Thinking whilst standing: An examination of the effects of standing desks on cognitive processing speed

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Declaration

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This Thesis/Dissertation/Research Project entitled: ‘Standing whilst thinking - An examination of the effects of standing desks on cognitive processing speed’ is submitted in partial fulfilment for the requirements for the Unitec degree of Master of Osteopathy

Candidate’s declaration

I confirm that:

• This Thesis Project represents my own work;
• The contribution of supervisors and others to this work was consistent with the Unitec Regulations and Policies.
• Research for this work has been conducted in accordance with the Unitec Research Ethics Committee Policy and Procedures, and has fulfilled any requirements set for this project by the Unitec Research Ethics Committee.

Research Ethics Committee Approval Number: 2014-1085

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Abstract

Recent evidence shows that high levels of prolonged sitting is negatively correlated with increased all-cause mortality. Moreover, it appears that physical activity may not negate this risk. Not only does musculoskeletal pain and discomfort impact employee health, but the cost to employers and the larger economy is great. The introduction of standing desks into the workplace offers a potential solution to this inactivity problem, and, therefore, it is logical to enquire about the effects of standing on cognitive performance. Processing Speed is a main component of cognition and is correlated with general measures of intelligence. Understanding the effects that standing desks have on Processing Speed can grant insight into the effects of these desks on general cognitive performance and resulting work output.

A cross-over design was used to investigate the effect of a standing desk compared with a seated desk on Processing Speed during a simulated “work” day. Thirty healthy participants (14 female, 16 male), aged between 20 and 49 years old, were recruited to complete a battery of cognitive tasks over two 7.5 hour long sessions, one session of standing and one of sitting. The battery of cognitive tasks included four tasks testing Processing Speed. Three of the tasks, Symbol Search, Cancellation, and Coding were derived from the Wechsler Adult Intelligence Scale (WAIS-IV) tests of cognition, and the fourth task was derived from the Woodcock-Johnson III test of cognitive ability.

A two-way repeated measures analyses showed that Processing Speed was not affected by standing when compared to sitting. A trend toward significance was found in the Coding task, revealing better performance in Processing Speed when standing.

The results of this study provide evidence to suggest standing desks can be implemented into the workplace without causing reductions in Processing Speed and may, in fact, be beneficial. Because sitting for prolonged periods is harmful to physical health and incorporates large health costs, employers should consider standing desks as an alternative to sitting desks that could improve workplace health, and thereby reduce the associated costs without effecting an important aspect of cognition.

Key words: Standing desk, active desk, cognitive performance, cognition, processing speed
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Chapter 1: Introduction

Background

Sedentary behaviour, the act of sitting or lying down where levels of energy expenditure are minimal, is extremely prevalent within our current society (World Health Organisation, 2007). Sedentary behaviour in adults can be divided into two activities, leisure activity and occupation. Office based workers are one of the largest occupational groups (Lacey & Wright, 2010) and are reported to have the highest levels of sedentary behaviour (Jans, Proper, & Hildebrandt, 2007). In the US 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), whereas leisure activities take 2 to 3 hours per day (Brown, Miller, & Miller, 2003; van Uffelen et al., 2010). High levels of sedentariness has also been found to be prevalent in American children aged from 11 and above in the school environment (Benden, Zhao, Jeffrey, Wendel, & Blake, 2014).

Two common side-effects of sedentary behaviour are low back pain, which is a direct result of sitting for prolonged periods of time (Drury et al., 2008; Gupta et al., 2015; Lourenço et al., 2015), and obesity (Speck & Schmitz, 2011). Indirect costs of low back pain, which include employment related costs, represent a majority of the overall costs and were estimated to reach $8 billion Australian dollars, and $19.8 billion American dollars per annum (Stewart, Ricci, Chee, Morganstein, & Lipton, 2003). Not only do these musculoskeletal-related costs reduce government income, but employers, employees and insurance companies are affected also. A study examining the top 20 most expensive health conditions for employers found low back pain to be the fourth most expensive condition costing an approximate $90.24 American per employee annually (Goetzel, Hawkins, Ozminkowski, & Wang, 2003) and it was estimated that the medical costs amounted to $1 billion Australian dollars per annum (Dagenais, Caro, & Haldeman, 2008). Obesity, a related risk of sedentariness, is also a large expense to the economy and employers. Obesity increases risk of developing diseases such as diabetes mellitus and cardiovascular diseases (Verweij, Coffeng, van Mechelen, & Proper, 2011), thus reducing work productivity. In Europe, obesity related health issues among obese workers resulted in an extra ten days off work each year (Neovius, Johansson, Kark, & Neovius, 2009). These two issues are not the only health-related risks associated with sedentary behaviour.
A recent meta-analysis has found strong and consistent associations between sedentary time in adults and diabetes, cardiovascular disease and all-cause mortality (Wilmot et al., 2012). Acute bouts of sedentary behaviour have also been shown to cause health risks as demonstrated by a recent systematic review that revealed less than seven days of sedentary behaviour caused measurable, rapid and deleterious changes in levels of cholesterol, insulin sensitivity, and glucose intolerance (Saunders, Larouche, Colley, & Tremblay, 2012). Attempts have been made to reduce these health risks through physical activity which has shown to provide many health-related benefits (Bosma et al., 2002; Ratey & Loehr, 2011; Xu et al., 2011). Wilmot et al. (2012) found, however, that these associations of sedentary time and health-related risks were largely independent of physical activity, suggesting that the impact on health may not be mediated through moderate-to-vigorous intensity physical activity. In addition to these findings, sedentary behaviour remains significantly associated with all-cause mortality and cardiovascular disease even when smoking, physical activity and diet are controlled for (Katzmarzyk, Church, Craig, & Bouchard, 2009). This implies that the effects of sedentary behaviour cannot be negated by the pursuit of other healthy activities, and must be modified in itself.

Recently, active desks have been investigated within the workplace as a way of reducing sedentary behaviour, and several systematic reviews have found promising results concerning reductions in sitting time (MacEwen, MacDonald, & Burr, 2015; M. Neuhaus et al., 2014) and increases in physical activity (Torbeyns, Bailey, Bos, & Meeusen, 2014). Active desks are desks that encourage higher levels of energy expenditure than sitting desks and include treadmill, cycling, standing and sit-stand desks. Standing and sit-stand desks have been the most popular to date due to practicality and work performance reasons. Their popularity has recently been demonstrated by the acquisition of a number of these desks for the Whitehouse in the US (Lebowitz, 2015).

Employers may find that the costs associated with the desks are offset by the health-related benefits that occur from using the active desks. Insurance companies may also see the value of improving health in the workplace environment providing employers with incentives to encourage this further. Closely associated with the everyday costs of the workplace is

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1 The sit-stand workstation can be adjusted into the sitting or standing position. This means that recorded times spent sitting or standing can vary depending on the participants preferences if no guidelines around time spent in each condition is given.
employee productivity. The literature examining active desks has divided productivity into work performance tasks and cognitive tasks (Commissaris et al., 2014; Torbeyns et al., 2014). While both of these outcomes have been reviewed in the literature, the effects of standing desks on cognitive performance is largely unknown (Burford et al., 2013; Torbeyns et al., 2014).

Cognitive performance is a broad term that encompasses many different aspects of cognitive ability. The research project outlined in this thesis formed part of a larger project investigating five different domains of cognition, including attention, working memory, executive function, perceptual reasoning and processing speed. The objective of the current project was to investigate the effect on performance in the cognitive domain of processing speed when using a standing desk in comparison to using a seated desk. It was hypothesised that processing speed would not reduce when participants used the standing desk when compared to the sitting desk.

Since the research into standing desks and cognitive performance is relatively new, this current study has contributed to a small emergent area of research. Understanding the effects that standing desks have on cognitive performance has important implications for the implementation of the desks in the workplace and classroom environments. The domain of processing speed is a strong indicator of cognitive ability, and, therefore, the results of this study will give an indication of the cognitive abilities of the participants when standing versus sitting. If processing speed does not reduce when standing, there will be an incentive for employers and employees due to the health related benefits that these desks provide. In addition, employers may want to consider potential benefits regarding employment related costs and worker productivity that could result from these health benefits.
Chapter 2: Literature review

Active desks

Cycling desks have been reported to decrease sedentary time in participants due to the active nature of the device (Carr, Walaska, & Marcus, 2012). Cycling desks do not encourage active movement like treadmill, standing or sit-stand desks. Instead, the upper half of the body is relatively more static than a treadmill desk while the lower extremities are dynamically active. According to Neptune and Hull (1995) cycling in the upright position on a narrow base may cause upper body movement via hip movement, and, thus, could impact office-based task performance. Several studies, however, have used “semi-recumbent elliptical devices” which reduce any upper body movements as a result of pedalling, thus reducing the negative impact on work performance tasks (Commissaris et al., 2014; Elmer & Martin, 2014).

Like the cycling desk, treadmill desks are also effective at reducing sedentariness due to their design (Dinesh John et al., 2011; Koepp et al., 2013; Parry, Straker, Gilson, & Smith, 2013; Thompson, Foster, Eide, & Levine, 2008). Koepp et al. (2013) found overall sedentariness to decrease by almost an hour each day while physical activity levels increased by this amount over a 12-month period in 36 office workers. John et al. (2011) also found total sedentary time to decrease in 12 overweight and obese office workers by up to 3 hours over a 9 month period. Interestingly, time spent using the treadmill desk seemed to reduce the longer they were available, suggesting that long-term usage of the desks may lead to behavioural changes which result in reductions in usability.

Standing desks have been shown to reduce sedentary behaviour by breaking up prolonged sedentary time through an increase in postural variability and movement at the desk (Alkhajah et al., 2012). Standing desks have been successfully introduced into the classroom with reported reductions in overall sedentariness in children (Hinckson et al., 2013). In the workplace sit-stand desks have also shown positive results for reducing sedentariness in adults compared to standard conditions (Grunseit, Chau, Van Der Ploeg, & Bauman, 2013; Healy et al., 2013; Straker, Abbott, Heiden, Mathiassen, & Toomingas, 2013). Over a 4-month period the median proportion of the day spent sitting decreased from 80 to 60 percent, and the median proportion of hours spent sitting at work decreased by 1.5 hours (Grunseit et
Alkhaja et al. (2012) found 18 participants reduced their overall sitting time by over 2 hours in the 8 hour workday at 1 week but also at 3 months following the implementing of the sit-stand desks. Combined with the sit-stand desks, Neuhaus, Healy, Dunstan, Owen, and Eakin (2014) compared a sit-stand group to a group using a multi-component intervention that included education, email reminders and face-to-face coaching. Participants in the multi-component group reduced sitting by 1.5 hours over an 8-hour workday, whereas the sit-stand group reduced sitting time by 33 minutes. Similarly, Davis & Kotowski (2014) trialled a computer software program that reminded participants to get up and move every 30 minutes. Results showed that it was successful alongside the sit-stand desks in reducing sitting time while increasing standing time, time away from the desk, and postural variability of participants (Davis & Kotowski, 2014).

Due to their design, active desks reduce sedentariness and encourage movement and postural variability. The effects of bodily movement on health outcomes is well documented (American College of Sports Medicine, 2015; Ministry of Health, 2015) and active desks that encourage movement utilise these health-benefits. The health risks associated with prolonged sedentariness should also be reduced due to the active nature of the desks and has been shown in a number of studies (Alderman, Olson, & Mattina, 2013; John P Buckley, Mellor, Morris, & Joseph, 2014; Elmer & Martin, 2014).

**Health-related outcomes**

Reported health-related outcomes at the cycling desk include reducing resting heart rate, improving oxygen consumption, ventilation per minute and systolic blood pressure levels (Elmer & Martin, 2014; J. Carr et al., 2014). Treadmill desks also improve cardiovascular health, but have also shown to improve metabolic markers and respiratory health as demonstrated by improvements in oxygen consumption (Alderman et al., 2013; Botter et al., 2013; Cox et al., 2011; Koepp et al., 2013; Miyashita et al., 2013; Straker, Levine, & Campbell, 2009).

Studies on standing desks have also revealed a number of positive health-related outcomes. A study of 32 desk-based office workers found HDL levels increased significantly in the standing desk group compared to the seated group over a three-month period (Alkhajah et al., 2012). In a study measuring cardiovascular health outcomes, postprandial glycaemic excursions were lower in the standing condition compared to the sitting condition (Buckley,
The greater peak glucose amplitude during seated work is of clinical significance, where such heightened amplitudes have been strongly associated with oxidative stress (Satya Krishna, Kota, & Modi, 2013). Measurements of glucose, total cholesterol, fasting blood lipids and triglycerides did not vary between the two groups. Participants did, however, experience weight loss in the intervention group over the 3-month period.

Health related outcomes appear to be apparent in all the active desks with noted improvements in cardiovascular, metabolic and respiratory health. The health benefits have been reported as a major incentive for their usage in the office by a number of participants trialling the active desks (Alkhajah et al., 2012; Chau et al., 2014). A number of other factors, however, are also affecting the usability of the desks and have been reviewed in studies looking at their acceptability.

**Acceptability**

Cycling desks appear to be reasonably well accepted in the office, as reported by 45 American office workers immediately after trialling the desk for 30 minutes (Carr et al., 2014). Participants involved in this study found the desk acceptable to use while completing tasks, but unfortunately long-term outcomes regarding acceptability were not gathered. Additional benefits included a self-reported positive impact on health without impairing productivity. In total, almost all (96%) of these participants reported that they would use the desk on a daily basis. A large number, however, also reported that they would not utilize the desks in a public setting, but their reasons were not given. This reveals a potential barrier that requires exploring in the future if the desks are to be utilized successfully.

In comparison, barriers to the usability of a height-adjustable treadmill desk were identified in a qualitative study of office workers over a six-month period (Cifuentes, Qin, Fulmer, & Bello, 2014). These included problems with shifting between seated and walking conditions, difficulties with communication while walking, and the effects of hierarchy-related work dynamics due to the height differences. The treadmill was also reported to produce a humming sound disrupting the workplace ambience. Importantly for potential buyers, the desks required additional office space when compared to the traditional seated desks and could demand additional physical resources to help with electrical problems and to assist in ergonomic evaluation and adjustment of the desk for the worker. In contrast, Thompson and
Levine (2011) reported that participants (11 medical transcriptionists) did not find the treadmill desks too noisy and that they did not interfere with work performance. These participants reported a preference for the treadmill desk compared to the seated desk. Koepp et al. (2013) claims that it took less than five minutes for 36 office workers to adjust to the new desk. The participants stated that they “tolerated the treadmill-based system well” over a one-year period (Koepp et al., 2013 p. 707). Thompson, Foster, Eide and Levine (2008) also received positive responses from participants who said they enjoyed using the desk and that if it was available they would use it.

High usability and acceptability has been reported in several studies examining the sit-stand and standing desks (Chau et al., 2014; Cifuentes et al., 2014; Grunseit et al., 2013; Hinckson et al., 2013; Straker et al., 2009). A study comparing seated, treadmill and standing desks found only 50% of participants reported the treadmill and cycling desks as a feasible option compared to well over half (83%) for the standing desk when compared to the seated desk (Straker et al., 2009). Hinckson et al. (2013) found that children and staff spoke enthusiastically about the use of the standing desks in the classroom environment, saying they offered “flexibility in learning” (Hinckson et al., 2013 p. 84). According to qualitative feedback in a 42-participant, four-week intervention study, benefits of using the sit-stand desk included self-reported feelings of improved posture, increased alertness, and enjoyment from having the choice of switching between postures (Chau et al., 2014). Factors conducive to standing were a supportive work environment, perceived physical health benefits, and perceived work benefits. A supportive work environment was said to make participants more comfortable when standing and encouraged a more sociable atmosphere within the office. The majority of participants said that they would like to continue with the sit-stand desk in the future. Problems with the desks included specific design issues that impacted user comfort and work ability. Several barriers to standing were discussed and included feeling self-conscious, concern over disturbing neighbouring colleague’s privacy and revealing confidential communications. In a study of 13 staff over a three-month period, Grunseit et al. (2013) identified several factors that influenced continual use. These included health benefits, perceived productivity, the time taken to transition between sitting and standing positions and whether the desk was set-up appropriately. Interestingly, Wilks, Mortimer and Nylén (2006) found that personnel at four different companies communicated interest in the desks, but showed poor compliance in using them. This shows that some barriers to usability do exist.
for the standing desk which will need to be fully explored if they are to be implemented into the workplace successfully.

The majority of the barriers identified for the active desks were related to self-confidence and issues relating to self-image. Technological issues occurred with the treadmill desks that were accompanied by additional problems unobserved in the other active desks. The standing and sit-stand desks seemed to be the most favourable overall. They did not require any additional space in the workplace and received the most positive feedback from participants, which would be an attractive factor for employers. One aspect of prolonged sitting that employers currently grapple with is musculoskeletal pain and discomfort, which has been reported to occur with prolonged sitting at a desk (Szeto, Straker, & Raine, 2002). This is an important aspect of acceptability which needs to be investigated in the active desks to determine whether pain and discomfort levels also occur when sedentariness is reduced.

Musculoskeletal discomfort
Discomfort from sitting is usually felt in the neck, shoulders and back regions (Drury et al., 2008). Musculoskeletal pain and discomfort has also been reported in active desks with upper limb discomfort to be highest at the seated desk, lower limb discomfort to be highest at the standing desk, and the lowest discomfort ratings overall to be at the sit-stand desk (Roelofs & Straker, 2002). The short-term effects of treadmill desks on musculoskeletal discomfort are varied, although one study found no significant differences in body complaints between the treadmill and seated desks (Edelson & Danoffz, 1989). In a more recent study, reports of leg discomfort were found in 30 office workers over a one day period (Straker et al., 2009). Interestingly, Cifuentes et al. (2014) found that knee and foot pain reduced after two weeks, which would imply that some degree of musculoskeletal pain reduces over time. However, participants were informed that they could use the treadmill at will and no data on time spent using the desks was given. This makes it difficult to understand the amount of treadmill walking that brought on this result.

A number of standing desk studies have reported similar levels of musculoskeletal pain and discomfort as sitting desks (Drury et al., 2008; Ebara et al., 2008; Hasegawa, Inoue, Tsutsue, & Kumashiro, 2001; Roelofs & Straker, 2002). A direct relationship exists between time, discomfort and the individuals’ perceptions of pain and discomfort. The longer the standing position was held for, the worse the self-reported ratings of pain and discomfort became.
Some studies show discomfort tends to be higher in the lower limbs, particularly the feet, but also the lower back in those using standing desks (Chester, Rys, & Konz, 2002; Drury et al., 2008; Roelofs & Straker, 2002). The sit-stand desk, however, has the unique ability of reducing prolonged static positions due to the option of changing between the seated and standing positions. This simple movement performed repetitively throughout the day encourages movement and postural variability, which relieves musculoskeletal tension (Roelofs & Straker, 2002). Studies have shown that musculoskeletal pain and discomfort in the upper back and neck reduce when a sit-stand desk is implemented (Davis, Kotowski, Sharma, Herrmann, & Krishnan, 2009; Husemann, Von Mach, Borsotto, Zepf, & Scharnbacher, 2009; Pronk, Katz, Lowry, & Payfer, 2012; Vink & Hallbeck, 2012).

In an attempt to decrease sedentariness further, a software system was implemented at the workstation to remind participants to move after a period of time and caused an increase in postural variability and a decrease in discomfort levels without effecting work performance (Davis et al., 2009; Davis & Kotowski, 2014). So far, this software has only been used on sit-stand desks, but has the potential to reduce discomfort levels in standing desks also.

It appears that prolonged static postures cause muscular pain and discomfort regardless of whether the individual is using a standing or seated desk, but differences exist in the location of the pain and discomfort. Interestingly pain and discomfort reduced in the treadmill desks after a short period of time. This does not seem probable for standing desks as they involve prolonged static positions similar to sitting desks. The sit-stand desk seems to offer the lowest levels of pain/discomfort, and when accompanied by a software system prompting participants to move, reduces these levels even further. Pain or discomfort that occurs during work is important to consider in relation to work performance and productivity. Pain can cause major distractions impairing the quality of work performance, and also result in absenteeism, as shown in low back pain research (Stewart et al., 2003). Employers may want to consider the employment-related costs associated with pain and discomfort and the effect that pain could have on work performance.

**Work performance**

When reviewing the effects that cycling desks have on work performance outcomes, the results vary substantially. Studies have reported that work performance did not change when compared to the seated desk in mouse dexterity (Carr et al., 2014), typing (Burford et al., 2014).
2013; Commissaris et al., 2014; Elmer & Martin, 2014; Carr et al., 2014), reading comprehension (Burford et al., 2013; Cho, Freivalds, Rovniak, Sung, & Hatzell, 2014; Commissaris et al., 2014) and telephone performance (Burford et al., 2013). In contrast, a number of studies have reported reduced work performance in typing performance and mouse dexterity tasks when using a cycling desk compared to using a seated desk (Burford et al., 2013; Cho et al., 2014; Commissaris et al., 2014; Straker et al., 2009).

The effects of the treadmill desk on work performance is unclear with two recent systematic reviews disagreeing on whether the desks cause a decrease in performance (MacEwen et al., 2015) or no effect (Torbeyns et al., 2014). When reviewing the literature, it is apparent that a significant proportion of studies have found treadmill desks impaired work performance (Burford et al., 2013; Commissaris et al., 2014; Funk et al., 2012; D John, Bassett, Thompson, Fairbrother, & Baldwin, 2009; Ohlinger, Horn, Berg, & Cox, 2011; Straker et al., 2009; Thompson & Levine, 2011). These reductions in work performance included tasks such as typing, mouse dexterity, reading performance and a digital finger tapping test. A small number of studies have found work performance to remain unchanged when using a treadmill desk. These studies focussed on reading performance, telephone tasks and typing performance (Burford et al., 2013; Commissaris et al., 2014; Funk et al., 2012). Interestingly, work performance decreased in the first three months and then increased thereafter resulting in no effect on performance outcomes. This suggests that an adaptive period occurs in which people get accustomed to the change of workplace. The act of performing two tasks (which in this case is the act of walking and performing work at a desk) becomes easier with practice due to adaptive cognitive processes (Borel & Alescio-Lautier, 2014). This could be the mechanism behind this result, and if this is the case, would have important implications for the results of short-term studies examining treadmill desks and work performance outcomes.

A large number of studies have revealed no detrimental effects on work performance when standing was compared to sitting (Burford et al., 2013; Commissaris et al., 2014; M. Neuhaus et al., 2014; Torbeyns et al., 2014). Outcome measures have included computer tasks, such as high precision mouse tasks and keyboard work (Burford et al., 2013; Davis et al., 2009; Straker et al., 2009), performance over the telephone (Burford et al., 2013; Cox et al., 2011; Davis et al., 2009), data entry (Husemann et al., 2009), fine motor work (Ohlinger et al., 2011; Straker et al., 2009), transcription (Beers, Roemmich, Epstein, & Horvath, 2008) and reading comprehension (Burford et al., 2013). Of the studies investigated, only one has reported a decrease in work performance, and this was in a mouse dexterity task.
The results of this study may have occurred due to the brief testing times, in which participants were tested for only 24-26 minutes.

The variety of work performance outcomes and different speeds used by the cycling and treadmill desks make the comparability of results difficult. Regardless of this, in both treadmill and cycle desk conditions, fine motor control (mouse control at the computer) seemed to be adversely affected. Of course, treadmill and cycling desks cause more upper body movement when compared to the sitting and standing desks, which could explain this effect on work performance. Of note, there seems to be an initial period of adjustment which could impact the results of short-term studies on treadmill desks and potentially affect the other active desks also. The standing desk has demonstrated the most satisfactory results when considering its impact on work performance. This could be a result of less body movement when compared to the treadmill and cycling desk, or could be due to the lower levels of musculoskeletal pain and discomfort, which have been reported as being similar to the seated desk. Musculoskeletal pain and discomfort can cause distraction while working which could reduce work performance in a number of tasks. While some indication of the effects that standing desks have on worker productivity has been discussed, work performance tasks primarily test for motor coordination and fine motor skills, but the effects that active desks have on cognitive performance has not yet been explored. The literature examining the effects of standing desks on cognitive performance is limited, and so an examination of the effects that physical activity and variations in posture have on cognitive performance will be examined to provide a deeper understanding of this area.

**Cognitive performance**

In 1967 Ulric Neisser, an American psychologist, described cognition as “all processes by which the sensory input is transformed, reduced, elaborated, stored, recovered, and used.” (Neisser, 1967 p. 4). Cognitive performance can be assessed through intelligence, “the global capacity of a person to act purposefully, to think rationally, and to deal effectively with his environment.” (David. Wechsler, 1939 p. 229). Cognitive processing speed, the main focus of this research project, is one of the main components in a wide range of cognitive domains and in psychometric intelligence (Takeuchi et al., 2011). It refers to how quickly individuals execute cognitive tasks, particularly elementary-level cognitive tasks (Salthouse, 1996). Processing speed measures skills that require focussed attention and the ability to quickly
scan, discriminate between and order visual information in sequence (Salthouse, 1996). Motivation, difficulty working under a time pressure, and motor coordination can have significant effects on the outcome. Processing speed has also been shown to be dependent on neural development and function. As the brain develops from childhood through to adulthood the level of processing speed increases (Kail, 2000). This effect reverses slowly from young adulthood (Ball et al., 2002; Kail & Salthouse, 1994; Salthouse, 1996) and has been correlated with the volume of white matter in the brain (Kerchner et al., 2012). Other factors that affect processing speed consist of impairments of the central nervous system, such as developmental problems and diseases (Kail, 2000). In a 50-year review of the literature, Sheppard and Vernon (2007) found that processing speed was significantly correlated with measured intelligence. This was confirmed by Coyle, Pillow, Snyder and Kochunov (2011) who also state that faster processing speeds correlate with better test results on general intelligence tests, implying that changes in processing speed can be loosely associated with similar changes in general cognitive ability.

**The effects of physical activity on cognition**

Animal research has revealed clear associations between improvements in fitness and both morphological and functional changes in the brains of older animals (Kramer et al., 2003). A meta-analysis similarly points to the benefits of physical activity on cognitive performance in older adult humans (Colcombe & Kramer, 2003). Fitness training has been found to have strong, but selective, benefits for cognition, with the largest benefits effecting executive function (Colcombe et al., 2003; Ratey & Loehr, 2011). In a correlational study conducted by Hillman et al. (2006), 241 people aged between 15-71 years were asked to report the level of physical activity performed on a daily basis and to participate in the Eriksen Flanker test (which measures processing speed and selective attention). The results revealed that higher levels of physical activity were correlated with higher scores in the task, and vice versa. Similarly, a recent systematic review and meta-analysis examining the effects of aerobic exercise on cognitive performance concluded that aerobic exercise was associated with modest improvements in attention, processing speed, executive function and memory (Smith et al., 2010).

The positive effects of exercise on cognitive performance has been shown to occur with acute bouts of aerobic and resistance exercise from as little as a single session, in which
improvements in reaction time, processing speed and executive function were recorded in a number of studies (Audiffren, Tomporowski, & Zagrodnik, 2008; Chang & Etnier, 2009a, 2009b; Hogervorst, Riedel, Jeukendrup, & Jolles, 1996; Joyce, Graydon, McMorris, & Davranche, 2009). This is similar to long-term studies of resistance training, which have found processing speed and decision-making skills to be better in participants whose physical fitness was 15 percent higher than their counterpart controls (Blomquist & Danner, 1987; Suominen-Troyer, Davis, Ismail, & Salvendy, 1986). Moderate to high volumes of exercise seem to improve cognitive performance also. Stroth et al. (2009) found that a six-week running program, where participants ran three times per week, improved visuospatial memory, while Masley, Roetzheim, and Gualtieri (2009) found that moderate volumes (3-4 days per week) and high volumes (5-7 days per week) of aerobic exercise were associated with improvements in cognitive flexibility over a ten-week period. In addition, the high volumes of exercise also improved participants’ reaction time and attention span.

Exercise intensity may also be considered, where higher exercise intensity has been shown to cause improvements in cognitive ability. In a study of 1927 healthy adults aged 45-70 years old, a more intensive weekly exercise regime caused better processing speed, memory, mental flexibility and overall cognitive function (Angevaren et al., 2007). Participants who partook in a greater variety of activities also had significantly greater performance in processing speed, memory, mental flexibility and overall cognitive function compared to those who partook in a lesser variety of activities. Not only have these cognitive effects been found in the studies listed above, but imaging studies have revealed the effects that physical activity has on the electrical activity of the brain (Kamijo & Takeda, 2010).

A number of electrophysiological studies have used electrodes placed on the scalp to measure certain brain activity. The P300 is a commonly studied component of event-related brain potentials that occurs soon after a stimulus. It has been shown to measure brain activity linked to attentional resources and to also give an indication of information processing and memory encoding (Polich, 2007). A higher amplitude P300 is suggested to reflect that more attention is required to encode the stimulus in working memory and a shorter latency reflects a higher level of speed of information processing. Studies have found correlations between exercise and better physical fitness, and larger P300 amplitudes and shorter P300 latencies (Hillman, Kramer, Belopolsky, & Smith, 2006; Hillman, Snook, & Jerome, 2003; Kamijo & Takeda, 2010; Pontifex, Hillman, Fernhall, Thompson, & Valentini, 2009). These findings highlight the role that exercise has in improving cognitive function through attentional
resources and speed of information processing. Neuroimaging studies using magnetic resonance imaging (MRI) and functional MRI have shown correlations between physically fit individuals and brain volume and function (Colcombe et al., 2003, 2004; Gordon et al., 2008). Erickson (2009) found that older, more aerobically fit adults, had increased hippocampal volume and performed better on spatial memory tasks than unfit older adults. In addition to this, higher preservation of brain matter was found in older adults that participated in 6 months of aerobic training compared to untrained control participants (Colcombe et al., 2006).

The cognitive improvements that are associated with exercise are believed to be a result of molecular and cellular effects. Studies have shown physical activity to increase blood levels of growth factors and neurotrophins (which support cognitive cellular function through neurogenesis and angiogenesis) in animals (Berchtold, Castello, & Cotman, 2010; Cotman & Berchtold, 2002) and in humans (Ferris, Williams, & Shen, 2007; Trejo, Llorens-Martín, & Torres-Alemán, 2008). Standing, while considered a higher level of activity than sitting, as demonstrated in a number of energy expenditure studies (Benden, Blake, Wendel, & Huber, 2011; Benden et al., 2014; Blake, Benden, & Wendel, 2012), is a low-intensity activity, whereas most studies examining the effects of physical activity on cognitive performance have used moderate-high intensity exercise. The molecular and cellular changes that cause cognitive performance to improve as a result of exercise may, therefore, be reduced due to this reduction in exercise intensity when standing. Closer comparisons of the effects that standing desks have on cognition may be done through an investigation into lower intensity activity, such as the standing posture. This has not yet been explored in the literature examining the effects of standing desks on cognitive performance, but may provide some understanding of the effects of lower intensity activity and cognitive performance.

The effects of posture on cognition

Research into the effects of posture on cognition is relatively new. Historically, research from the psychological sciences and research into posture did not consider the interrelations between the two conditions, and instead they were researched separately. In reality, these functions coexist (Fraizer & Mitra, 2008). Cognitive functions, other than the ones used to maintain balance and movement, often play key roles in the facilitation of such supra-postural functions (Stoffregen, Pagulayan, Bardy, & Hettinger, 2000), and postural alterations can
often impede the performance of cognitive functioning (Fraizer & Mitra, 2008). Balance demands vary greatly between postures, with more difficult postures (e.g., perturbed standing posture) requiring more attentional demand compared to less difficult postures (e.g., sitting or lying supine). In addition, health status and expertise directly impact the level of cognitive investment. Attentional investment tends to be higher in stroke patients and patients with vestibular loss, and lower in gymnasts compared to controls (Roerdink, Hlavackova, & Vuillerme, 2011). Processing speed has an important role within gait and balance (Borel & Alescio-Lautier, 2014), where reductions in processing speed were associated with increased fall frequency in 27 participants aged between 50 and 75 years with multiple sclerosis (Sosnoff et al., 2013).

Dual tasking is the act of performing two cognitive tasks in coordination. It is commonly used to examine how attentional resources are allocated (Borel & Alescio-Lautier, 2014). A limited capacity to process information requires careful allocation of resources in dual tasking, as additional attentional resources are being used. If the performance of both the tasks exceeds the attentional capacity, a limited amount of information can be processed and performance is lower than if the participant performed each task separately (Borel & Alescio-Lautier, 2014). Automatic processing includes activities that have been learnt to a sufficient level that they can occur automatically without much allocation of resources (Shiffrin & Schneider, 1977). This allows for a larger amount of information to be processed at one time. If, in contrast, the task requires controlled processing, it requires a larger allocation of resources and usually results in the reduced performance discussed earlier. Everyone has a limited amount of resources, but elderly participants have a reduced capacity compared to younger adults, so they are effected more severely in dual task situations (Borel & Alescio-Lautier, 2014; Smolders, Doumas, & Krampe, 2010). Age related decline in the sensorineural system, muscular system and cognitive systems play a role in causing this difficulty (Borel & Alescio-Lautier, 2014). This may have important implications for office workers, especially the older population, with the implementation of active desks. The older population may have reduced performance when performing cognitive tasks in the standing position due to the unfamiliarity of the situation and the increased attentional resources that are required as a result.

There are consistent findings within the literature that show trying to regain balance or maintain balance requires the same cognitive loading used to perform cognitive tasks (Frank & Earl, 1990; Horak, Diener, & Nashner, 1989; Quant, Adkin, Staines, Maki, & McIlroy,
2004; Quant, Maki, & McIlroy, 2005) and cognitive task performance has consistently shown to be detrimentally affected when stance is mechanically or visually perturbed (Andersson & Hagman, 2002; Andersson, Yardley, & Luxon, 1998; Brauer, Woollacott, & Shumway-Cook, 2001; Brown, Shumway-Cook, & Woollacott, 1999; Rapp, Krampe, & Baltes, 2006; Redfern, Jennings, Martin, & Furman, 2001; Redfern, Talkowski, Jennings, & Furman, 2004; Shumway-Cook & Woollacott, 2000; Yardley et al., 2001). This is more pronounced in the elderly and balance-impaired adults. Furthermore, when balance was being perturbed and a cognitive task was performed, balance became worse as measured by postural sway, demonstrating the effect that cognitive tasks can have on balance control (Adkin, Frank, Carpenter, & Peysar, 2000; Brauer et al., 2001; Marsh & Geel, 2000; McNevin & Wulf, 2002). This again was worse in older adults. In contrast, a number of studies reported sway reduced when balance was being perturbed when a cognitive task was completed in young healthy adults (Andersson & Hagman, 2002; Brauer et al., 2001; Dault, Yardley, & Frank, 2003; Riley, Baker, & Schmit, 2003). This could demonstrate that younger adults are able to rationalise more readily and subconsciously focus on the more demanding task at hand. If this is the case, then younger adults using standing desks should have less difficulty when competing for balance over cognitive performance, and older adults may have difficulties with balance while standing when additional cognitive loading is required.

Neuroimaging has shown an increase in cortical activity when orthostatic posture became more vertical as measured by EEG (Thibault, Lifshitz, Jones, & Raz, 2014). These changes occurred regardless of whether the participant was performing an arithmetic task (counting backwards) or had their eyes open or closed. The authors suggested that this increase in activity could be linked to changes in the cerebrospinal fluid and subsequent release of cortical noradrenalin (Thibault et al., 2014). This has been demonstrated further through the investigation of insight problems. Insight problems are problems that tend to be solved in a moment of sudden awareness (Metcalfe, 1986). There have been anecdotal reports (Mazzarello, 2000) and research (Wagner, Gais, Haider, Verleger, & Born, 2004) suggesting that insight occurs commonly during, or can be encouraged by sleep, as a result of being supine. Anagrams can be characterised as insight problems, and were used in a study looking at the ability to solve anagrams in the supine position versus the standing position (Lipnicki & Byrne, 2005). In the supine position anagrams were solved 3.1 seconds faster by participants than in the standing position. Results from this study also suggested that in the more vertical position physiological mechanisms caused an increased level of cortical activity.
which interfered with cognitive processes (Walker, Liston, Hobson, & Stickgold, 2002). In the supine position this interference does not occur and the brain can focus its processing on the task without dual tasking. Participants may have less ability to perform cognitive tasks in the standing position due to this increase in cortical activity reducing their performance in the cognitive tasks.

This, however, was not reflected in the results of a systematic review examining the effects of comfortable versus uncomfortable occupational postures on performance (Drury et al., 2008). Of the 18 studies examined, five revealed that a more comfortable posture (lying supine or sitting) degrades performance and a less comfortable posture (standing) enhances performance. Six studies showed the opposite, with a more comfortable posture (lying or sitting) enhancing performance or a less comfortable posture (standing) degrading performance, and seven studies found that posture had no significant effect on performance.

Neuroimaging studies have revealed why tasks become more difficult in the standing position, demonstrating the neurophysiological mechanisms that could be responsible for a decrease in cognitive performance when standing (Thibault et al., 2014). This was not demonstrated in a systematic review, however, that examined the effects of comfortable postures on performance (Drury et al., 2008). It is, therefore, unknown as to how the standing posture effects cognitive performance. Will the increased activity of standing reduce attentional capacity, or will the act of standing be automatic enough to cause no effect on cognition? The effect that certain power postures have on physiological mechanisms can provide an alternative perspective.

Body posture has been associated with psychological, physiological, and behavioural changes in a number of studies (Carney, Cuddy, & Yap, 2010; Huang, Galinsky, Gruenfeld, & Guillory, 2011; Park, Streamer, Huang, & Galinsky, 2013). These changes have been linked to feelings of power. Power postures tend to be open and expansive. Standing with hands placed on a desk, separated beyond shoulder width, with fingers spread is one common posture. A seated posture includes one leg crossed so that the ankle rests on the contralateral thigh, one hand placed on the desk and another on the armrest of the chair. Carney et al. (2010) measured the effects of these power postures on testosterone and cortisol levels, as well as feelings of power and tolerance to risk. In the high-power postures, testosterone levels increased, cortisol levels decreased, and feelings of power and tolerance to risk were increased (Carney et al., 2010). In another study, the effects of body posture versus the
effects of hierarchal role on posture were examined (Huang et al., 2011). Body posture was shown to have a stronger effect on influencing thoughts and behaviours related to power. To act and think like a powerful person does not require a strong hierarchal role, only to adopt a powerful posture. It can be speculated that posture does not have a direct effect on behaviour and cognition, but carries its influence through its symbolic meaning. This symbolic meaning can be universal in some postures. Postures that are most related to dominance in the animal kingdom tend to have this effect (Darwin, 1872). These findings suggest that power postures could influence cognitive performance in the workplace when standing compared to sitting through physiological, behavioural, and psychological mechanisms. Another mechanism that could be responsible for changes in cognitive performance is the link between body postures and the retrieval of information.

Embodiment theorists regard the mind as being shaped by the body (Dijkstra, Eerland, Zijlmans, & Post, 2014). The body plays a key role in the processing and storing of information, and in the retrieval of this information. Cognitive processes are said to depend upon a sensory-motor system in the brain that reactivates past experiences. When this occurs, neural states are re-enacted from the systems that stored the original experience. For example, participants accessed their memories with less effort and in less time in body positions similar to which they formed that memory (Dijkstra, Kaschak, & Zwaan, 2007). Autobiographical memories include the retrieval of our experiences in an environment, including the visual, sensorimotor and affective components of the experience. Posture is thought to facilitate this process as autobiographical memories can be considered a form of “embodied simulation in which persons remembering an event in the past go through similar visual, kinaesthetic, spatial, and affective aspects that were part of the original experience” (Wilson, 2002 p.633). In addition to this, when cognitive tasks and body positions were arranged to facilitate one another, fewer processing resources were needed due to the cue that these postures can provide with memory retrieval (Barsalou, Niedenthal, Barbey, & Ruppert, 2003). Based on this theory, the implementation of standing desks into classrooms may provide an early opportunity to develop learning capabilities in the standing position that may be used more efficiently in the future when standing in the workplace. Fewer processing resources will be required and by imitating the position in which the information was learnt, retrieval of that information through embodied simulation will be more effective.
Active desks and cognition

Only three studies were found that examined the effects of a cycling desk on cognitive measures in comparison to sitting (Burford et al., 2013; Commissaris et al., 2014; Carr et al., 2014). The first found the cycle desk caused reaction time and accuracy to improve in cognitive tasks measuring visual perception and working memory (Burford et al., 2013). In accordance with this, accuracy improved in the task measuring implicit social cognition, and reaction time improved in the task measuring processing speed and selective attention. In contrast, accuracy reduced and reaction time worsened in two other tasks measuring implicit social cognition, and processing speed and selective attention respectively, when compared with the sitting condition. The second study found that accuracy in the N-Back test (a test of working memory) decreased in the bicycle ergometer at a rate of 40 percent heart rate reserve (Commissaris et al., 2014). None of the other cognitive tasks measuring attention and executive memory performance were affected. When the cycling intensity was reduced to 25 percent heart rate reserve there were no measurable changes in cognitive performance when compared to sitting. This is reiterated by the third study, which found no between-group differences in cognitive performance when compared to the sitting desk (Carr et al., 2014).

The interaction between treadmill desks and cognition has not been reviewed in the long-term. The short-term benefits have been explored by a large number of studies that show walking desks have no effect on cognitive ability (Burford et al., 2013; Commissaris et al., 2014; John et al., 2009; Kline, Poggensee, & Ferris, 2014; Ohlinger et al., 2011). Positive effects have been noted, however, with better reaction time scores in the Subtizing task and the Eriksen Flanker task, and improvements in accuracy in the Go/No-Go task and a working memory task when compared to sitting (Burford et al., 2013). One study found that during treadmill walking performance decreased significantly in a mathematics task (John et al., 2009). The study was the first of its kind to examine the effects of treadmill walking on cognitive performance. The decrease in performance was small and could have been due to the lack of an acclimatization period (Ruthruff, Van Selst, Johnston, & Remington, 2006). In addition, the results may not be comparable to results from an office setting because the participants were not employed office workers and the duration of the testing consisted of only 60 minutes.

There are a limited number of studies examining the effects of standing desks on cognitive performance, and conclusions are difficult to draw considering the large variability in results.
and outcome measures tested. A small number of studies have found cognitive performance to decline when using standing desks. One such study by Yardley (2001) found that participants had better scores in spatial and non-spatial tasks when sitting compared to standing, yet the results did not reach significance. Hasegawa et al. (2001) also found working memory performance was better in the seated group in a study in which the participants were required to multiply one-digit numbers together. A more recent study examined the effects of standing desks on multiple cognitive domains administered via a “CNS Vital Signs test battery” (Schraefel, Kenneth, & Anderson, 2012 p. 2). The test battery assessed the cognitive domains of executive function, complex attention, cognitive flexibility, psychomotor speed, reaction time and processing speed. Sixteen healthy males were tested over an hour and ten minute period in both the standing and sitting conditions. Results demonstrated that complex attention was significantly greater in the sitting condition, while the other domains did not reach significance. Limitations within the methodology were identified that could have confounded these results. The sitting and standing durations lasted for a short time, which was not a true representation of a typical working day, and may have prevented the detection of the effects of fatigue. Additionally, each participant performed both the standing and sitting conditions on the same day without a washout period. The results of this study imply that the ability to concentrate and perform tasks uninterrupted is compromised when standing. Additional research is required due to the limitations in this study to develop a better understanding of the effects of standing on cognitive performance and ensure that these conclusions are sound.

A number of studies have reported no changes in cognitive performance when standing compared to sitting at a desk (Commissaris et al., 2014; Drury et al., 2008; Schraefel et al., 2012). Commissaris et al. (2014) found no difference in attention, executive memory, or working memory when participants were using a standing desk. In addition, no change in attention or working memory was detected when standing compared to sitting in a number of studies (Dault, Frank, & Allard, 2001; Drury et al., 2008; Ehrenfried, Guerraz, Thilo, Yardley, & Gresty, 2003; Maylor, Allison, & Wing, 2001).

Several studies have reported improvements in multiple cognitive domains when standing compared to sitting (Burford et al., 2013; Caldwell, Prazinko, & Caldwell, 2003; Cann, 1990). Burford et al. (2013) tested 12 office-based participants with tasks that measured cognitive performance in working memory, implicit social cognition, visual perception,
processing speed and selective attention. In the standing condition reaction time improved in all tasks when compared to sitting. Accuracy also improved in all tasks except the ones measuring working memory and visual perception. Caldwell et al. (2003) found that in the standing position participants showed more EEG arousal and demonstrated greater levels of sustained attention when performing a psychomotor vigilance task. This was demonstrated by reaction time, which was better when participants were standing. Interestingly, Cann (1990) found that posture caused reaction time to vary depending on the age of the person when performing a simple finger tapping task. There were no effects found within the younger age group but significant improvements in reaction time within the older group when standing compared to sitting.

Overall, there is a scarcity of research examining the effects of standing desks on cognitive performance, and specifically the domain of processing speed. Comparing these studies is difficult due to a variety of methodological processes and outcome measures used. In particular, the time that participants are standing needs to be reported and standardised. Results also varied depending on the cognitive domain being tested, making general conclusions on the effects of standing desks on cognition difficult. The studies that have examined the effects of a standing desk on processing speed are few and reveal inconsistent results. One study has tested processing speed specifically and found it to improve (Burford et al., 2013) and one study shows processing speed remains unchanged when standing compared to sitting at a desk (Schraefel et al., 2012). Further research is required to improve upon the methodology of past studies and strengthen the level of evidence supporting the use of standing desks in the office by examining the effects that these desks have on cognitive performance. This project has contributed to this limited area of research by investigating the effects of standing desks on the cognitive domain of processing speed. Thirty healthy volunteers were randomised and tested over two full days, one day standing and the other sitting. The purpose of this was to determine whether standing desks caused processing speed to change when standing compared to sitting over a full working day. Any changes in processing speed performance while standing will better inform office workers and employers of the effects that standing desks have on cognitive performance.

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It should be noted that this study was published prior to inferential statically analysis, so any mention of results should be taken with caution.
Chapter 3: Methods

Design
A randomised, controlled, repeated measures cross-over design was used to examine the cognitive effects of standing at a desk compared to sitting at a desk. Five separate research projects simultaneously examined five domains of cognition (attention, working memory, perceptual reasoning, executive function and processing speed), which were tested via a large battery of tests. Each participant completed two full work days, one standing at a desk and one sitting at a desk, while completing the cognitive tests three times per day (morning, midday and afternoon). A washout period of at least one week was included between the two testing days. The project reported here was concerned with the cognitive domain of processing speed only. The details of the other research projects are not reported. The study was approved by the Unitec Research Ethics Committee (Ethics approval number: 2014-1085) and all participants provided written consent (Appendix A).

Participants
Thirty healthy volunteers (14 females and 16 males) with an average age of 28.53 years (SD = 7.58) and 27.14 years (SD = 5.11), respectively, were randomised (stratified block (blocks of 2) randomisation) into two groups (sitting or standing on the first day). These groups were matched by strata of age and gender. Participants were recruited via word-of-mouth and advertising through the website ‘ResearchStudies.co.nz’. All potential participants were required to register on the website and read the information sheet. In addition, an eligibility questionnaire containing questions concerning the study’s exclusion criteria was completed at this point. 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, influencing their ability to perform cognitive tasks, 3) current usage of any medications which may affect concentration and/or cognitive performance, 4) poor fluency in written or verbal English (fluency was determined by the researcher over the phone if there were any doubts with the participants’ ability), 5) clinically diagnosed colour blindness, and 6) current usage of a standing desk. On completion of the study each
participant was given an option of fuel vouchers (MTA Gift Vouchers) and/or gift cards (Westfield Gift Card) to the value of $200 in appreciation of their time.

**Outcome measures**

Nineteen cognitive tasks and four work tasks\(^3\) were derived from common tests of cognition to ensure that the five cognitive domains were thoroughly analysed. Since the participants were tested with the same tasks three times each day over two days (Appendix D), each task was modified six times to prevent a learning effect. Thus, one version of each task was performed once at each time of the day (Figure 1). In addition, the tasks were matched at each time of the day to ensure that task difficulty was as similar across both days.

Four of the cognitive tasks were used to measure processing speed, three of which were adapted from the WAIS-IV (Symbol Search, Coding, and Cancellation tasks) (Wechsler, 1955) and the fourth (Rapid Picture Naming) was adapted from the Woodcock-Johnson III test of cognitive ability (Woodcock, McGrew, & Mather, 2001). The WAIS-IV is a world-renowned test of IQ which has proven to be a reliable and valid measure of cognitive performance in the cognitive domains of verbal comprehension, perceptual reasoning, working memory and processing speed (Cherry, 2014; Climie & Rostad, 2011). The Woodcock-Johnson III test of cognitive ability is also a reliable and valid measure of a broad range of cognitive abilities (Hale & Fiorello, 2004).

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\(^3\) Work tasks were included to emulate “real world” work related performance, such as typing, proof reading and data entry performance.
<table>
<thead>
<tr>
<th>Time</th>
<th>Testing sessions</th>
<th>Task versions</th>
</tr>
</thead>
<tbody>
<tr>
<td>9:00 – 10:45 a.m.</td>
<td>Morning testing session</td>
<td>Version 1 of all the tasks performed</td>
</tr>
<tr>
<td>11:00 – 11:45 a.m.</td>
<td>Lunch Break</td>
<td></td>
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<tr>
<td>12:00 – 1:45 p.m.</td>
<td>Midday testing session</td>
<td>Version 2 of all the tasks performed</td>
</tr>
<tr>
<td>2:00 – 2:15 p.m.</td>
<td>Afternoon Tea Break</td>
<td></td>
</tr>
<tr>
<td>2:30 – 4:15 p.m.</td>
<td>Afternoon testing session</td>
<td>Version 3 of all the tasks performed</td>
</tr>
</tbody>
</table>

*Figure 1. Overview of the testing procedure including time of day of the testing sessions*

**Measure 1: Coding**

The Coding task measured visual-motor coordination, motor and mental speed, and visual working memory (Wechsler, 1955). The task consists of using a coding key at the top of the page which contains nine numbers in ascending numerical order (1-9), each of which were paired with a symbol (Figure 3). Participants were asked to match the symbols from left to right with the corresponding number from the coding key (e.g., $\Omega = 1$, $\Sigma = 2$, and so on) as quickly as possible without skipping any items. Participants were given 60 seconds to complete as many items as possible. Data for this task was the number of items correctly identified and recorded within the timeframe (Coding Number Correct) and this variable was statistically analysed. Data for the variable, Coding Number of Errors, was collected, but not analysed due to a scarcity of data points from participants.
Figure 3. Example of the Coding task with some correct responses.

Measure 2: Symbol Search

The Symbol Search task measured visual perception, analysis, and scanning speed (Wechsler, 1955). Participants were required to locate either of two target symbols on the left of their page within a group of five symbols on the right of their page (Figure 4). If either of the target symbols was within the group of symbols on the right then the ‘Y’ was circled indicating “Yes”. If not, ‘N’ was circled indicating “No”. These constituted correct responses. The participant was given 60 seconds to make as many responses as possible. The variables Symbol Search Number Correct and Symbol Search Number of Errors were collected and analysed.

Figure 4. Example rows of the Symbol Search task with correct responses.
Measure 3: Cancellation

The Cancellation task was the final task adapted from the WAIS-IV. It measures visual-perception speed (Wechsler, 1955). For this task participants were asked to identify, and cross out with a pen, two target shapes amongst a multitude of other shapes acting as distractors. In Figure 5, 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 without skipping any. The variable Cancellation Correct represented the number of items correctly scribed in this time, and this variable was collected and analysed.

![The two target shapes to be identified](image)

Figure 5. Example of a portion of the Cancellation task showing correct responses.

Measure 4: Rapid Picture Naming

The Rapid Picture Naming task measured speed and fluency of the retrieval of stored information and the efficiency of oral production of recognised objects (Woodcock et al., 2001). For this task participants were asked to verbally identify 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 6). 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 and analysed as the variable Rapid Picture Naming Time to Complete. The variable Rapid Picture Naming Correct was also collected, but has not been reported here due to discrepancies with the data collection across the five different research
projects. This task was designed to measure processing speed or the fluidity in which the participant could bring associated names to the fore in response to a visual stimulus. It was not designed to test general knowledge of common tangible objects and animals. During testing there was not time for the researchers to record participant’s responses when strictly incorrect, and additionally, it was not possible to anticipate all common and acceptable ‘mis-namings’ of every item. For this reason the data for accuracy was dropped.

*Figure 6.* Example of three of the Rapid Picture Naming task items, “chicken” (or “hen”), “banana” and “pencil”.

**Materials**

Booklets were created to enhance consistency across all five research projects. Each booklet contained all 19 cognitive tasks and the four work tasks. Six testing booklets were designed for each participant, one for each time of day across both testing days (Figure 1). Three of the processing speed tasks were compiled in the testing booklet (i.e., Symbol Search, Cancellation and Coding), in which the participant wrote in, while the Rapid Picture Naming task was performed at the computer. Each task within the testing booklet had one A4 sized page containing the instructions and an example, followed by the task (Appendix C).

**Procedure**

*Workplace arrangement*

Data was collected individually in a quiet office at Unitec Institute of Technology, Auckland, New Zealand. In the sitting condition a standard chair was used. Two standing desks were
custom built for the standing condition, one slightly taller than the other to allow for height differences between participants. Participants were required to stand in a comfortable position with an unobstructed view of the computer monitor and/or testing booklet.

**Familiarization session**
Prior to the first testing day participants were required to attend a familiarization session of approximately one hour. The familiarization session was structured to inform the participant of the study, the procedure for each testing day, the instructions of the tasks to be completed, and to address any questions they may have.

**Testing days**
The entire day, including filling out documents and performing the tasks, took 7 - 7.5 hours. Both days consisted of three testing sessions and two breaks (Figure 1). Each testing session lasted two hours and included all 19 of the cognitive and four work performance tasks. If a participant completed the tasks in the session early, they were instructed to put additional time into the work performance tasks until the two hours of testing was completed. Participants were encouraged to stay within the premises and to spend quiet time alone during breaks to avoid further cognitive exertion. Several factors were controlled for over the day. A participant log (Appendix D) was given to participants before any testing had ensued. This was to keep a record of any confounding variables that may have impacted their performance on the day, such as level of alcohol consumption in the last 24 hours, sleep deprivation, etc. Participants were also required to keep a nutritional intake form detailing their food and drink intake at the end of both days with the expectation that they eat and drink similar amounts on each day (Appendix E).

**Data analysis**
Data were collated using Microsoft Excel, and then analyzed using SPSS version 19 (SPSS and IBM company., Chicago IL). Variables were explored for assumptions of normality by analyzing the values for skewness and kurtosis with their standard errors and completing a Shapiro-Wilk test. Two-way repeated measure ANOVAs were used to identify main effects of Condition and Time of Day on each measure. Mauchley’s tests for sphericity were conducted, and Greenhouse-Geisser corrections applied when sphericity was violated.
Chapter 4: Results

Effects for all variables were analysed using repeated-measures ANOVAs with Condition (sitting and standing) and Time of Day (morning, midday and afternoon) as the within-subjects factors.

Cancellation task

For the variable Cancellation Correct there was no main effect of Condition, $F(1,29) = 0.81$, $p = 0.375$, but there was a main effect of Time of Day, $F(2,58) = 5.61$, $p = 0.008$. Pairwise tests revealed there was a significant increase in task performance between Morning ($M = 75.97$, $SE = 5.36$) and Midday ($M = 80.28$, $SE = 5.30$), $p = 0.022$, and between Morning and Afternoon ($M = 81.25$, $SE = 5.16$), $p = .033$, but no difference between Midday and Afternoon, $p = 0.99$. Additionally, there was no interaction between Condition and Time of Day, $F(2,58) = 0.17$, $p = 0.837$ (Figure 7.)

![Figure 7. Mean number of items correctly identified (Number Correct) for the Cancellation task, during Standing and Sitting conditions at three times across the day. Error bars represent standard error of the mean.](image-url)
Coding task

For the variable Coding Correct there was a trend toward significance for Condition, $F(1,29) = 3.06, p = 0.091$, showing better performance when standing compared to sitting. There was no main effect of Time of Day, $F(2,58) = 0.25, p = 0.773$, and no interaction between the two variables, $F(2,58) = 0.67, p = 0.496$ (Figure 7).

![Figure 8](image)

*Figure 8.* Mean number of items correctly identified (Coding Correct) for the Coding task, during Standing and Sitting conditions at three times across the day. Error bars represent standard error of the mean.

Symbol Search task

For the variable Symbol Search Correct there was no main effect of Condition, $F(1,29) = 0.01, p = 0.922$, but there was a main effect of Time of Day, $F(2,58) = 16.30, p < 0.001$, showing a significant increase in task performance between midday ($M = 23.12, SE = 0.91$) and afternoon ($M = 25.12, SE = 0.90$), $p < 0.001$, and between morning ($M = 23.10, SE = 0.83$) and afternoon, $p < 0.001$, but no difference between morning and midday, $p = 0.99$. There was no interaction between Condition and Time of Day, $F(2,58) = 0.37, p = 0.958$ (Figure 8).
Figure 9. Mean number of items correctly identified (Symbol Search Correct) for the Symbol Search task, during Standing and Sitting conditions at three times across the day. Error bars represent standard error of the mean.

For the variable Symbol Search Errors there was no main effect of Condition, $F(1,29) = 0.92$, $p = 0.345$, or Time of Day, $F(2,58) = 1.64$, $p = 0.210$. There was also no interaction between Condition and Time of Day, $F(2,58) = 0.374$, $p = 0.689$ (Figure 9).
Figure 10. Mean number of errors for the Symbol Search task, during Standing and Sitting conditions at three times across the day. Error bars represent standard error of the mean.

**Rapid picture naming task**

For the variable Rapid Picture Naming Time to Complete there was no main effect of Condition, $F(1,29) = 0.55, p = 0.465$, but there was a trend toward significance for Time of Day, $F(1,29) = 3.04, p = 0.055$. Pairwise comparisons revealed no differences between Morning ($M = 56.92, SE = 2.82$) and Midday ($M = 59.30, SE = 3.14$), $p = 0.294$, nor Midday and Afternoon ($M = 60.26, SE = 3.50$), $p > 0.99$. There was, however, a trend toward a significant increase in the time taken to complete the task in Afternoon compared with Morning, $p = 0.69$. There was no interaction between Condition and Time of Day, $F(2,58) = 2.32, p = 0.11$ (Figure 10).
Figure 11. Mean time to complete for the Rapid Picture Naming task, during Standing and Sitting conditions at three times across the day. Error bars represent standard error of the mean.
Chapter 5: Discussion

This study examined whether standing at a desk when compared to sitting at a desk over two full working days altered cognitive processing speed. The results show that processing speed performance did not reduce when standing compared to sitting in any of the four tasks (Cancellation, Coding, Symbol Search and Rapid Picture Naming). In fact, in the Coding task a trend toward better performance when standing was revealed, which is similar to a number of studies which have found standing desks improve cognitive performance (Burford et al., 2013; Cann, 1990).

Performance in several of the tasks was shown to vary depending on the time of day. Performance (regardless of Condition) in the Cancellation task and Symbol Search task improved later in the day, which was demonstrated by an increase in the number of correctly identified objects. This could suggest that participants were able to develop strategies to improve their visual perception and scanning speed performance as they became more experienced with the task. Comparatively, in the Rapid Picture Naming task participants performed more swiftly at the beginning of the day, suggesting that reaction times may have been affected by fatigue as the day progressed.

Overall, the results presented here provide evidence that standing desks could replace sitting desks without altering processing speed. Due to the relationship that processing speed has with measures of general intelligence these results also provide some insight into the effects of standing desks on cognition generally. It could be speculated that cognitive performance will remain unchanged in the other domains of cognition similar to that of the processing speed domain.

The results of this project are similar to a number of studies in which cognitive performance was not found to be significantly affected by standing at a desk (Commissaris et al., 2014; Dault et al., 2001; Drury et al., 2008; Ehrenfried et al., 2003; Maylor et al., 2001; Schraefel et al., 2012). This study tested participants over a full working day, the longest that cognitive performance has been tested to date. It seems that cognitive performance does not vary when compared to other studies examining the effects of standing desks on cognitive performance when testing times are increased to a day-long period. This is interesting, since rapid changes
in cortical activity have been shown to occur in EEG research (Thibault et al., 2014). These rapid changes that arise almost immediately after a change to a more vertical posture may be the only changes that occur when cognitive performance is tested for longer. The cognitive effects of using a standing desk for longer than two days, however, is unknown as this study has implemented the longest cognitive testing times to date. Further studies examining the long-term effects of cognitive performance when standing at a desk may reveal additional changes that have not been found thus far. Due to the results of this study, and the results of a number of studies examining standing desks and cognitive performance (Commissaris et al., 2014; Drury et al., 2008; Schraefel et al., 2012), there appears to be no significant changes to cognitive performance when compared to the sitting desk. Specifically, tasks that require processing speed should not be impacted and performance in them may even improve when using these desks.

Similar to the results in the Coding task showing a trend towards better performance, are the results from one study in which a significant improvement in processing speed was found when participants used a standing desk (Burford et al., 2013). A randomized repeated measures design was used to examine the effects of a standing desk on cognitive performance in 12 participants (Burford et al., 2013). Four tasks were used to test the different cognitive domains of visual perception, processing speed, attention and memory. Testing times were short with each task being performed on each participant once and for only five minutes. These testing times were short enough to cause cognitive changes, which is in accordance with the results of EEG research showing cortical activity to also change rapidly (Thibault et al., 2014). It was assumed, however, that this increase in cortical activity would reduce attentional capacity and lead to reductions in cognitive performance. This was not demonstrated by Burford et al. (2013) or by the results of the Coding task showing a trend towards better performance when standing. Additional research is required to examine these rapid cortical changes on cognitive performance and examine whether any additional changes occur over the long-term.

**Underlying mechanisms**

Improvements in cognitive performance were not found in this study, which was somewhat unexpected when the research into the effects of acute or long-term bouts of aerobic physical activity on cognitive performance is considered. Physical activity has been shown to improve
cognitive ability and processing speed specifically (Colcombe & Kramer, 2003; Ratey & Loehr, 2011; Smith et al., 2010). This is apparent in imaging studies which have revealed quicker processing speed capabilities in physically active individuals compared to less physically active individuals (Hillman et al., 2003; Kamijo & Takeda, 2010). Standing requires more physiological activity than sitting as shown by studies examining energy expenditure (Tudor-Locke, Schuna, Frensham, & Proenca, 2013), however, that level of physical activity must not be significant enough to result in measurable cognitive benefits that are seen in participants that train at higher activity levels.

The effects of standing as a power posture on cognition seem to be non-apparent when considering the results of this study. Standing is considered more of a power posture then sitting, and cognitive performance has been presumed to improve due to the physiological and psychological mechanisms that occur as a result of these postures (Carney et al., 2010). The results in this project do not reflect this, apart from the slight trend towards better performance in the Coding task. Other cognitive effects, however, could have occurred in other cognitive domains, but were not measured in this study.

Neuroimaging has shown cortical activity to increase in correlation with a more vertical position (Thibault et al., 2014). This would imply that more attentional resources are required to help maintain the upright position and perform additional tasks, such as talking or decision making. Since attentional resources are limited (Borel & Alescio-Lautier, 2014) it could be hypothesised that standing will cause a reduction in the performance of some of these cognitive tasks due to the additional attentional resources required while standing. In this study, any increase in cortical activity associated with standing does not appear to be great enough to reduce attentional resources when solving processing speed tasks. In fact, the results of the Coding task demonstrated a trend towards better performance in processing speed when standing, and a significant improvement has been shown in one other study (Burford et al., 2013). An increase in cortical activity must not be directly related to a reduced capacity to perform cognitive tasks, and other mechanisms must occur to cause this. One such mechanism is described in the theory of dual-tasking. This theory assumes that less attentional resources are required for automatic processes (Borel & Alescio-Lautier, 2014; Shiffrin & Schneider, 1977). Standing is considered an automatic process due to frequent dual-tasking that occurs daily with people standing and performing other activities and cognitive tasks simultaneously. This may prevent any noticeable increase in attentional resources when standing, causing processing speed to remain unchanged or even improve. An
interesting area for further research could be to examine the effects that a standing desk has on cognition in individuals with reduced attentional resources, such as the elderly or mentally impaired populations, as standing will require more effort and, therefore, have more of an effect on additional tasks occurring simultaneously.

**Limitations**

Various limitations within the data collection process that could impact the results of this study need to be acknowledged. Firstly, five assistant researchers supervised data collection and performed data entry for six participants each. This meant that only one-fifth of the data across all cognitive domains was handled by the author of this thesis. All assistant researchers were wholly briefed on the data collection process, including how to mark each task and record the information correctly, but, understandably, variations may have occurred that are difficult to identify. Secondly, this study is the first to test participants over a working day and a novelty effect may have obscured any effects of Condition, as could have fatigue. Since this area of research is only just emerging, more studies are required to investigate the effects that standing desks have on cognitive performance over a full working day, or longer, to test for this.

**Conclusion**

This study has shown that using a standing desk for a full working day does not lead to cognitive performance reductions in the domain of processing speed. In contrast, a trend toward better performance was found for participants that used the standing desks when completing the Coding task. Because sitting for long periods of time is detrimental to health, office workers have an alternative in standing desks that have been shown to reduce sedentary-related health risks without reducing the performance in tasks involving processing speed. The long-term cognitive effects from using a standing desk have not been sufficiently examined and research into this area may reveal certain unknown effects that standing desks have on cognitive ability. One such effect may be that the familiarity of using the desks will facilitate changes that were not observed in this study. Further research is also required to improve on the limitations of this study, which were acknowledged within the data collection and data entry processes. Other areas that could improve the knowledge-base of standing
desks include examining the financial cost/benefit of implementing standing desks into the workplace for the employer, examining the cognitive effects that standing desks have on populations with reduced attentional resource capacity, and performing longitudinal studies to examine the cognitive effects that standing desks have on office workers and school children in the classroom. This research has important implications for office workers interested in improving their health without impacting on, and even possibly improving, work performance in the cognitive domain of processing speed. It reveals that standing desks can be implemented into the workplace to combat sedentary-related problems related to the sitting desk without causing cognitive processing speed to reduce.
References


Roelofs, A., & Straker, L. (2002). The experience of musculoskeletal discomfort amongst bank tellers who just sit, just stand or sit and stand at work. Ergonomics SA.


# Appendices

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Appendix A: Ethics approval letter

Jamie Mannon and Lucy Patton
Osteopathy
Building 52
University Mt Albert Campus
Auckland

25.9.14

Dear Jamie and Lucy,

Your file number for this application: 2014-1085
Title: To what extent does working from a standing desk influence cognitive performance.

Your application for ethics approval has been reviewed by the Unitec Research Ethics Committee (UREC) and has been approved for the following period:

Start date: 25.9.14
Finish date: 25.9.17

Please note that:

1. The above dates must be referred to on the information and consent forms given to all participants.
2. You must inform UREC, in advance, of any ethically relevant deviation in the project. This may require additional approval.

You may now commence your research according to the protocols approved by UREC.

We wish you every success with your project.

Yours sincerely,

Sara Donaghey
Acting Deputy Chair, UREC
Appendix B: Ethics written consent form

Participant Consent Form

To what extent does working from a standing desk influence cognitive performance

I have had the research project explained to me and I have read and understand the information sheet given to me.

I understand that I don't have to be part of this if I don't want to and I may withdraw at any time prior to the completion of the research project.

I understand that everything I say is confidential and none of the information I give will identify me and that the only persons who will know what I have said will be the researchers and their supervisor. I also understand that all the information that I give will be stored securely on a computer at Unitec for a period of 5 years.

I understand that I can see the finished research document.

I have had time to consider everything and I give my consent to be a part of this project.

Participant Signature: ………………………………………………………………………………….. Date:
……………………………………

Participant Name: …………………………………………………………………………………………
…………

Project Researcher: ………………………………………………………………………………. Date:
……………………………………
UREC REGISTRATION NUMBER: 2014-1085

This study has been approved by the UNITEC Research Ethics Committee from 25.9.14 to 25.9.17. If you have any complaints or reservations about the ethical conduct of this research, you may contact the Committee through the UREC Secretary (ph: 09 815-4321 ext 6162. Any issues you raise will be treated in confidence and investigated fully, and you will be informed of the outcome.
Appendix C: Participant information sheet

Information for participants

Research Project Title:

To what extent does working from a standing desk influence cognitive performance?

Synopsis of project

Recent evidence shows that a high level of sedentary behaviour, such as prolonged sitting, is negatively correlated with an increased metabolic risk score, risk of cardiovascular events, and all-cause mortality.

The introduction of standing desks into the workplace offers a potential solution to the inactivity problem. Given that desks are typically workplace tools, it is logical to enquire about the effects of a standing desk on cognitive performance.

The goal of this project is to evaluate the effects of working from a standing desk compared with a seated desk on cognitive performance during a simulated working day.
What we are doing

To find out more we are asking all participants to perform 7.5 hours of tasks that emulate a typical office working day (e.g., transcription, data entry…) and various validated cognitive performance measures (e.g., solving puzzles, recalling numbers). All participants will attend two days; one day performed from a normal sitting desk, and one from a standing desk. Scheduled breaks are included, and standing desk participants are allowed to sit when they feel they need to (but are “encouraged” to stand as much as comfortable).

Participants will be asked to wear comfortable footwear, and match their dietary intake (i.e., coffee, sugars) for both days.

To participate in this study you will need to be between 18 and 50 years of age, and will need to feel confident in your ability to stand comfortably for extended periods of time. You will not be able to participate if you have 1) musculoskeletal pathologies preventing or influencing your ability to stand for prolonged periods, and 2) cognitive pathologies, such as chronic fatigue or any previous serious head injury, or be taking medications, which may affect concentration and cognitive performance.
What it will mean for you

Involvement in this study will require you to attend a familiarisation session of approximately 90 minutes at the Unitec Mount Albert campus. During this session you will get to see all the tasks that will be performed during the study, and will be given the opportunity to ask questions about the study before choosing to enrol.

If you choose to enrol, you will attend a full day (9:00 am to 4:30 pm) at the Unitec Mount Albert campus where you will be allocated to either a standing or sitting desk. You will be provided with numerous tasks to perform throughout the day, and will be guided through all tasks by a researcher. All tasks can be completed from the desk, and all tasks involve varying amount of cognitive load (i.e., they are all thinking tasks). There are three break periods throughout the day, and standing desk participants are allowed to sit when needed.

You will need to also attend a second day, approximately one week later, where you will repeat the day using a different desk (everyone will do one day from each desk). Upon completion of the second day you will be compensated with $200 for your time. You may also be sent an overview of the findings upon completion of data analysis and interpretation.

If you agree to participate, you will be asked to sign a consent form. This does not stop you from changing your mind if you wish to withdraw from the project. Your parent/guardian can also ask for you to be withdrawn.

Your name and information that may identify you will be kept completely confidential. All information collected from you will be stored on a password protected file and only you and the researchers involved will have access to this information.

Please contact us if you need more information about the project. At any time if you have any concerns about the research project you can contact the principal investigators:
This study has been approved by the UNITEC Research Ethics Committee from 25.9.14 to 25.9.17. If you have any complaints or reservations about the ethical conduct of this research, you may contact the Committee through the UREC Secretary (ph: 09 815-4321 ext 6162). Any issues you raise will be treated in confidence and investigated fully, and you will be informed of the outcome.
Appendix D: Outline of all the tasks in one testing session

<table>
<thead>
<tr>
<th>Number order that the tasks were completed in</th>
<th>Task name</th>
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<tbody>
<tr>
<td>1.</td>
<td>Trail Making</td>
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<tr>
<td>2.</td>
<td>Symbol Search</td>
</tr>
<tr>
<td>3.</td>
<td>CPT-AX</td>
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<td>4.</td>
<td>Spatial Span</td>
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<td>5.</td>
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<td>6.</td>
<td>Stroop Effect</td>
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<td>7.</td>
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<td>8.</td>
<td>Figural Intersection</td>
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<td>9.</td>
<td>Letter Number Seq.</td>
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<tr>
<td>10.</td>
<td>Visuospatial Search</td>
</tr>
<tr>
<td>11.</td>
<td>Rapid Pic Naming</td>
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<tr>
<td>12.</td>
<td>CPT-Inhibition</td>
</tr>
<tr>
<td>13.</td>
<td>Arithmetic</td>
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<tr>
<td>14.</td>
<td>Matrix Reasoning</td>
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<tr>
<td>15.</td>
<td>Verbal Fluency</td>
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<tr>
<td>16.</td>
<td>Coding</td>
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<td>17.</td>
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<td>Visual Reproduction</td>
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<td>Alphabetising</td>
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<td>W2.</td>
<td>Data Entry</td>
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<td>W3.</td>
<td>Proof Reading</td>
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<td>W4.</td>
<td>Transcription</td>
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Appendix E: Processing speed task instructions

Set 1 – Task 16: Coding

Instructions to Participants:

In the example below there is a coding key [point to coding key] that shows a symbol for each of the numbers one through to nine.

Your task is to fill in the correct numbers for the symbols in the rows below [point to rest of rows].

You must start here [point to first square, first row] and add a number for each symbol in turn, without missing any [point to 3 or 4 squares in order].

You will have 60 seconds to complete as many as you can. Work as quickly and as accurately as possible.

Complete the example to show your understanding of the task.

Example:

<table>
<thead>
<tr>
<th>≥</th>
<th>×</th>
<th>ω</th>
<th>ε</th>
<th>α</th>
<th>+</th>
<th>×</th>
<th>φ</th>
<th>≤</th>
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<td>1</td>
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<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>8</td>
<td>9</td>
</tr>
</tbody>
</table>

| α | × | ≥ | φ | ω | ε | × | ε | + | × | ε | ≥ | + | φ | × |

Do you have any questions? [answer any questions]

Ok, are you ready? Go!

For research use only:

<table>
<thead>
<tr>
<th>Number completed</th>
<th>Number correct</th>
<th>Number of errors</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Set 1 – Task 2: Symbol Search

Instructions to Participants:

In this task you work your way down a page of lines with symbols similar to that shown here [point to example]. Do each line in turn.

You will see two target symbols on the left [point to target symbols in example] and a line of symbols on the right [point to line of symbols in example].

Your task is to decide whether either of the two target symbols on the left [point] appear in the line of symbols on the right [point].

If either of the target symbols on the left appears in the line of symbols on the right, circle the ‘Y’ [point to Y in example] indicating “yes”.

If neither of the target symbols are in the line of symbols, circle the ‘N’ [point to N in example] indicating “no”.

You will have 60 seconds to complete as many items as possible. Work as quickly as you can without making mistakes. It’s ok to correct mistakes as you go.

Here is an example for you to try out before we begin.

Example:

<table>
<thead>
<tr>
<th>♦</th>
<th>#</th>
<th>≤</th>
<th>Ø</th>
<th>D</th>
<th>#</th>
<th>øe</th>
<th>Y</th>
<th>N</th>
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<td>≠</td>
<td>+</td>
<td>Ω</td>
<td>G</td>
<td>Y</td>
<td>N</td>
</tr>
</tbody>
</table>

Do you have any questions? [answer any questions]

Ok, are you ready? Go!

For research use only:

<table>
<thead>
<tr>
<th>Number completed</th>
<th>Number correct</th>
<th>Number of errors</th>
</tr>
</thead>
</table>
Set 1 – Task 7: Cancellation

Instructions to Participants:
For this task you are required to put a line through two target items as you work through a line of items of similar colour and shape.

The two target items are shown in a box at the top of the page [point to box in example], so in this example you would be searching for all the red triangles and blue circles. You wouldn’t put a line through blue triangles or red circles.

It is important to note that you need to work along the lines from left to right [researcher to indicate direction in example], crossing through as you go, and this means that you cannot go backwards [indicate backwards], so try not to miss any as you work along the lines of shapes.

The red triangle and the blue circle do not have to appear together in order for you to cross them out. Just cross any red triangle and any blue circle that you come to.

Here is an example for you to practice on. Work as quickly as you can without making mistakes.

Example:

![Example Image]

When we begin on the next page, you will be given 60 seconds to cross through as many of the target items as you can.

Do you have any questions? [answer any questions]

Ok, are you ready? [turn page] Go!

For research use only:

<table>
<thead>
<tr>
<th>Number of items completed</th>
<th>Number correct</th>
</tr>
</thead>
</table>
Set 1 – Task 11: Rapid Picture Naming

Instructions to Participants:

In this task an image will be displayed on the computer screen.

Your task is to say the name of the image as quickly as you can.

Once you have identified the image the next image will be displayed. This will continue until you have finished the set.

Name the images as quickly as you can and I will time how long it takes for you to name all 40 images.

Do you have any questions? [answer any questions]

Ok, are you ready? Go!

---

For research use only:

<table>
<thead>
<tr>
<th>Time to complete set (in minutes and seconds)</th>
<th>Number correct</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>


Appendix F: Participant log

1. What day of the week is it today? Circle one.

   Monday   Tuesday   Wednesday   Thursday   Friday   Saturday   Sunday

2. In the last 24 hours, what exercise have you engaged in? Include the exercise type and intensity.

3. Do you currently have any injuries or pain? If so, please describe.

4. Are you currently on any medication or supplements? If so, please describe?

5. Do you smoke? If so, how many cigarettes have you had in the last 24 hours

   ☐ I do not smoke       ☐ 1-5
   ☐ 6-10              ☐ 10+

6. How much alcohol have you consumed in the last 24 hours?

   ☐ no drinks       ☐ 1-2 drinks
   ☐ 3-4 drinks     ☐ 5-6 drinks
   ☐ 7+ drinks

7. Have you taken other substances in the last 24 hours? If so, please describe?
8. How many hours sleep have you had in the last 24 hours?

9. If you were to rate your quality of sleep in the last 24 hours, what score would you give it?

<table>
<thead>
<tr>
<th></th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Poor</td>
<td>Excellent</td>
<td></td>
<td></td>
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</tbody>
</table>

10. How are you feeling today (please comment on fatigue, energy, pain, discomfort, feeling unwell or rundown, have any significant life events occurred recently)?

11. What shoes are you wearing today?
(Please ensure that you wear the same shoes each time you engage in the study)

12. Has your morning routine changed in the last 24 hours? If so, please describe.
Appendix G: Nutritional intake form

1. Please provide a list of drinks you have had today (include coffee, tea, water, juices, and any energy drinks or supplement drinks. If nil, please state)

2. Provide a detailed list of food (and quantity where possible) you have consumed today (including snacks)

<table>
<thead>
<tr>
<th>Breakfast</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Morning Tea</td>
<td></td>
</tr>
<tr>
<td>Lunch</td>
<td></td>
</tr>
<tr>
<td>Afternoon Tea</td>
<td></td>
</tr>
</tbody>
</table>

3. Provide a list of any supplements consumed today (Example: Multivitamin, fish oil, protein powder. If Nil, please state)
Full name of author:  

Aaron Nathaniel Henry

Full title of thesis/dissertation/research project:  

Standing Whilst Thinking: An examination of the effect of standing desks on cognitive processing speed

Department of:  

Osteopathy

Degree:  

Masters of Osteopathy  
Year of presentation:  

2015

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Date:  22.12.2015