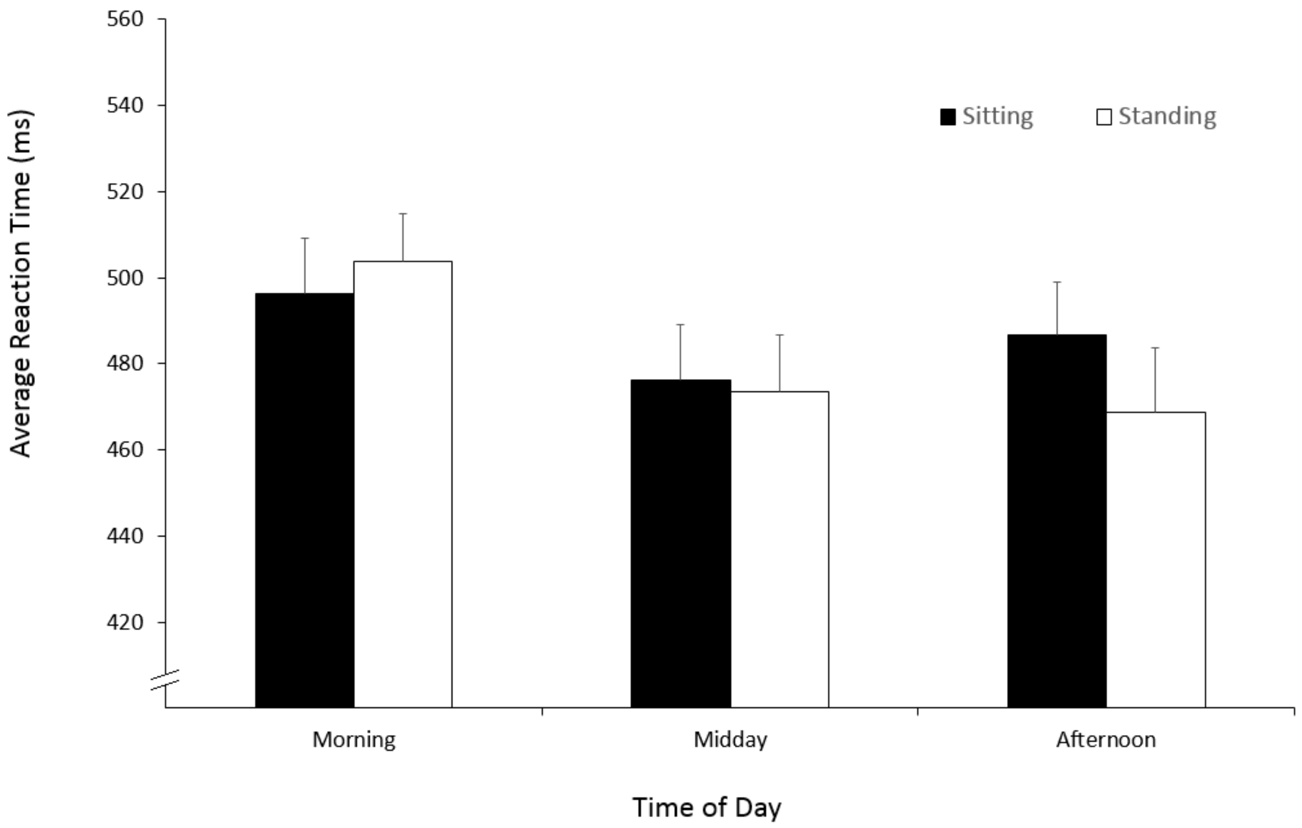


Figure 3. Mean Reaction Time (ms) for the CPT-Inhibition task during sitting and standing conditions at three times of the day. Error bars represent standard error of the mean.

DISCUSSION

Participants were tested on a large battery of cognitive tasks over three consecutive sessions (morning, midday and afternoon) on two different days in this exploratory study. On one day participants stood to perform tasks and on the other they sat. Overall, there was no difference in cognitive performance (in any of the 19 tasks) between sitting and standing.

Due to the long testing-day duration (7.5 hours), three sessions were administered, and when analysed, nine tasks showed statistical differences across the three sessions. While different sets were created for each session in an attempt to limit familiarity with task materials, an overall improvement in performance was, nonetheless, significant in seven of the 19 tasks and apparent in many others.

The results for the fatigue scale showed a significant increase in perceived fatigue scores between all three sessions of the day. There was, however, no effect of Condition nor was there an interaction between Condition and Time of Day, suggesting that participants felt more fatigued in general as the day progressed, but that this was not contingent on whether they were sitting or standing.

There were three statistically significant tasks (at an uncorrected level .05), and all three were in the direction of better performance while standing. These were part of the Working Memory (Spatial Span) and Attention (Figural Intersection and CPT-Inhibition) domains. While no previous research has reported significant sit-stand differences in working memory, Schraefel et al. previously found superior performance in a task measuring complex attention when participants were sitting (Schraefel et al., 2012), which is opposite to the findings here. In the current study, tasks associated with Executive Function, Processing Speed and Perceptual Reasoning did not reveal any significant effects. These null findings concur with the majority of previous research. While a study of high school students reported improved executive function associated with standing (Mehta et al., 2015), as discussed previously, the lack of a sitting control group does not allow us to rule out the possibility that this effect was confounded by participants' increasing age.

Understanding the effects that standing desks have on cognitive performance raises important implications for the implementation of sit-stand desks in the workplace. This study has provided further evidence to demonstrate that standing desks are able to replace sitting desks in the office environment without impeding cognitive performance, and may even improve cognitive performance in certain areas, such as attention and working memory.

If standing to work can be further infiltrated into desk-bound workspaces (because there is no detriment to cognition) the benefits to employees, and therefore employers, are obvious. The sedentary-related health risks to individuals are reduced, and so too are public health costs associated with sedentary-related diseases in the adult population. The benefits of sitting less could also be extrapolated beyond the workforce and be particularly relevant to students in learning institutions.

If cognition can be enhanced in adults by standing instead of sitting, then this should certainly be explored in terms of our schooling and tertiary practices. The positive effects of increased physical activity on academic performance have already been reported in young people (Gronwall & Sampson, 1974; Hogan, Mata, & Carstensen, 2013) and so it is plausible that a simple shift from 'mostly sitting to learn' to 'mostly standing to learn' could also have a positive association with learning. The idea of shifting learning and working spaces to 'mostly standing' is especially pertinent, given the recent Western shift toward extended sitting time outside of school, tertiary study and work hours, due to increased game playing and technological-device pastime pursuits (Lowry, Wechsler, Galuska, Fulton, & Kann, 2002). Standing habitually to learn and work may, therefore, concurrently produce superior cognitive growth and efficiency, while reducing daily sedentary time. This is important, given the evidence suggesting that increased physical activity alone is not enough to protect or reverse the damage of sedentary living (Biswas et al., 2015; Katzmarzyk et al., 2009).

Since the research into standing desks and cognitive performance is relatively new, this explorative study has illustrated that using standing desks in the workplace environment does not cause detriment to cognitive performance. Moreover, the study has provided some weak evidence for increased cognition in some areas, which warrants further investigation. One limitation of the current study is that all participants were habitual sitters and were new to using a standing desk. Thus, the novelty of standing may have given participants a boost in motivation that influenced their cognitive performance. To rule this out, we are in the process of conducting follow-up research which includes both habitual sitters and habitual standers. Given that the use of standing desks is likely to have relevant health benefits, future research should focus on longer-term investigation of the effects of standing desks on cognitive performance. Additionally, exploration of physiological and/or neural mechanisms underlying these findings may also be warranted.

APPENDIX 1

Extra Work Tasks

Task 1: Alphabetising

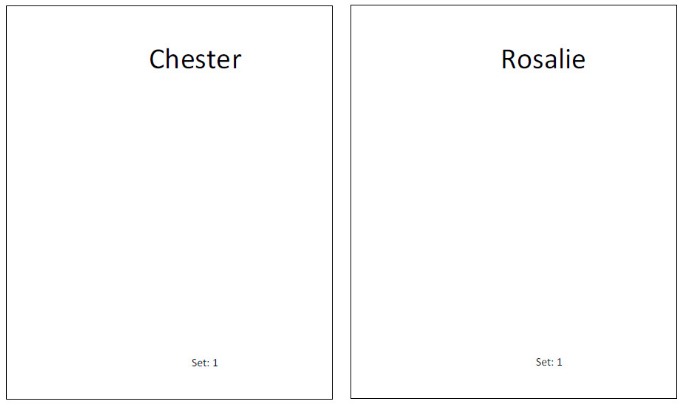


Figure 1. Examples of name card for the Alphabetising task.

Participants were given 50 A6-sized white cards with common men's and women's names printed in large black font toward the top (Figure 1). Participants were instructed that the cards were presented in random order currently, but they were required to arrange them so that the names were in alphabetical order, face up, with the A's at the top and the Z's at the bottom, as quickly and as accurately as possible. Participants were given 4 minutes to complete as much of the task as possible and the number of correct orderings (out of 50) was recorded and converted to percentage correct.

Task 2: Data Entry

Participants were provided with a large table of data (all 3-digit numbers between 100 and 999) printed on A4 paper (Figure 2) and were asked to enter the data into an Excel spreadsheet on a computer. Participants were able to enter data by columns or rows and were asked to work as quickly and as accurately as possible for 4 minutes. The number of correctly entered data points was recorded.

Task 3: Proofreading

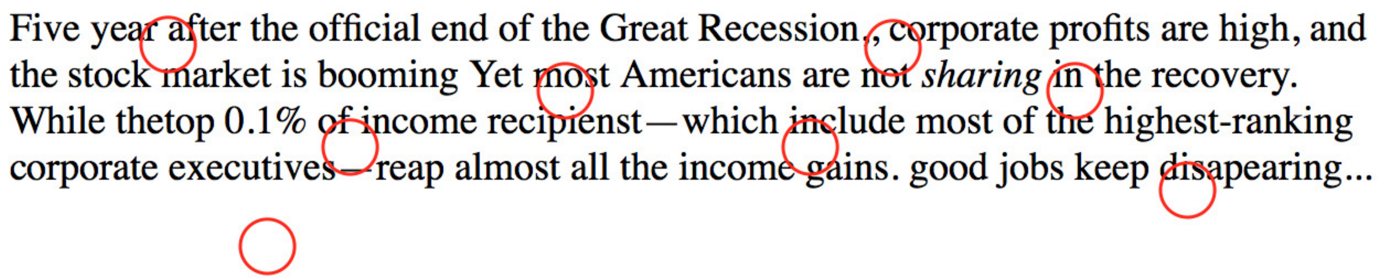
Participants were provided with a short piece of written material on A4 paper (Figure 3) and were required to proofread the material and circle any errors they found. Types of errors to look for were stipulated as 1) spelling errors, 2) grammatical errors, 3) punctuation errors and 4) font style inconsistencies. Participants were given 4 minutes to work as quickly and as accurately as possible. The number of correctly identified errors was recorded.

Task 4: Transcription

Participants were provided with a written article and were required to type the article verbatim into a Notepad document on a computer. The spelling and grammar detection was turned off but participants were instructed they were able to correct any mistakes they made at any time. Participants were given 4 minutes to transcribe as quickly and as accurately as possible. The number of correctly transcribed words was recorded.

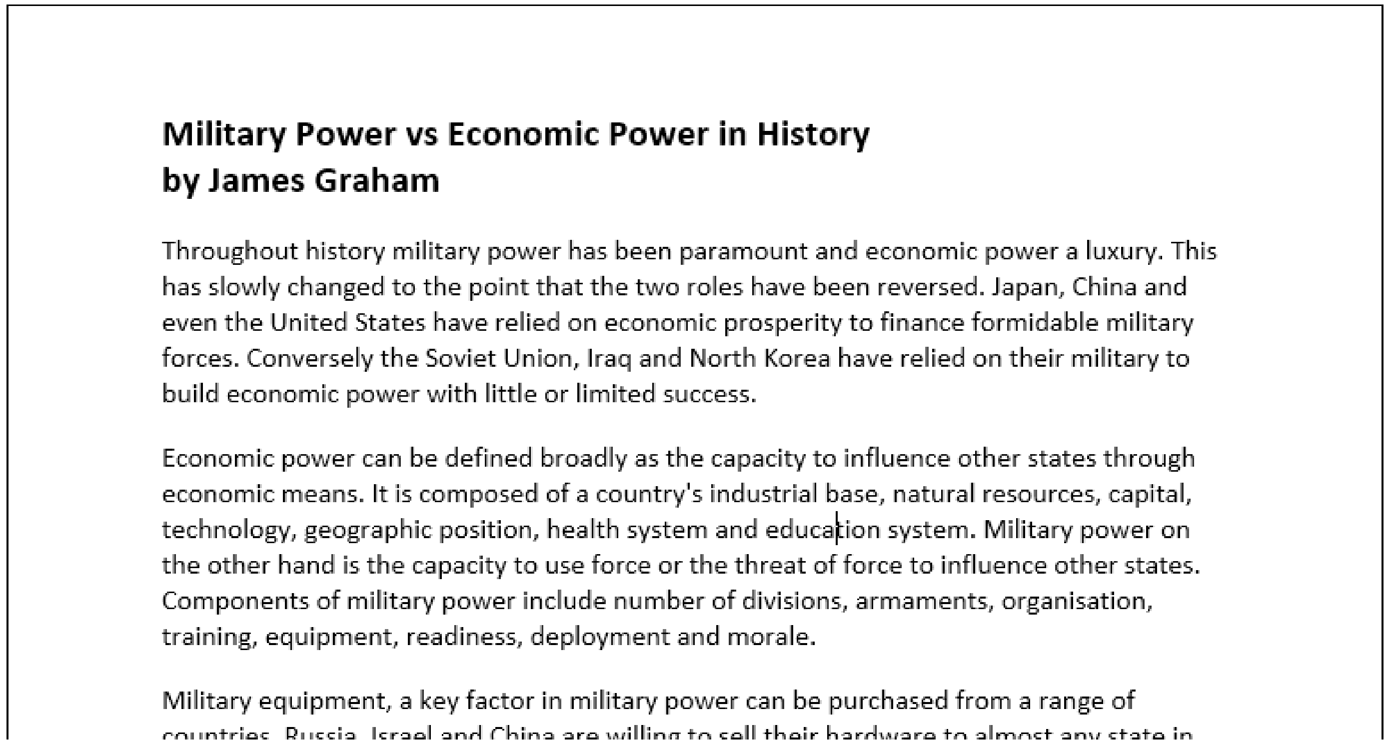
Column 1	Column 2	Column 3	Column 4	Column 5	Column 6	Column 7	Column 8
121	684	500	702	184	685	666	738
336	173	516	495	611	221	773	233
998	292	372	787	467	832	237	994
142	577	524	174	481	204	489	873
767	656	847	623	890	889	300	918
664	559	436	511	232	669	207	450
354	406	203	158	159	264	352	161
678	654	666	575	289	336	476	206
186	916	160	855	995	595	794	515

Figure 2. Example rows of the Data Entry task.



Five year after the official end of the Great Recession , corporate profits are high, and the stock market is booming Yet most Americans are not *sharing* in the recovery. While thetop 0.1% of income recipienst—which include most of the highest-ranking corporate executives—reap almost all the income gains. good jobs keep disapearing...

Figure 3. Example given to participants before completing the Proofreading Task. Red circles denoted errors.



Military Power vs Economic Power in History
by James Graham

Throughout history military power has been paramount and economic power a luxury. This has slowly changed to the point that the two roles have been reversed. Japan, China and even the United States have relied on economic prosperity to finance formidable military forces. Conversely the Soviet Union, Iraq and North Korea have relied on their military to build economic power with little or limited success.

Economic power can be defined broadly as the capacity to influence other states through economic means. It is composed of a country's industrial base, natural resources, capital, technology, geographic position, health system and education system. Military power on the other hand is the capacity to use force or the threat of force to influence other states. Components of military power include number of divisions, armaments, organisation, training, equipment, readiness, deployment and morale.

Military equipment, a key factor in military power can be purchased from a range of

Figure 4. Example of part of an article provided for the Transcription task.

APPENDIX 2

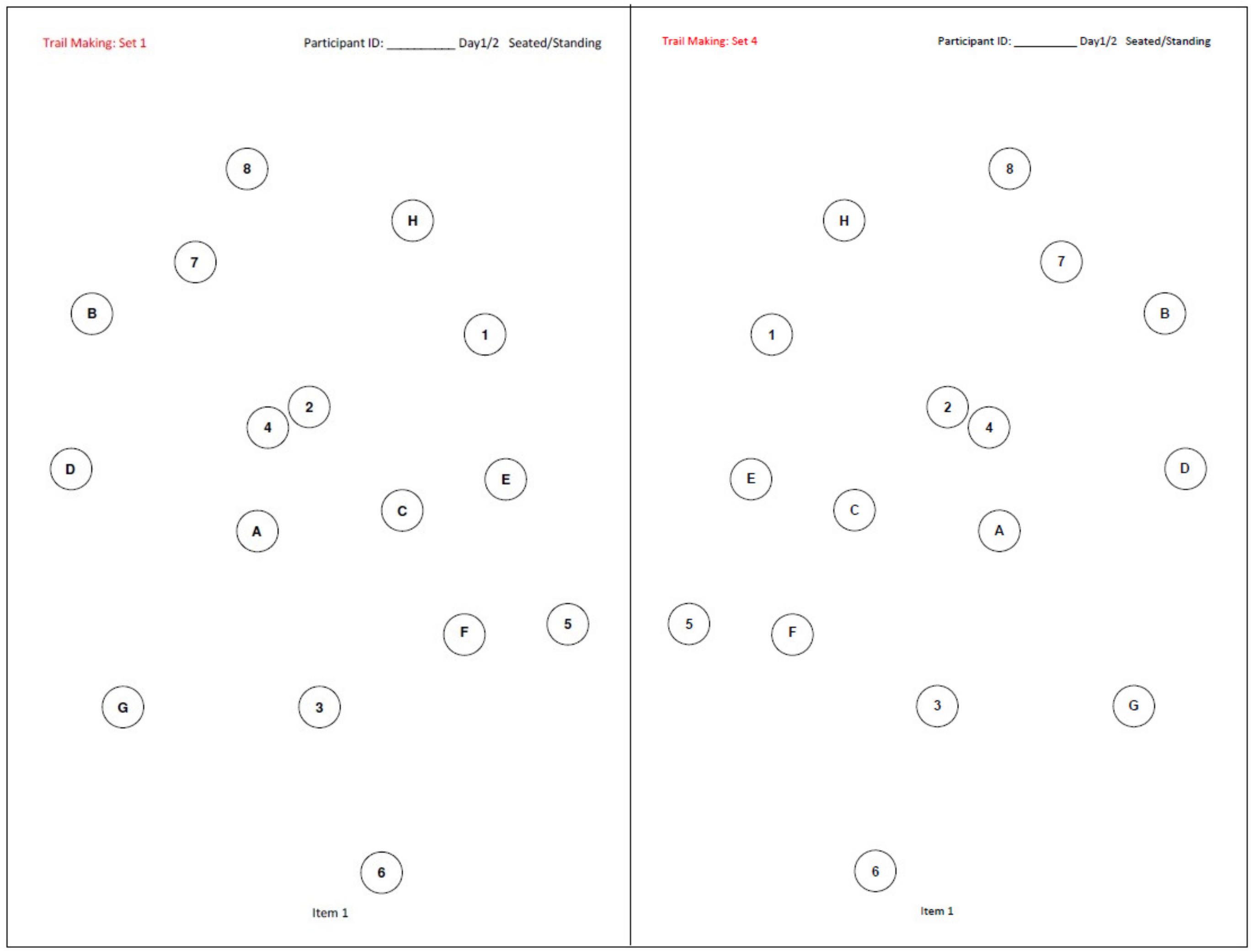


Figure 1. Example layout of an item in the Trail Making task.

TASK DESCRIPTIONS

Task 1: Trail Making (adapted from Partington & Leiter, 1949)

Participants were given a sheet of paper with eight circled letters (A to H) and eight circled numbers (1 to 8) and were asked to draw one continuous line connecting these in an alternating number-letter sequence (e.g., 1 – A – 2 – B, and so on) as quickly as possible until each letter and number had been visited (Figure 1). The time (in seconds) taken to complete each item was recorded and the average of seven items was calculated.

Task 2: Symbol Search (adapted from the WAIS-III: Wechsler, 1997a)

Participants were required to locate either of two target symbols on the left of the page within a group of five symbols on the right of the page (Figure 2). If either of the target symbols was present within the group of symbols on the right then the 'Y' was circled, indicating "Yes". If not, 'N' was circled, indicating "No". The participant was given 60 seconds to make as many responses as possible. The number of correct responses was recorded.

Task 3: Continuous Performance Task (CPT) – AX (adapted from Conners & Sitarenios, 2011)

Participants were presented with a variety of non-consecutive letters which were displayed one after the other on a blank computer screen. Participants were asked to press the spacebar on the keyboard as quickly as possible every time they saw the letter 'X' immediately after an 'A' (Figure 3). The task ran for four minutes and included a total number

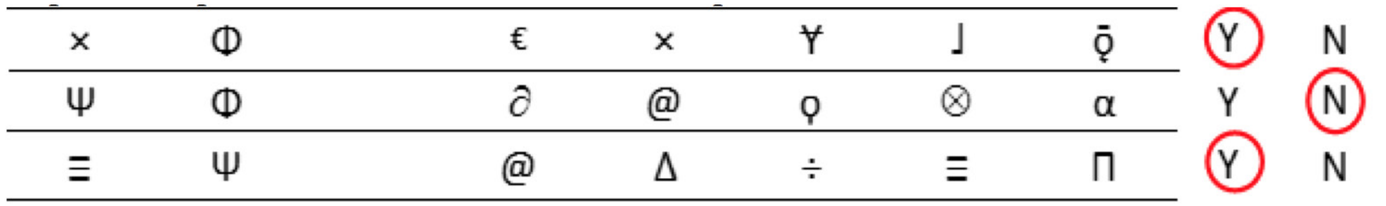


Figure 2. Example rows of the Symbol Search task, with correct responses marked to the right.

of 240 items, which appeared at the rate of one per second. The reaction time (ms) for correctly identified items was recorded and the average was calculated.

Task 4: Spatial Span (adapted from the WMS-III: Wechsler, 1997b)

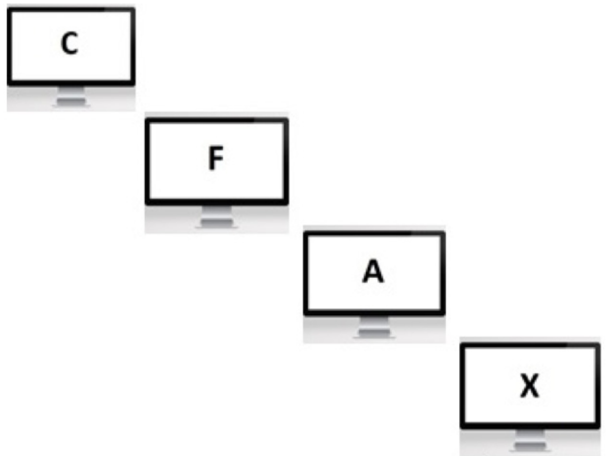


Figure 3. Schematic of the Continuous Performance Task-AX, showing successive letters being displayed on the computer screen.

Participants were seated opposite the researcher with the board and 10 block apparatus in between them (Figure 4). The researcher pointed to a numbered sequence of blocks at the speed of one block per second (e.g., 5 – 8 – 4) and participants were required to respond by pointing to the same sequence at any speed. Ten sequences commenced with a three-block arrangement and became progressively more difficult up to a maximum of six-block arrangements. The number of correct responses was recorded and transformed to Percent Correct.

Task 5: Figure Weights (adapted from the WAIS-III: Wechsler, 1997a)

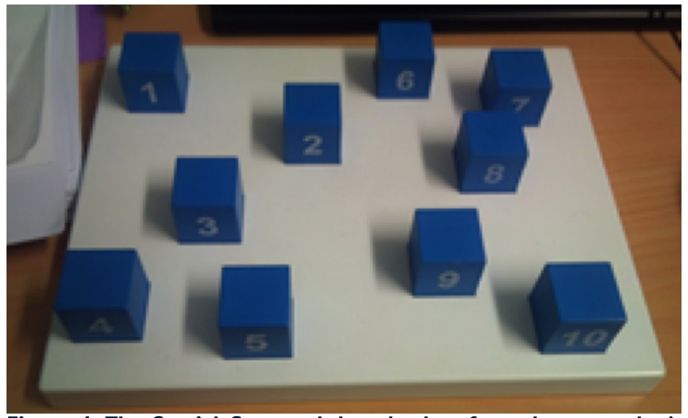


Figure 4. The Spatial Span task board taken from the researcher's perspective.

Participants were asked to solve the problems presented to them by selecting the correct answer from one of five options below the pictured scales. The seven items progressed in difficulty with more challenging problems requiring participants to balance three sets of scales (Figure 5). Participants were given 40 seconds maximum per item before being recorded as an incorrect response. The number of correct responses was recorded and transformed to Percent Correct.

Task 6: Stroop Effect (adapted from Stroop, 1935)

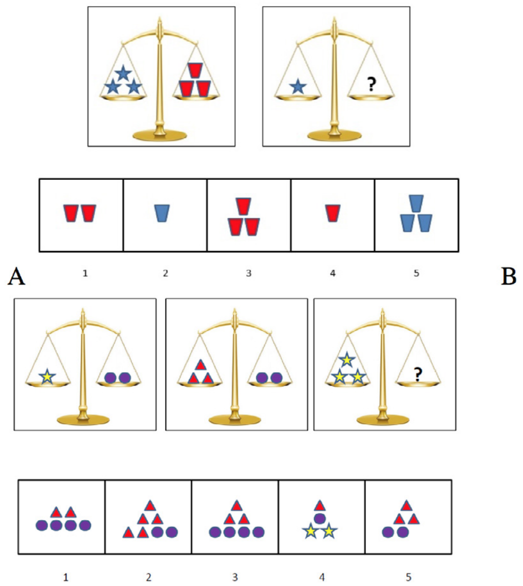


Figure 5. Example items in the Figure Weights task. Fig. A shows a two-scale item and Fig. B shows a three-scale item.

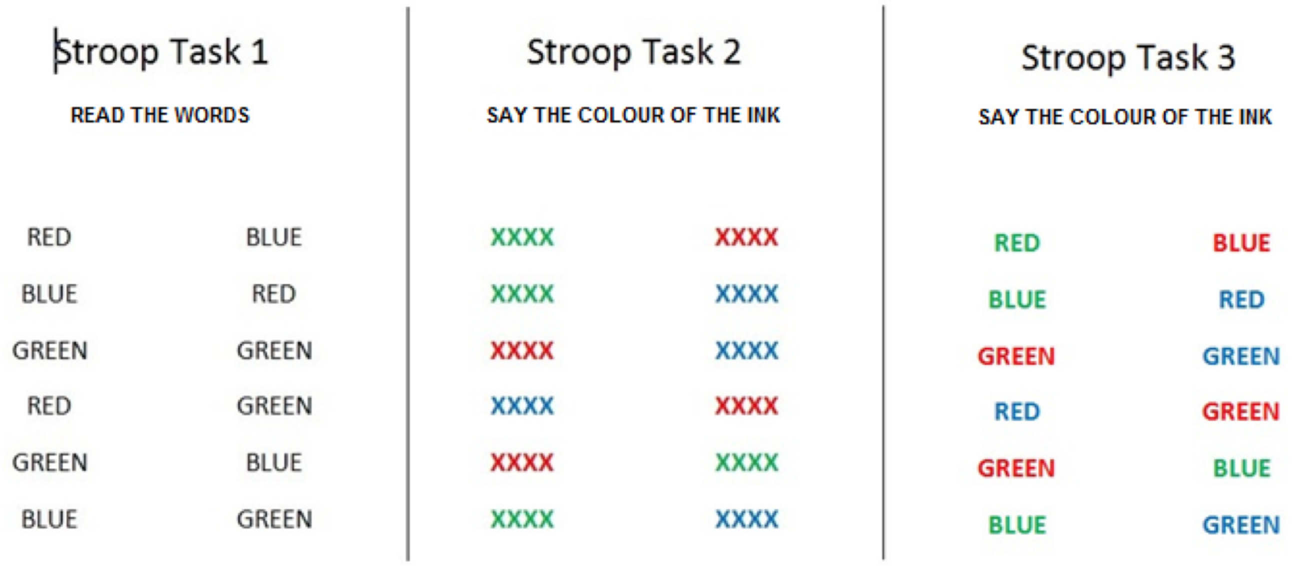


Figure 6. Examples of the Stroop task cards (actual cards contained four rows of 20 items each).

Participants were presented with three task cards containing 4 columns of 20 items (Figure 6). The first task card was a word-naming task, with words of different colours (RED, GREEN and BLUE) printed in black ink. For this card, participants were asked to read the items down the columns aloud, as quickly as possible, for 45 seconds. The second task card was a colour-naming task, with "XXXX" printed in red, blue and green ink. Participants were asked to name the colour of the ink for each item, moving down the columns as quickly as possible, for 45 seconds. The third task card was a colour-word task with colour words (RED, GREEN and BLUE) printed in conflicting colours, for example the word "GREEN" might be printed in red ink. Again, participants were asked to name the colour of the ink for each item moving down the columns as quickly as possible for 45 seconds. In each case the number of items correctly named was recorded.

Task 7: Cancellation (adapted from the WAIS-III: Wechsler, 1997a)

Participants were asked to identify, and then cross out with a pen, two target shapes amongst a multitude of other shapes acting as distractors (Figure 7). In Figure 7, the orange circles and blue triangles represent the target shapes. The participant was given 60 seconds to cross out as many items as possible, working from left to right and without skipping any items. The number of correctly crossed items was recorded.

Task 8: Figural Intersection (adapted from Pascual-Leone & Baillargeon, 1994)

Figural Intersection items consisted of overlapping geometric shapes (Figure 8) with progressing difficulty from two shapes to eight shapes. Participants were required to locate the one area of common intersection among the shapes by drawing a dot inside the area. The number of correct responses was recorded and transformed to Percentage Correct.

Task 9: Letter Number Sequencing (adapted

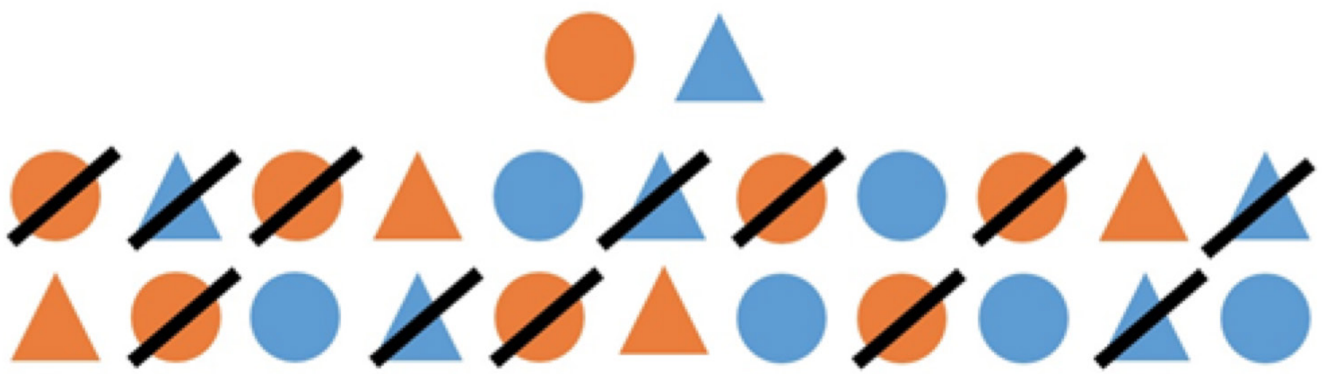


Figure 7. Example of a portion of the Cancellation Task showing correct responses.

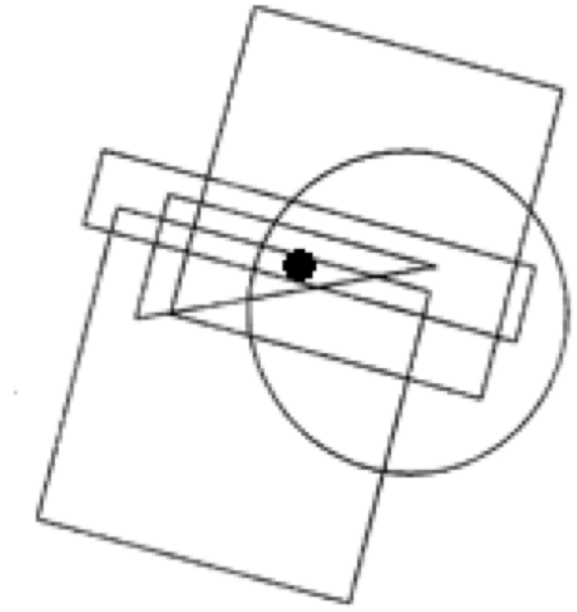


Figure 8. Example of a Figural Intersection task six-shape item with correct response.

from the WAIS-III: Wechsler, 1997a)

For this task, the researcher read aloud a series of letters and numbers to the participant, at a pace of one digit or letter per second. The participant was asked to remember them, re-order them into the correct sequence, and verbally repeat them back to the researcher. The correct order was numbers first, in ascending numerical order, and then letters, in alphabetical order. All given numbers were between 1 and 9 and all letters given were between A and F. For example, for a sequence read as "B-2-A-1," the correct response would be "1-2-A-B." The sequences in this task became progressively more difficult as letters and numbers were added to subsequent items. The number of correct responses was recorded.

Task 10: Visuospatial Search (adapted from Patston & Tippett, 2011)

The Visuospatial Search task consisted of boxed designs created from 12 different geometric shapes and six, seven or eight coloured dots (Figure 9). Participants were required to locate the difference between two nearly identical visual designs placed next to each other and to indicate the quadrant in which this difference appeared. Changes could consist of a dot changing colour or a dot changing place within the designs in one of four quadrants (participants were provided with a template showing the location of the quadrants beforehand). Participants were given three minutes to respond to as many different items as possible by indicating the quadrant in which this difference appeared. The number of correct responses was recorded.

Task 11: Rapid Picture Naming (adapted from Woodcock-Johnson III: Woodcock et al., 2001)

Participants were asked to verbally identify, as quickly as possible, 40 items in a sequence displayed via Microsoft PowerPoint (one item per slide). Items were black and white images of commonly identifiable objects such as animals, vehicles, fruit, furniture and stationery (Figure 10). Once they were happy with their verbalised response, the participant pressed the space bar on the keyboard to continue to the next item. The time taken (in seconds) to complete all 40 items was recorded.

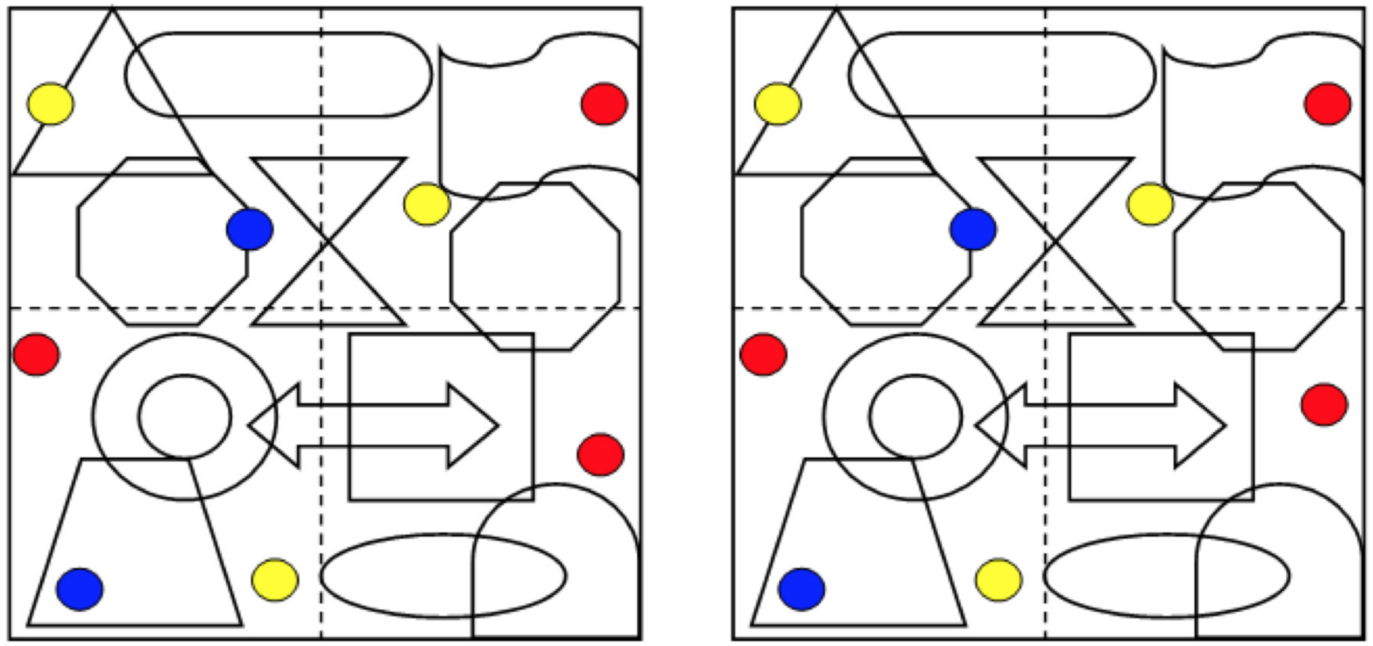


Figure91. An example illustration of one of the Visuospatial Search task items. The correct response is "4" as the dot in quadrant 4 has changed place.

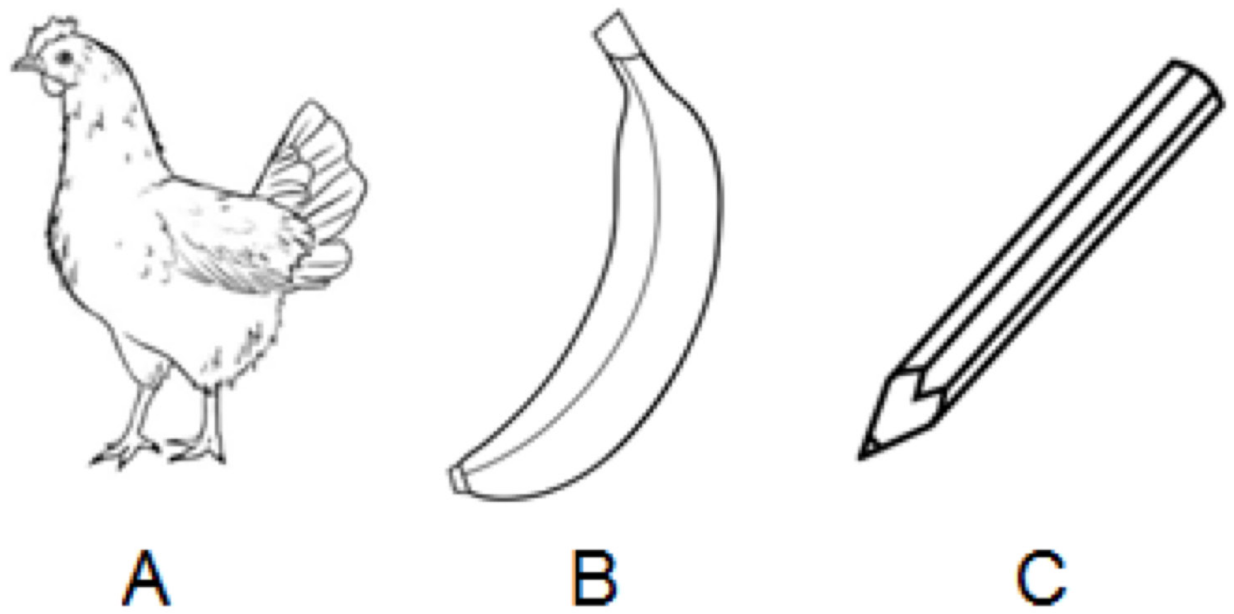


Figure 10. Example of three of the Rapid Picture Naming task items. Figure A represents a "chicken" (or "hen"), Figure B represents a "banana" and Figure C represents a "pencil".

Task 12: Continuous Performance Task (CPT) – Inhibition (adapted from Conners & Sitarenios, 2011)

Participants were presented with a variety of non-consecutive letters displayed one after the other on a blank computer screen. Participants were asked to press the spacebar on the keyboard as quickly as possible for every letter that they saw, except the letter 'X'. The task ran for four minutes and included a total number of 240 items, which appeared at the rate of one per second. The reaction time (ms) for correctly identified items was recorded and the average was calculated.

Task 13: Arithmetic (adapted from the WAIS-III: Wechsler, 1997a)

Participants were asked to solve an arithmetic problem that was read aloud by the researcher at a steady pace (e.g., "A dog has three biscuits in his bowl inside and four biscuits in another bowl outside. The neighbours' cat eats half the biscuits in the outside bowl. How many biscuits are left?"). The participants were asked to verbally report their answer to the researcher in their own time. There were 10 items that progressed in difficulty and a discontinue rule of three consecutive incorrect answers was upheld. The number of correct responses was recorded.

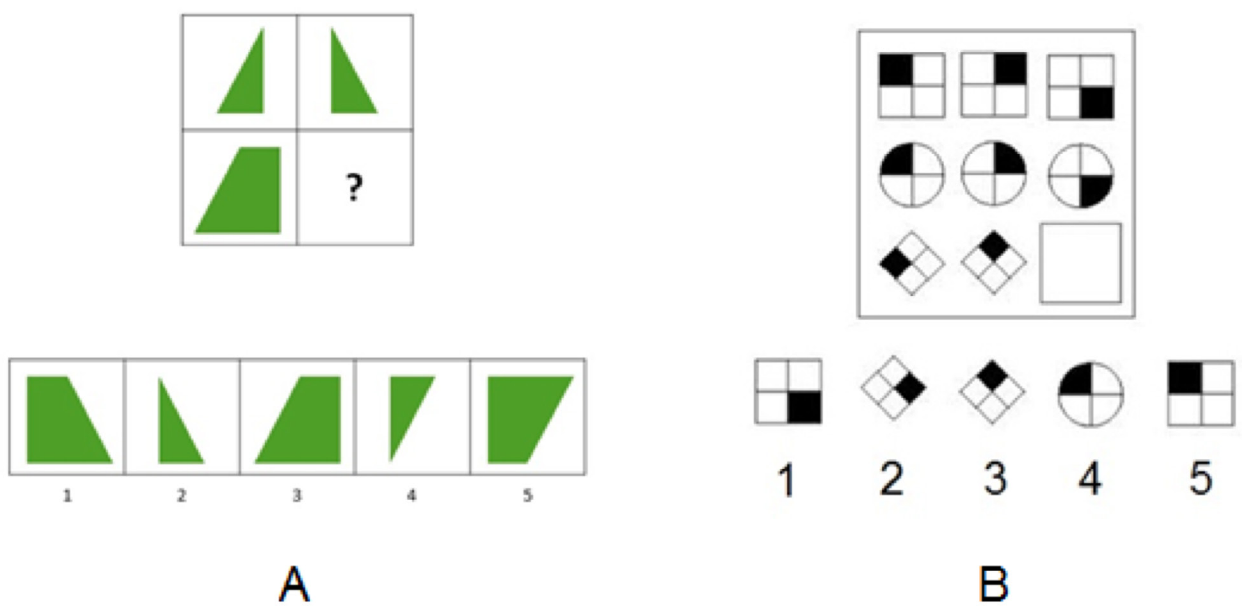


Figure 11. An example item from the Matrix Reasoning task (A) and an example item from the Raven's Standard Progressive Matrices (B). The correct responses are (1) and (2), respectively.

Ω	Σ	∫	×	ϴ	≡	Ↄ	Ϫ	†
1	2	3	4	5	6	7	8	9

∫	Ↄ	×	Ω	Ϫ	†	Σ	∫	ϴ	Σ	Ω	×	Ↄ	≡	Ω
3	7	4	1											

Figure 12. Example of the Coding task with the first four responses shown as correct.

Task 14: Matrix Reasoning (adapted from the WAIS-III: Wechsler, 1997a and Raven's Progressive Matrices: Raven et al., 1998)

The Matrix Reasoning task was comprised of items adapted from the Matrix Reasoning task from the WAIS-III and items adapted from the Raven's Standard Progressive Matrices (Raven, Raven, & Court, 1998). Participants were required to observe an incomplete problem (or puzzle) and choose the most appropriate response (from five options displayed below the image) (Figure 11). Participants were given 40 seconds maximum per item before being recorded as an incorrect response. The number of correct responses was recorded and transformed to Percentage Correct.

Task 15: Verbal Fluency (adapted from Pendleton, 1982)

Participants were asked to name as many nouns beginning with a specific letter, or falling within a specific category, as they could within a 45-second period. Potential errors included repetition of words, plural words, proper nouns, and words that began with the wrong letter or did not fit the category. The number of correct responses was recorded.

Task 16: Coding (adapted from the WAIS-III: Wechsler, 1997a)

The Coding task consisted of a coding key at the top of a page containing nine numbers in ascending numerical order (1 through to 9), each paired with a symbol (Figure 12). Participants were asked to match the symbols from the coding key to rows of only symbols on the page below (e.g., Ω = 1, ∑ = 2, and so on). Participants were given 60 seconds to complete as many items as possible and were instructed to work from left to right along the row of symbols without missing any. The number of correct responses was recorded.

Task 17: Paced Auditory Serial Addition Test (PASAT) (adapted from Gronwall & Sampson, 1974)

An auditory computer program was used to present 41 single digits at a rate of every two seconds. The participants were required to add each new digit to the one immediately prior to it and verbalise their answers out loud. The participants were informed that they were not asked to give a running total, but rather the sum of only the last two numbers that were presented to them (Figure 13). The score was the total number of correct sums given (out of a possible 40) in each trial. The number of correct responses was recorded and transformed to Percentage Correct.

Sequence of numbers read to the participant (Researcher)

1 6 5 9 4 9 2 8

Correct answers (participant)

7 11 14 13 13 11 10

Figure 13. Example of a section of the Paced Auditory Serial Addition Test with corresponding correct answers.

Figure 14. Example of a design provided in the Block Design task.

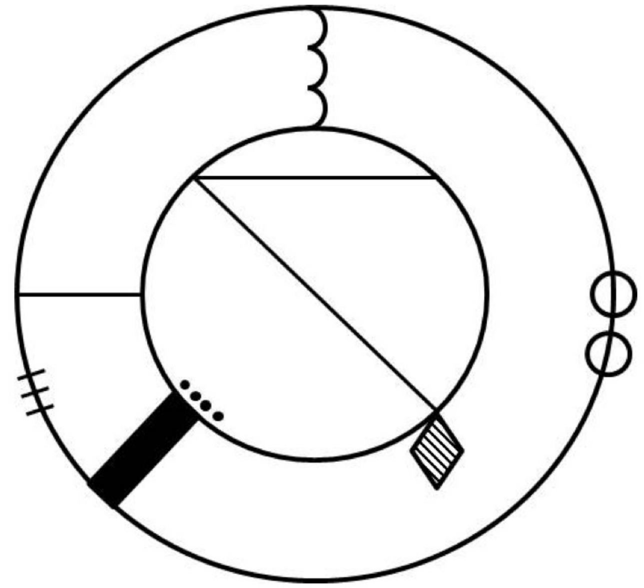


Figure 15. Example of an image in the Visual Reproduction task.

Task 18: Block Design (adapted from the WAIS-III: Wechsler, 1997a)

Participants were required to replicate a visual 2D pattern (Figure 14). presented to them by using a set of nine blocks that were painted half red and half white diagonally. Participants were given time to familiarise themselves with the blocks and were instructed that the top surface of the blocks should match the design presented (and not to be concerned with the edges). Time to complete (in seconds) was recorded and the average of six items was calculated.

Task 19: Visual Reproduction (adapted from the WMS-III: Wechsler, 1997b)

Participants were instructed to look at an abstract image for 20 seconds and memorise it (Figure 15). The image was then removed from sight and the participant was given 40 seconds to reproduce the image with pen and paper. Each reproduction could score a maximum of 10 points if all elements were replicated with correct orientation, location, proportion, shape, quantity and opacity. Half marks were scored if an element was partially correct, but not exactly the same as in the original image. Scores were recorded and averaged across seven items.

REFERENCES

Bantoft, C., Summers, M., Tranent, P., Palmer, M., Cooley, P., & Pedersen, S. (2015). Effect of standing or walking at a workstation on cognitive function: A randomized counterbalanced trial. *Human Factors: The Journal of the Human Factors and Ergonomics Society*, 58, 140-149. http://dx.doi.org/10.1177/0018720815605446

Benden, M. E., Blake, J. J., Wendel, M. L, & Huber, J. C. (2011). The impact of stand-biased desks in classrooms on calorie expenditure in children. *American Journal of Public Health, 101*(8), 1433-1436. http://dx.doi.org/10.2105/AJPH.2010.300072

Ben-Ner, A., Hamann, D. J., Koepp, G., Manohar, C. U., & Levine, J. (2014). Treadmill workstations: The effects of walking while working on physical activity and work performance. *PLoS One, 9*(2), 1-11. http://dx.doi.org/10.1371/journal.pone.0088620

Biswas, A., Oh, P. I., Faulkner, G. E., Bajaj, R. R., Silver, M. A., Mitchell, M. S., Alter, D. A. (2015). Sedentary time and its association with risk for disease incidence, mortality, and hospitalization in adults: A systematic review and meta-analysis. *Annals of Internal Medicine, 162*, 123-32.

Boksem, M. A. S., Meijman, T. F., & Lorist, M. M. (2005). Effects of mental fatigue on attention: An ERP study. *Cognitive Brain Research, 25(1)*, 107-116.

Buckley, J. P., Mellor, D. D., Morris, M., & Joseph, F. (2014). Standing-based office work shows encouraging signs of attenuating post-prandial glycaemic excursion. *Occupational & Environmental Medicine, 71*(2), 109-111. http://dx.doi.org/10.1136/oemed-2013-101823

Cifuentes, M., Qin, J., Fulmer, S., & Bello, A. (2015). Facilitators and barriers to using treadmill workstations under real working conditions: A qualitative study in female office workers. *American Journal of Health Promotion, 30*(2), 93-100. http://dx.doi.org/10.4278/ajhp.140123-QUAL-43

Conners, C. K., & Sitarenios, G. (2011). Conners' Continuous Performance Test (CPT). In J. S. Kreutzer, J. DeLuca, & B. Caplan (Eds.), *Encyclopedia of Clinical Neuropsychology* (1st ed., pp. 681-683). New York: Springer. http://dx.doi.org/10.1007/978-0-387-79948-3_1535

Csathó, Á., Van Der Linden, D., Hernádi, I., Buzás, P., & Kalmár, G. (2012). Effects of mental fatigue on the capacity limits of visual attention. *Journal of Cognitive Psychology, 24*(5), 511-524.

Ebara, T., Kubo, T., Inoue, T., Murasaki, G., Takeyama, H., Sato, T., ... Itani, T. (2008). Effects of adjustable sit-stand VDT workstations on workers' musculoskeletal discomfort, alertness and performance. *Industrial Health, 46*(5), 497-505.

Gilson, N. D., Suppini, A., Ryde, G. C., Brown, H. E., & Brown, W. J. (2012). Does the use of standing 'hot' desks change sedentary work time in an open plan office? *Preventive Medicine, 54*(1), 65-67. http://dx.doi.org/10.1016/j.ypmed.2011.10.012

Gronwall, D., & Sampson, H. (1974). *The psychological effects of concussion*. Auckland, New Zealand: Auckland University Press.

Grunseit, A. C., Chau, J. Y-Y., van der Ploeg, H. P., & Bauman, A. (2013). "Thinking on your feet": A qualitative evaluation of sit-stand desks in an Australian workplace. *BMC Public Health, 13*(1), 365. http://doi.org/10.1186/1471-2458-13-365

Healy, G. N., Wijndaele, K., Dunstan, D. W., Shaw, J. E., Salmon, J., Zimmet, P. Z., & Owen, N. (2008). Objectively measured sedentary time, physical activity, and metabolic risk: The Australian Diabetes, Obesity and Lifestyle Study (AusDiab). *Diabetes Care, 31*(2), 369-71.

Hedge, A., Jagdeo, J., Agarwal, A., & Rockey-Harris, K. (2005). Sitting or standing for computer work – does a negative-tilt keyboard tray make a difference? *Proceedings of the Human Factors and Ergonomics Society 49th Annual Meeting, 108-112*.

Hinckson, E. A., Aminian, S., Ikeda, E., Stewart, T., Oliver, M., Duncan, S., & Schofield, G. (2013). Acceptability of standing workstations in elementary schools: A pilot study. *Preventive Medicine, 56*(1), 82-85.

Hogan, C. L., Mata, J., & Carstensen, L. L. (2013). Exercise holds immediate benefits for affect and cognition in younger and older adults. *Psychology and Aging, 28*(2), 587-594.

Hooper, C. J., Luciana, M., Conklin, H. M., & Yarger, R. S. (2004). Adolescents' performance on the Iowa Gambling Task: Implications for the development of decision making and ventromedial prefrontal cortex. *Developmental Psychology, 40*(6), 1148-1158.

Husemann, B., Von Mach, C. Y., Borsotto, D., Zepf, K. I., & Scharnbacher, J. (2009). Comparisons of musculoskeletal complaints and data entry between a sitting and a sit-stand workstation paradigm. *Human Factors, 51*(3), 310-320.

John, D., Bassett, D., Thompson, D., Fairbrother, J., & Baldwin, D. (2009). Effect of using a treadmill workstation on performance of simulated office work tasks. *Journal of Physical Activity & Health, 6*(5), 617-624. http://dx.doi.org/10.1123/jpah.6.5.617

Katzmarzyk, P. T., Church, T. S., Craig, C. L., & Bouchard, C. (2009). Sitting time and mortality from all causes, cardiovascular disease, and cancer. *American College of Sports Medicine, 41*(5), 998-1005. http://dx.doi.org/10.1249/MSS.0b013e3181930355

Kline, J. E., Poggensee, K., & Ferris, D. P. (2014). Your brain on speed: Cognitive performance of a spatial working memory task is not affected by walking speed. *Frontiers in Human Neuroscience, 8*, 288. http://doi.org/10.3389/fnhum.2014.00288

Koepp, G. A., Manohar, C. U., McCrady-Spitzer, S. K., Ben-Ner, A., Hamann, D. J., Runge, C. F., & Levine, J. A. (2013). Treadmill desks: A 1-year prospective trial. *Obesity, 21*(4), 705-11. http://doi.org/10.1002/oby.20121

Lebowitz, S. (2015, October 13). The White House is ordering up to $700,000 of standing desks -- here's why you should consider getting one, too. Business Insider Australia. Retrieved from: https://www.businessinsider.com.au/the-white-house-requests-standing-desks-2015-10?r=US&IR=T.

Lowry, R., Wechsler, H., Galuska, D. A., Fulton, J. E., & Kann, L. (2002). Television viewing and its associations with overweight, sedentary lifestyle, and insufficient consumption of fruits and vegetables among US high school students: Differences by race, ethnicity, and gender. *Journal of School Health, 72*(10), 413-421.

Luciana, M., Conklin, H. M., Hooper, C. J., & Yarger, R. S. (2005). The development of nonverbal working memory and executive control processes in adolescents. *Child Development, 76*(3), 697-712.

Luna, B., Garver, K. E., Urban, T. A., Lazar, N. A., & Sweeney, J. A. (2004). Maturation of cognitive processes from late childhood to adulthood. *Child Development, 75*(5), 1357-1372.

Mehta, R. K., Shortz, A. E., & Benden, M. E. (2015). Standing up for learning: A pilot investigation on the neurocognitive benefits of stand-biased school desks. *International Journal of Environmental Research and Public Health, 13*(1) 59.

Partington, J. E., & Leiter, R. G. (1949). Partington's Pathway Test. *The Psychological Service Center Bulletin*, 1, 9-20.

Pascual-Leone, J., & Baillargeon, R. (1994). Developmental measurement of mental attention. *International Journal of Behavioral Development, 17*, 161-200.

Patston, L. L. M., & Tippett, L. J. (2011). The effect of background music on cognitive performance in musicians and nonmusicians. *Music Perception, 29*(2), 173-183. http://dx.doi.org/10.1525/MP.2011.29.2.173

Pendleton, M. (1982). Diagnositc utility of the Thurstone word fluency test in neuropsychological evaluations. *Journal of Clinical Neuropsychology, 4*(4), 307-317. http://dx.doi.org/10.1080/01688638208401139

Raven, J., Raven, J. C., & Court, J. H. (1998). *Standard progressive matrices*. Oxford, UK: Oxford Psychologists Press.

Reiff, C., Marlatt, K., & Dengel, D. R. (2012). Difference in caloric expenditure in sitting versus standing desks. *Journal of Physical Activity and Health, 9,* 1009-1011.

Russell, B. A., Summers, M. J., Tranent, P. J., Palmer, M. A., Cooley, P. D., Pedersen, S. J., Russell, B. A., et al. (2015). A randomised control trial of the cognitive effects of working in a seated as opposed to a standing position in office workers. *Ergonomics, 139,* 1-8.

Russell, B. A., Summers, M. J., Tranent, P. J., Palmer, M. A., Cooley, P. D., Pedersen, S. J. (2016). A randomised control trial of the cognitive effects of working in a seated as opposed to a standing position in office workers. *Ergonomics, 59*(6), 737-744. http://dx.doi.org/10.1080/00140139.2015.1094579

Saunders, T. J., Larouche, R., Colley, R. C., & Tremblay, M. S. (2012). Acute sedentary behaviour and markers of cardiometabolic risk: A systematic review of intervention studies. *Journal of Nutrition and Metabolism*, 2012, 712435. http://dx.doi.org/10.1155/2012/712435

Schraefel, M., Kenneth, J., & Andersen, L. (2012). Assessing the effect of self-positioning on cognitive executive function. *Journal of Ergonomics, 2*(4), 110. http://dx.doi.org/10.4172/2165-7556.1000110

Singh, A., Uijtdewilligen, L., Twisk, J. W. R., van Mechelen, W., & Chinapaw, M. J. M. (2012). Physical activity and performance at school: A systematic review of the literature including a methodological quality assessment. *Archives of Pediatrics & Adolescent Medicine, 166*(1), 49-55. http://doi.org/10.1001/archpediatrics.2011.716

Stamatakis, E., Hamer, M., & Dunstan, D. W. (2011). Screen-based entertainment time, all-cause mortality, and cardiovascular events: Population-based study with ongoing mortality and hospital events follow-up. *Journal of the American College of Cardiology, 57*(3), 292-299.

Straker, L., Levine, J., & Campbell, A. (2010). The effects of walking and cycling computer workstations on keyboard and mouse performance. *Human Factors: The Journal of the Human Factors and Ergonomics Society, 51*(6), 831-844. http://doi.org/10.1177/0018720810362079

Stroop, J. R. (1935). Studies of interference in serial verbal reactions. *Journal of Experimental Psychology*, 18, 643-662.

Tudor-Locke, C., Hendrick, C. A., Duet, M. T., Swift, D. L., Schuna, J. M., Martin, C. K., … Church, T. S. (2014). Implementation and adherence issues in a workplace treadmill desk intervention. *Applied Physiology, Nutrition, and Metabolism, 39*(10), 1104-1111. http://doi.org/10.1139/apnm-2013-0435

Van Uffelen, J. G. Z., Wong, J., Chau, J. Y., van der Ploeg, H. P., Riphagen, I., Gilson, N. D., … Brown, W. J. (2010). Occupational sitting health risks: A systematic review. *American Journal of Preventive Medicine, 39*(4), 379-388. http://dx.doi.org/10.1016/j.amepre.2010.05.024

Wechsler, D. (1997a). *Wechsler Adult Intelligence Scale* (3rd ed). San Antonio, TX: Psychological Corporation.

Wechsler, D. (1997b). *Wechsler Memory Scale* (3rd ed). San Antonio, TX: Psychological Corporation.

Wijndaele, K., Duvigneaud, N., Matton, L., Duquet, W., Delecluse, C., Thomis, M., … Philippaerts, R. (2009). Sedentary behaviour, physical activity and a continuous metabolic syndrome risk score in adults. *European Journal of Clinical Nutrition, 63*(3), 421-429.

Wilmot, E. G., Edwardson, C. L., Achana, F. A., Davies, M. J., Gorely, T., Gray, L. J., … Biddle, S. J. H. (2012). Sedentary time in adults and the association with diabetes, cardiovascular disease and death: Systematic review and meta-analysis. *Diabetologia, 55*(11), 2895-905. http://doi.org/10.1007/s00125-012-2677-z

Woodcock, R. W., McGrew, K. S., & Mather, N. (2001). Woodcock-Johnson III tests of cognitive abilities: *Examiner's manual standard and extended batteries.* Itasca, IL: Riverside.

World Health Organisation. (2010). *Global Recommendations on Physical Activity for Health.* Geneva, Switzerland. Retrieved from http://whqlibdoc.who.int/publications/2010/9789241599979_eng.pdf?ua=1

AUTHORS

Dr Lucy Patston is a cognitive psychologist, currently working in the emerging area of standing desks and the effect of standing on cognitive performance. She has previously investigated the functioning of the brain of the classically trained musician. Initially employed to teach neuroscience to osteopathy students, Lucy has worked at Unitec Institute of Technology for four and a half years. Her current role, in Te Waka Urungi, involves helping to coordinate course redevelopment across the institution.

Jamie Mannion is currently working in the Business Enterprise and High Technology Network at Unitec. He provides leadership and support to the Computing Pathway and has a central role in the transformation of qualifications and courses in the network. He comes from a background of sports and exercise science, and has a research interest in health, exercise, and pain neurophysiology.

CONTRIBUTIONS

Patston and Mannion developed the study concept and contributed to the study design and project management. Testing and data collection were performed by Henry and four other Masters of Osteopathy students under the training and supervision of Patston. Patston and Mannion performed the data analysis and all authors contributed to the interpretation of results. All authors collaborated on the drafting of the manuscript, led by Patston and revised by McEwen and Ewens-Volynkina. All authors approved the final version of the manuscript for submission.

ACKNOWLEDGEMENTS

The authors would like to thank the participants and the four other student researchers, Houman Haddadi, Sara Milovic, Islay Robertson and Nick Leahy, who assisted with the task preparation and collection of data. We would also like to acknowledge the time and effort afforded by four of our colleagues, Philippe Dussart, Andrew Latham, Jesse Mason and Nikki Timu, for supporting the student researchers during this study. Finally, thank you to the Unitec Faculty of Social and Health Sciences Faculty Development Fund for its financial contribution.

ePress Unitec Institute of Technology TE WHARE WĀNANGA O WAIRAKA