THE EFFECT OF TOTAL STANDING DURATION DURING SIT–STAND REGIMES ON COGNITIVE PERFORMANCE, RATING OF PERCEIVED EXERTION AND HEART RATE FREQUENCY

BY

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ABSTRACT

Although there may be numerous health benefits of sit-stand workstations, the effects of sedentary or non-sedentary work configurations on cognitive performance and executive function remain unclear (Bantoft *et al.*, 2016). It is essential to determine any performance effects of these different work configurations; as improvements in the workplace, working posture and discomfort need to be justified in terms of improvements (or no deterioration) in work performance (Liao and Drury, 2000). The aim of the current research was to investigate the effect of two sit-stand regimes differing in total standing duration, on cognitive task performance, physiological responses and subjective ratings of perceived exertion.

This laboratory based investigation incorporated a repeated measures design, where a test battery was utilized. Three experimental conditions were tested during three separate testing sessions by 30 participants. Condition 2 (15 minutes standing, followed by 45 minutes seated) and Condition 3 (15 minutes seated, followed by 15 minutes standing, followed by 15 minutes seated, followed by 15 minutes standing) were compared to each other and Condition 1 (60 minutes seated).

The findings of this study show that even though the two different sit-stand regimes did not result in a significant impact on cognitive task performance, an immediate postural effect for psychomotor response time and a delayed postural effect for working memory were found. The participants perceived Condition 3 as the most physically exerting condition. Heart rate frequency was not significantly different between the conditions, but the immediate seated posture had a significantly lower heart rate frequency compared to the standing posture; indicating that being seated elicited lower energy expenditure compared to standing. Heart rate frequency while standing had a greater degree of variation compared to being seated.

Taking the findings of this study into account, it is recommended that: one should be seated while performing this type of working memory task; that one should be standing while performing this type of psychomotor task; that the recommendation that implementing standing at work can be used as a blanket strategy to increase energy expenditure in all individuals needs to be explored further and that individual differences may impact energy expenditure.

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CHAPTER 1

INTRODUCTION

Office work exposes people to high amounts of sedentary time (Pesola *et al.*, 2014), consisting of long periods of sitting with minimal muscle activity (Ainsworth *et al.*, 2000). It has been estimated that most people spend eight to nine hours of their daily waking time being sedentary (Straker *et al.*, 2013). Although desk and computer work have traditionally been performed while seated (Wilks *et al.*, 2006), the introduction of non-sedentary work configurations, which encourage standing rather than sitting, have become more popular in work environments (Knight and Baer, 2014). Standing may be a practical working position for workers handling heavy equipment, as the processes require frequent movements and large degree of freedom (Halim *et al.*, 2012), but office workers tend to prefer being seated, as sitting uses less energy than standing (Lehman *et al.*, 2001) and because standing becomes increasingly tiring after a period of time (Lehman *et al.*, 2001).

Sedentary time has been found to be a significant contributor to hypokinetic disease risk (Dunstan *et al.*, 2012). Hypokinetic diseases are those diseases caused by a lack of movement (Hoeger, 2002). Prolonged static sitting has been linked with less healthy metabolic profiles compared to interrupted sitting (Healy *et al.*, 2008), indicating that it is not only the duration of sedentary time which is a significant contributor to hypokinetic disease risk, but also the frequency at which sedentary time is accumulated (Healy *et al.*, 2008). In response to the unfavourable associations of the duration (Dunstan *et al.*, 2012) and frequency (Healy *et al.*, 2008) of sedentary time, non-sedentary work configurations have been promoted in office work environments (Knight and Baer, 2014).

Since most office workers work for an average of eight hours each weekday, the workplace has been seen as the ideal setting in which to introduce strategies to reduce sedentary time and to break up periods of prolonged sitting in order to improve worker health (Alkhajah *et al.*, 2012). Sit-stand workstations offer a potential solution to the problem of hypokinetic disease risk associated with prolonged sitting (Pickens *et al.*, 2016). A sit-stand workstation is defined as a workstation that allows a user to perform the same tasks from either a seated or standing posture, by adjusting the work surface height quickly and safely with minimal disruption in task performance (Karakolis *et al.*, 2014). The sit-stand work paradigm consists of a worker performing their duties while periodically alternating between sitting and standing throughout the day to introduce whole body postural variation (Karakolis *et al.*, 2014).

Although there may be numerous health benefits of sit-stand workstations, the effects of sedentary or non-sedentary work configurations on cognitive performance and executive function remain unclear (Bantoft *et al.*, 2016). It is essential to determine any performance effects of these different work configurations; as improvements in the workplace, working posture and discomfort need to be justified in terms of improvements (or no deterioration) in work performance (Liao and Drury, 2000). The aim of the current research was to investigate the effect of different sit-stand regimes on cognitive task performance, physiological responses and subjective ratings of perceived exertion. Further aims of this study was to determine whether there was any immediate effects of a standing posture versus a seated posture and any delayed (after) effects of the initial posture (standing versus seated).

CHAPTER 2

REVIEW OF LITERATURE

It has been estimated that most people spend eight to nine hours of their daily waking time being sedentary (Straker *et al.*, 2013). Metabolic equivalent tasks (METs) quantify the energy expenditure of activities, where one MET corresponds to the resting metabolic rate. Sedentary behaviours are defined as sitting or reclining while awake, resulting in little or no energy expenditure and characterized by an energy expenditure ≤1.5 METs (Ainsworth *et al.*, 2000). Workers in desk-based roles have high occupational sitting time (Parry and Straker, 2013; Thorp *et al.*, 2011). Occupational sitting is defined as a sedentary behaviour that is accrued as part of, or relating to, work (Straker *et al.*, 2016). Furthermore, sedentary behaviour has been more precisely defined as too much sitting as distinct from too little physical activity (Júdice *et al.*, 2016). Research shows that prolonged occupational sitting results in low activity energy expenditure (Hamilton *et al.*, 2007), acute negative metabolic effects (Healy *et al.*, 2008), greater associations with cardiovascular morbidity (Hamilton *et al.*, 2007) and musculoskeletal pain (Lis *et al.*, 2007). Additionally, prolonged sitting has been found to be a risk factor for all-cause mortality, independent of physical activity (van der Ploeg *et al.*, 2012). Consequently, reducing sitting time is emerging as a priority for workplace health, in order to reduce these risks in office workers (Chau *et al.*, 2010; Healy *et al.*, 2011).

2.1. Energy Expenditure

Humans have been increasingly spending more time in sedentary behaviours, especially involving prolonged sitting (Hamilton *et al.*, 2007). Church *et al.* (2011) estimated that occupational physical activity has, since 1960, declined by an average of 142 kilocalories (kcal) a day. Of greater concern is that those who are sedentary for a large proportion of their working day do not compensate by increasing their physical activity levels and/or reducing their sedentary behaviour during leisure time (Parry and Straker, 2013). This alone could explain a substantial amount of weight gain in the population (Church *et al.*, 2011). Ainsworth and colleagues' (2000) Compendium of Physical Activities show that energy is expended at a rate of 1.0 to 1.5 METs during sitting, compared with 1.6 to 2.9 METs during standing. It must be acknowledged that the Compendium of Physical Activities provide 'general guidelines' for energy expenditure equivalence per activity and do not take individual differences that may impact energy expenditure into account (Ainsworth *et al.*, 2000). Evidence of the energetic cost of standing versus sitting is equivocal at best, with large variation in reported mean values (Miles-Chan *et al.*, 2013). Reiff *et al.* (2012) investigated whether being seated or standing while working resulted in differences in energy expenditure. This study made use of a repeated measures design, utilizing twenty healthy young adults, who performed a series of mathematical problems for 45 minutes while sitting at a standard desk and while standing at a standing desk. Indirect calorimetry was used to determine energy expenditure. The results indicated significant greater energy expenditure in the participants while using the standing desk compared to the traditional seated desk.

Similarly, Speck and Schmitz (2011) compared the energy expenditure of sitting at rest to working on a computer while sitting on a chair, sitting on an exercise ball and standing. This study also used a repeated measures design, but comprised thirteen obese individuals, whom arguably would benefit from the proposed supplementary energy expenditure. However, the computer task was performed for a duration of only seven minutes for each condition. Indirect calorimetry was used to determine energy expenditure and no significant differences in energy expenditure were found between the different computer activity positions. These two opposing findings could be owing to the fact that seven minutes was too short a duration to elicit any significant results or it may suggest that individual differences may influence the difference in energy expenditure between standing and seated work.

Miles-Chan *et al.* (2013) found that mean standing energy expenditure (using indirect calorimetry) was significantly higher compared to mean sitting energy expenditure of 20 healthy young adults. This finding was in agreement with the finding of Reiff *et al.* (2012); however, upon further examination and taking individual differences into account, the following differences in phenotypes relating to energy expenditure during standing were revealed: some may benefit from a 10% increase in energy expenditure, others show only an acute increase, or little or no increase at all (Miles-Chan *et al.*, 2013). This study discovered three distinct phenotypes based on the magnitude and time-course of the energy expenditure response to steady-state standing. Firstly, non-responders who showed little or no change in energy expenditure during standing relative to sitting; secondly, responders who showed sustained, elevated energy expenditure during standing and lastly, responders who decreased their energy expenditure to baseline sitting values during the second half of the standing period. This indicates that for the last phenotype, the transition from seated to standing resulted in a greater level of energy expenditure and not the actual standing posture. Furthermore, no correlation was found between energy expenditure response and anthropometry (body weight or height), BMI or body composition (Miles-Chan *et al.*, 2013).

Júdice *et al.* (2016) determined that the metabolic cost of a single sit-stand transition was about 0.32 kcal (35% above sitting) and suggested that workers should frequently interrupt sitting with standing, as the accumulative effects of the higher energy expenditure of sit-stand transitions may be beneficial. In agreement with the findings of Miles-Chan *et al.* (2013), Júdice *et al.* (2016) also found that the energy expenditure response is significantly independent of sex and body composition. These findings challenge the recommendation that implementing standing at work can be used as a blanket strategy to increase energy expenditure in all individuals. Individual differences that may impact energy expenditure need to be considered.

2.2. Metabolic Health

Although strategies to increase occupational energy expenditure would be beneficial for preventing weight gain, it has been proposed that prolonged sitting may lead to other harmful health-related consequences (Healy *et al.*, 2008). During standing, postural muscles (predominately those of the lower limbs) are continually contracting in order to keep the body upright and prevent loss of balance, which is absent while sitting (Hamilton *et al.*, 2007). This leads to changes in two key physiological responses that can promote poor metabolic health (Bey and Hamilton, 2003). Firstly, skeletal muscle lipoprotein lipase (LPL) production is suppressed. The LPL enzyme is necessary for breaking down triglycerides in the body and the suppression of LPL induced through a sedentary state can lead to elevated triglyceride levels, raising the risk of heart disease. Secondly, the breaking down and use of glucose is reduced, thereby contributing to elevations of glucose within the blood, which can lead to diabetes. The decline in LPL activity observed with being sedentary does not appear to exist when incidental, light-intensity activity (including standing) is introduced (Hamilton *et al.*, 2007). In contrast, the findings of a study by Bailey and Locke (2014) suggest that interrupting sitting time with frequent brief bouts of standing (two minutes of still standing every 20 minutes) imparts no beneficial postprandial responses that may enhance cardiometabolic health, but interrupting sitting time with frequent brief bouts of light-intensity activity (two minutes of light-intensity walking every 20 minutes) does. The long-term effects of sedentary behaviour on LPL activity and the extent to which this may be counteracted by regular bouts of incidental activity is however unknown (Hamilton *et al.*, 2007).

2.3. Musculoskeletal Discomfort and Fatigue

The area of support in static standing and static sitting are different, leading to different trunk muscle activity to stabilise the body and therefore resulting in different spinal shrinkage. Static standing is defined as a posture in which a worker stands still while performing a task (Messing and Kilbom, 2001, Balasubramanian *et al.*, 2008). Spinal shrinkage over the course of the day is part of the normal diurnal height change where approximately 1% of total stature loss occurs (Tyrell *et al.*, 1985). These losses are predominantly a result of height reductions in the intervertebral discs (Watson *et al.*, 2012). This occurs through the initial lateral bulging of the annulus fibrosus (Rodacki *et al.*, 2005) and the subsequent fluid loss from the nucleus pulposis (Adams and Hutton, 1980). Reducing the height of the intervertebral discs increases or causes abnormal loading on the zygapophysial joints and spinal ligaments (Pollintine *et al.*, 2004), which has been associated with low back pain (Adams and Hutton, 1980).

Leivseth and Drerup (1997) found that while working over six and a half hours, total spinal shrinkage was greater in a static standing posture, compared to a static seated posture. This was a result of a decrease in the stature of both the lumbar spine and the thoracic spine. The decrease in stature of the thoracic spine was found to be similar in both postures, while the decrease in stature of the lumbar spine was greater in the standing posture compared to the sitting posture. The additional shrinkage of the lumbar spine during standing resulted in the greater total spinal shrinkage found. Leivseth and Drerup (1997) concluded that it may be that the standing posture predominantly loads the lumbar spine. It must be noted that whether seated or standing, shrinkage of the spine resulted over time; standing work however, led to a quicker and greater shrinkage of the spine compared to seated work.

Balasubramanian *et al.* (2008) found that during a one hour task, a static standing posture fatigues the lower extremity muscles at a faster rate than a dynamic standing posture. Dynamic standing is defined as a posture in which the worker intermittently moves around while performing a task (Messing and Kilbom, 2001, Balasubramanian *et al.*, 2008). Kraemer *et al.* (1985) described how disc nutrition was dependent on variations in the intradiscal pressure creating a fluid flow into and out of the discs. It could therefore be reasoned that the variation between sitting and standing may be beneficial for the intervertebral discs (Wilks *et al.*, 2006) and to decrease fatigue rates of the lower extremity muscles (Balasubramanian *et al.*, 2008).

Prolonged standing in the workplace has also been shown to cause body discomfort and muscle fatigue, especially in the lower extremities of workers, by the end of the workday (Halim *et al.*, 2012). Body discomfort or subjective fatigue can be linked to psychological fatigue and this has been recognized as a factor in the decline of alertness, mental concentration, and motivation (Simonson and Weiser, 1976). Halim *et al.* (2012) assessed workers through questionnaire surveys and found that they experienced psychological fatigue due to prolonged standing. The complaint of fatigue was reported in the gastrocnemius muscle, which experienced fatigue before the erector spinae muscles and the tibialis anterior muscles. Halim *et al.* (2012) also found objective muscle fatigue using electromyography, which supported the finding of subjective fatigue as reported by workers. Halim *et al.* (2012) went on to explain that in a worst case scenario, the effects of prolonged standing may result in a performance decrement, such as low productivity and efficiency, increased medical costs and demoralized workers.

Based on the results obtained, Halim *et al.* (2012) proposed that standing with intermittent sitting would be the best solution to minimize discomfort and muscle fatigue associated with prolonged standing. They also noted that sitting for long periods of time is also not good for health and that sitting is a much less strenuous posture than standing, mostly because it requires fewer muscles to be contracted to stabilize the body. Chester *et al.* (2002) found that workers subjectively preferred sitting for 90 minutes, compared to standing or using a sit-stand chair.

Therefore, neither static standing nor static sitting is recommended, as the alternation between the two postures allows for increased rest intervals of specific body parts and a reduced potential for risk factors commonly associated with musculoskeletal disorder development (Roelofs and Straker, 2002). Corlett (1978) recommended that work spaces should be arranged in such a way, that work may be done in either a seated or standing position, as the combinations of postures are useful in reducing the workload and the monotonous feelings of a repetitive task. Beach *et al.* (2005) also advocate that extended periods of sitting be interrupted with other non-sedentary activities.

2.4. Cognitive Performance

When it comes to cognitive performance and executive function, the benefits of standing or sitting are less clear. Cognitive function largely involves the area of the brain known as the pre-frontal cortex, which is the anterior part of the frontal lobes of the brain, lying in front of the motor and premotor areas (Schraefel *et al.*, 2012). The term Cognitive Executive Function is often used as an umbrella-term for cognitive activities such as planning, working memory, attention, problem solving, verbal reasoning, multi-tasking and monitoring of actions among others, and are processes localized in the pre-frontal cortex (Schraefel *et al.*, 2012).

Human cognitive processing resources are limited; therefore, the effectiveness of performing cognitive work while standing can differ from that of performing cognitive work while seated (Kahnemann, 1973). Usually the performance on one or both tasks is often lower when tasks are performed simultaneously compared to when they are performed separately. This deterioration in performance is known as the dual-task cost (Pashler, 1994). In the case of dual-task costs, it is assumed that the tasks compete for the same sort of information processing resources (Wickens, 1984). However, a highly automated task (like standing), usually needs low information processing and although highly automated tasks compete for the same resources, dual-task costs should be low given that few resources are taken up (Beilock *et al.*, 2002). Therefore, in a sit-stand workstation paradigm, there may be competition for the same resources, which may lead to a reduction in cognitive performance (Husemann *et al.*, 2009).

Postural control while standing has been considered a highly automated process and it can therefore be presumed that it consumes minimal attention and cognitive resources (Regnaux *et al.*, 2005). Maintaining balance while standing is a highly practiced daily task for healthy adults and standing at work routinely takes place while at least one other concurrent task is being performed. Despite the high degree of automaticity, postural control processes may still require motor preparatory attention to facilitate multi-sensory integration and the generation of motor commands (Regnaux *et al.*, 2005). Therefore, maintaining an upright stance may drain cognitive resources, such as attentional processes, when the standing conditions are challenging or when attentional interference between postural control and cognitive processes is high. A growing body of scientific work shows that maintaining postural stability requires considerable information processing resources, which might in turn reduce performance on a second task (Jamet *et al.*, 2007; Siu and Woollacott 2007; Woollacott and Shumway-Cook, 2002).

Apart from the potential occurrence of a dual-task cost, the cognitive task will be interrupted by a short break when changing work positions (Husemann *et al.*, 2009). This break could lead to reduced efficiency or, alternatively, to improved cognitive performance because of activation of the cardiovascular system (Watanabe *et al.*, 2007) and increased arousal and awareness (Caldwell *et al.*, 2003). The degree of task complexity also seems to influence the extent to which postural effects become apparent (Woods, 1981). Arousal effects seem to appear only in instances where the task is of sufficient complexity to utilise all currently available resources. Woods (1981) found that a simple response time test did not reveal any postural effects, because the task was simple enough to be performed with existing resources. A choice response time test, on the other hand, was of sufficient complexity to require the older participants to make use of additional processing resources that may have been produced during the standing condition.

Research on the effects of acute physical movement on cognitive performance while simultaneously performing both tasks has generated equivocal evidence (Dutke *et* *al.*, 2014). Performing physical movement might not only generate cognitive resources, but also consume cognitive resources; as the motor control needed for the execution of physical movement also requires resources which cannot be simultaneously allocated to the cognitive task (Dietrich and Sparling, 2004). This competition for processing resources between the physical and cognitive task requirements can be observed when cognitive functioning becomes impaired during physical movement (Dietrich and Sparling, 2004). Thus, physical movement will only positively support cognitive performance when it induces an increase in resources that exceeds its resource consumption (Huertas *et al.*, 2011).

Husemann *et al.* (2009) performed a randomised control trial on 60 male participants between the ages of 18 to 35 years. Participants in the control group performed a 45 minute data entry task in a sitting position, while the intervention group performed a 45 minute data entry task in a sitting position for 30 minutes followed by 15 minutes in a standing position. A small non-significant loss of efficiency in data entry occurred in the intervention group. This is in accordance with several other studies on young adults performing a cognitive task that report no significant occurrence of dual-task cost while standing (Jamet *et al.*, 2007; Lindenberger *et al.*, 2000; Marsh and Geel, 2000; Redfern *et al.*, 2001). Commissaris *et al.* (2014) conducted an experiment measuring both objective and perceived work performance. With the exception of a high precision mouse task (a task that requires fine motor actions of the hands), short term work performance (typing, reading and correcting) was unaffected by working at a standing workstation. Participants perceived their short term work performance to deteriorate in all tasks while using the standing workstation, although this is in contradiction with the objective performance measures. Typing performance was also not negatively affected with 120 minutes of sit-stand workstation use (Ebara *et al.*, 2008). This study revealed that although the use of sit-stand workstations can contribute to keeping workers' arousal level steady, it had an adverse effect in light of musculoskeletal discomfort. No significant changes in typing performance were found between sitting and standing postures in studies which tested for a duration of 40 minutes (Drury *et al.*, 2008), 20 minutes (Beers *et al.*, 2008) and 3 minutes (Straker *et al.*, 2009).

Schraefel *et al*. (2012) conducted a study comparing the effect of two different body postures on six different cognitive executive function domains. The six cognitive executive function domains included: executive function, complex attention, cognitive flexibility, psychomotor speed, response time and processing speed. Only complex attention (measured by working memory) had a significant difference between the standing and seated conditions, with the seated condition having a more favourable outcome. Similarly, no effect of being seated or standing for 60 minutes was found on measures of working memory, selective and sustained attention, and information-processing speed (Bantoft *et al*., 2016). A study looking at the effect of the long term use of sit-stand desks on concentration performance found no difference over a 12 week period (Donath *et al*., 2015).

2.5. Productivity

Garrett *et al*. (2016) examined the productivity differences between two groups of call centre employees over the course of six months and found that those with sit-stand workstations were 45% more productive than those with seated desk configurations. Productivity was measured by how many successful calls workers completed per hour at work. Further, productivity of the stand-capable desk users significantly increased over time, from approximately 23% in the first month to approximately 53% over the next six months. The amount of time standing or frequency standing was however not measured. Contrary to this finding, a study by Chau *et al*. (2016) found that sit-stand desks increased standing time at work in call centre workers without affecting productivity (positively or negatively) over the course of 4 months.

2.6. Physiology of Sit-Stand Transitions

Postural adjustment from a sitting to a standing position is an orthostatic challenge (Hennig *et al*., 2000). As body requirements change, the autonomic nervous system regulates cardiac function, in order to maintain a stable internal environment (Watanabe *et al*., 2007). Upon standing from a seated position, the blood volume will shift downward toward the lower arms, legs and abdomen, reducing the quantity of blood available to maintain oxygen supply to the brain (Grubb and Karabin, 2008). Standing is accompanied by an automatic increase in heart rate, an increase in myocardial contractility and vasoconstriction in the lower part of the body to maintain a constant oxygen supply to the brain and upper body (Grubb and Karabin, 2008).

These responses reflect sympathetic arousal (Hennig *et al.*, 2000). Sit-stand transitions result in an increase in energy expenditure, as the metabolic cost of a single sit-stand transition is about 0.32 kcal (35% above sitting) (Júdice *et al.*, 2016).

2.7. Sit-Stand Transition Arousal

The ascending reticular activating system is thought to be responsible for maintaining a state of arousal and it has been found that standing stimulates the reticular activating system more than sitting (Lee and Dan, 2012). Arousal is a physiological and psychological state of being awake or reactive to stimuli. It involves the activation of the reticular activating system in the brain stem, the autonomic nervous system and the endocrine system, leading to increased heart rate and blood pressure and a condition of sensory alertness, mobility and readiness to respond (Coull, 1998). Attention may be thought of in the simplest terms as the appropriate allocation of processing resources to relevant stimuli (Coull, 1998).

Yerkes and Dodson (1908) described an inverted U-shaped curve relating performance with physiological arousal, suggesting that if arousal gets either too high or too low, performance will decrease and that maximal performance occurs when arousal states are neither very low nor very high. Research has found that different tasks require different levels of arousal for optimal performance (Diamond *et al.*, 2007). It has been proposed that the level of neural activation (a measure of physiological arousal) is an additional mediating variable with regard to response time (Vercruyssen *et al.*, 1989) and it appears that increased levels of arousal can improve performance on information processing tasks, in instances when the individual is initially functioning in a physiological state of under-arousal. The ideal level of arousal also depends on the complexity of the task (Diamond *et al.*, 2007). For more simple tasks, it is best for arousal to be high, while for more complex tasks, the best performance occurs around lower levels of arousal (Diamond *et al.*, 2007).

2.8. Compliance

The provision of sit-stand desks to workers with high occupational sitting time does not necessarily mean employees will shift from sitting to standing. Sit-stand desks have been found to have high usability and acceptability, while leading to reduced sitting time at work (Grunseit *et al.*, 2013). Wilks *et al.* (2006) found that 60% of men and women, across four companies (all desk-based work settings) who had recently been provided with sit-stand desks, reported using them once a month or less. It was noted that those who had received ergonomic education about sit-stand work configurations, reported more use of the sit-stand desks (Wilks *et al.*, 2006).

A randomized control trial by Robertson *et al.* (2013) investigated the effects of office ergonomics training combined with a sit-stand workstation on musculoskeletal discomfort, behaviours and performance. Ergonomics trained participants experienced minimal musculoskeletal discomfort across fifteen days, varied their postures and demonstrated significantly higher performance compared to the minimally trained group who had a significantly higher number of symptoms of discomfort; suggesting that ergonomics training plays a critical role in amount of use of sit-stand workstations, musculoskeletal discomfort and performance. With the provision of an adjustable sit-stand workstation, participants appeared to effectively transfer the training to appropriately change and adjust their workstation to mitigate symptoms, adopt healthy computing behaviours and enhance their performance.

CHAPTER 3

METHODOLOGY

3.1. Experimental Concept

This study aimed to investigate whether the total duration of standing time during different sit-stand regimes had an effect on cognitive task performance, subjective ratings of perceived exertion and heart rate frequency. This laboratory based investigation incorporated a repeated measures design, where a test battery was utilized. Experimentation occurred under controlled laboratory conditions; the laboratory was quiet and removed of distractions. A repeated measures design was chosen in order to minimize the effects of individual differences that could occur. The test battery used in this study included a variety of resource-specific tests designed to isolate perceptual, cognitive and motor resources that form part of the information processing chain (Wickens, 1984). Diggles *et al.* (1984) indicated that posture may have a greater influence on the specific stages of information processing, rather than a more generalized effect. Therefore, a variety of tasks requiring various cognitive resources in different magnitudes would be essential in order to determine whether posture has an influence on the specific stages of information processing.

Each cognitive test contained in this study included at least two levels of difficulty, considering that there is evidence to suggest that the degree of task complexity seems to influence the extent to which postural effects become apparent (Vercruyssen *et al.*, 1989). Postural effects seem to appear only in instances where the task is of sufficient complexity to utilise all current available resources (Woods, 1981). Woods (1981) found that a simple response time test did not reveal any postural effects, because the task was simple enough to be performed with existing resources. A choice response time test, on the other hand, was of sufficient complexity to require the participants to make use of additional processing resources that may have been produced during the standing condition. While the results would depend on the nature of the modality or stage of information processing being tested, this disparity warranted the inclusion of at least two levels of difficulty.

3.2. Experimental Design

3.2.1. Length of each condition

Each condition lasted 60 minutes. A 60 minute task duration was chosen as there is no definite indication that sit-stand regimes have an effect on cognitive task performance over an eight hour work shift. It was decided that in order to test for an entire work shift of eight hours, research on a shorter duration would be needed to motivate for the longer testing duration.

3.2.2. Conditions

Given the benefits with the reduction in sedentary exposure, Karakolis *et al.* (2014) proposed that it would seem warranted to target sitting to standing time somewhere between 1:3 and 3:1. The optimal frequency for changing postures has not been establish, however, Karakolis *et al.* (2014) suggested limiting standing to 15 minutes for newly implemented sit-stand workstations, which has been shown to be below the initiation time point for low back pain development. The test battery used in this study was designed to last fifteen minutes, in order for a complete cycle of fifteen minutes to occur either standing or seated and not a combination of both. Three experimental conditions were tested during three separate testing sessions.

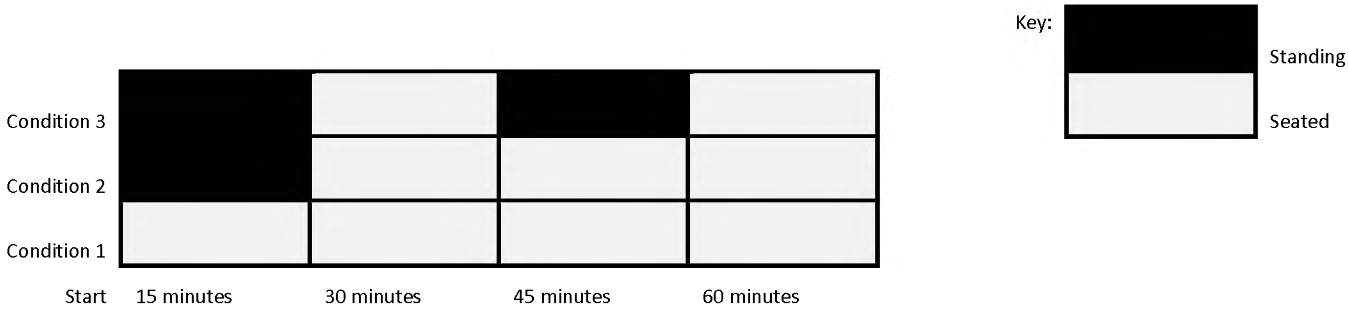


Figure 1: Postures for each 15 minute interval during the three conditions

Figure 1 illustrates the postures for each of the 15 minute intervals during the three conditions. Condition 1: 60 minutes seated, Condition 2: 15 minutes standing, followed by 45 minutes seated and Condition 3: 15 minutes seated, followed by 15 minutes standing, followed by 15 minutes seated, followed by 15 minutes standing.

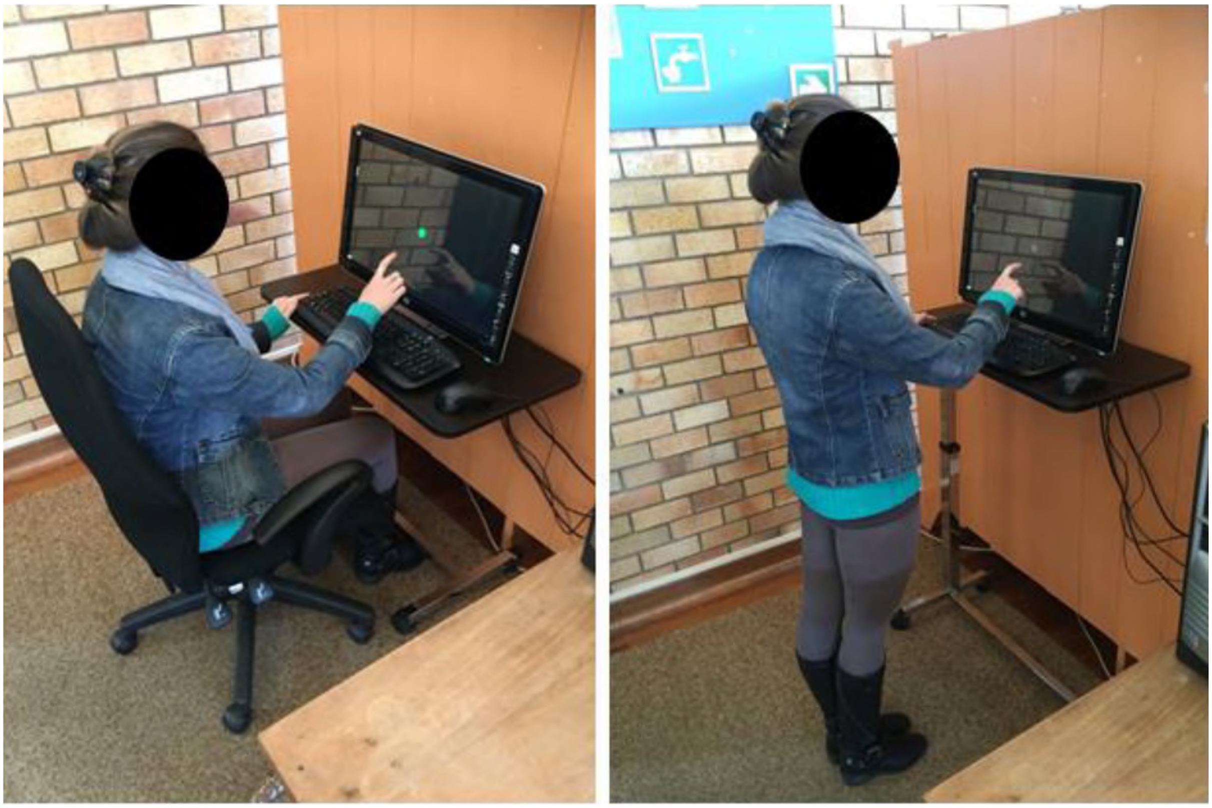


Figure 2: Participant in the seated positon (left) and the standing position (right)

Figure 2 depicts the two different postures employed in this study. A manually adjustable desk was used in this study and was adjusted for each participant to their body proportions and the recommended ergonomic guidelines (BIFMA, 2002).

3.3. Dependent Variables

3.3.1. Cognitive performance measures

Response time

Response time is a reliable indicator of the speed of processing of sensory stimuli by the central nervous system and its execution in the form of a motor response (Garg *et al.*, 2013). Response time is defined as the interval of time between the presentation of an external stimulus and the initiation of an appropriate voluntary motor response (Balakrishnan *et al.*, 2014). It reflects the speed of the flow of neurophysiological, cognitive and information processes which are created by the action of a stimulus on the person's sensory system (Balakrishnan *et al.*, 2014). The receipt of information, its processing, decision making and giving the response or execution of the motor act are the processes which follow one another and produce what is known as the response time (Baayen and Milin, 2010). Responses that take more time to initiate are assumed to require longer information processing times (Garg *et al.*, 2013).

There are three different types of response time experiments: simple, choice and recognition response time experiments (Balakrishnan *et al.*, 2014). In simple response time experiments, there is only one stimulus and one response. In choice response time experiments, there are multiple stimuli and multiple responses and the participant must give a response that corresponds to the stimulus presented (Miller and Low, 2001). In recognition response time experiments, there are some stimuli (the "memory set") that should be responded to and others (the "distracter set") that should not be responded to. It has been reported that the time for motor preparation and motor response was the same in all three types of response time tests, implying that the differences in response time are due to processing time (Miller and Low, 2001, Baayen and Milin, 2010).

Figure 3: Screenshot of the simple response time test

For the simple response time test (Figure 3), the participant was placed in front of a Hewlett Packard (HP) 23" LCD computer screen, where they had to respond to the presentation of a large green circular stimulus as rapidly as possible by clicking the left mouse button. Within this cognitive test, the performance characteristic measured was response time in seconds. This test lasted for three minutes (180 seconds) and during each test the participants were presented with 40 stimuli, with a randomised inter-stimulus interval of 500-3000ms (Davy, 2010).

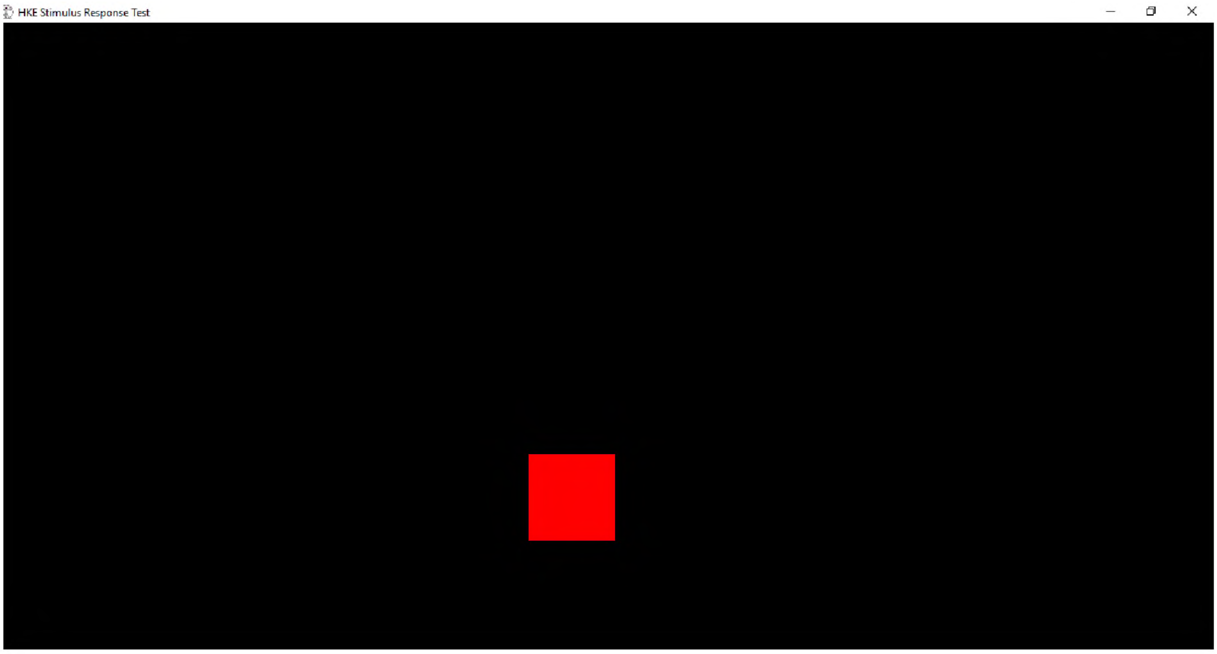


Figure 4: Screenshot of the choice response time test showing the red square stimulus requiring a response in the form of a right mouse button click

This choice response time test, adapted from Goble (2013), had the participants responding with a left or right mouse click in accordance to whether a green circle (left click) or a red square (right click) appeared on the screen in front of them (Figure 4). The green circular stimulus was identical to that of the simple response time test. Response time in seconds and the percentage of times that participants responded with the wrong mouse button (wrong button pressed) were recorded as performance measures in this test. This test lasted for three minutes (180 seconds) and during each test the subjects were presented with 192 stimuli with a randomised inter-stimulus interval of between 100-300ms (Davy, 2010).

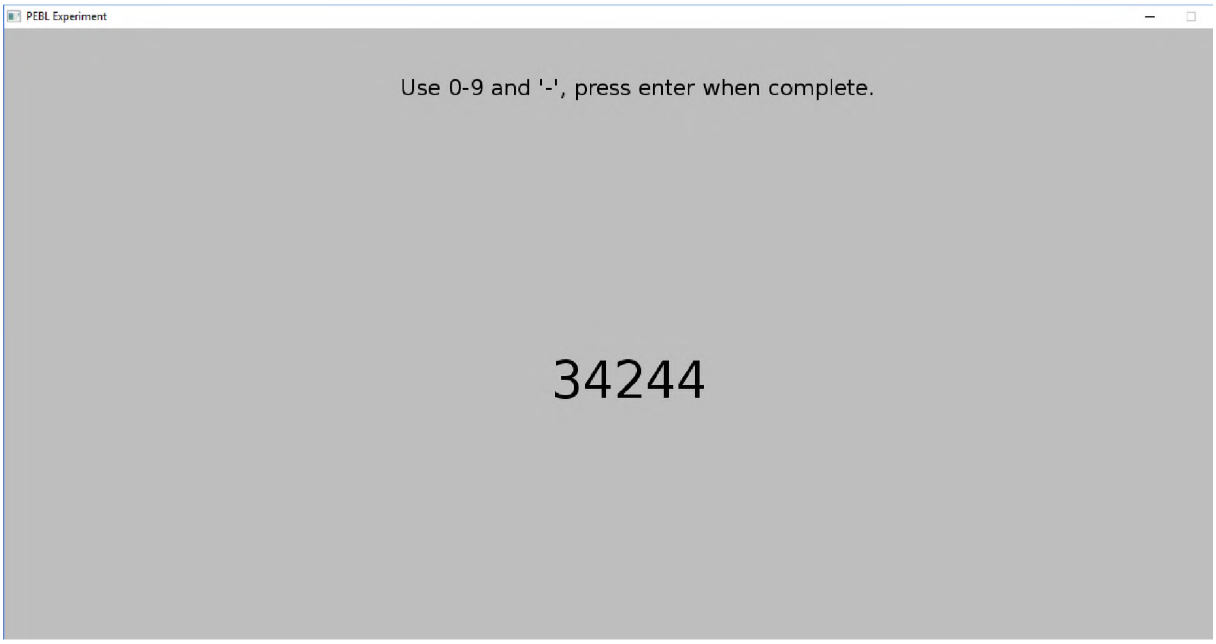
Figure 5: Screen shot of the recognition response time test, showing the red critical stimulus

The recognition response time test (Figure 5) implemented in this study was used to strain the visual system while simultaneously measuring stimulus recognition (Goble, 2013). The objective of this test was to differentiate and recognise one red critical stimulus among numerous white stimuli moving in random directions from one another. This measure has previously been sensitive to the effects of alcohol (Goble, 2013).

This test presented 60 white stimuli. The size of all stimuli was set at 2mm x 2mm and all were shaped in the form of dots. The participant was required to respond as quickly as possible to the critical stimulus (red star) with a critical response (left mouse button click) as soon as the critical stimulus was observed. The critical stimulus appeared in varying spatial orientations on the screen at random intervals between three and ten seconds (Goble, 2013). The response time to each target stimulus was recorded and the average response time over the test duration of 90 seconds was calculated. The percentage of errors of omission and commission over the test duration were also recorded.

Working memory performance

Working memory is a critical part of the information processing chain, as the short term retention of material has an impact on the decision making process and the appropriate response to the situation (Diamond, 2013). John *et al.* (2009) found that while walking on a treadmill, math problem solving performance decreased. This impact on math problem solving is consistent with the resource theory prediction that arousal impedes working memory (John *et al.*, 2009). In a sitting versus standing study, the low-arousal position of sitting gave the expected working memory advantage (Schraefel *et al.*, 2012). This study therefore included a version of a digit recall memory test (Figure 6) from the PEBL psychological test battery.



Use 0-9 and '-', press enter when complete.

34244

Figure 6: Screen shot of the PEBL working memory test showing a five string number

The participants were required to memorize the sequence of a string of numbers that were presented visually. Following a short delay after the presentation of the last number, the participant had to remember and input the sequence of numbers originally presented by keying them in using a keypad on the computer, pressing enter to confirm the sequence. Errors in the number of strings did not result in a reduction of the sequence length that needed to be recalled.

This test included two levels of difficulty; in both levels, participants were required to memorize a string of numbers, the only difference being the length of the string

(Goble, 2013). The easier level incorporated a string of five numbers (Figure 6), whereas the more difficult version incorporated a string of seven numbers. This test was repeated for five strings of five numbers and five strings of seven numbers. The duration of the tests were not limited, as some participants took longer to input (type) in their responses than others. The PEBL software recorded all relevant data including both correct and incorrect sequences. This information was translated into a Microsoft Excel spreadsheet for data analysis. Performance outcomes from this test included the amount of correctly recalled numbers.

Psychomotor performance

A computer task that requires fine motor actions of the hands (mouse pointing and clicking) was affected by movements at a standing workstation (Commissaris *et al.*, 2014). A tapping task, adapted from Chaplin (2013), Huysamen (2014) and Davy (2010) based on the Fitts' Task (Fitts, 1954), isolated the effects of the imposed conditions on motor programming and motor response time.

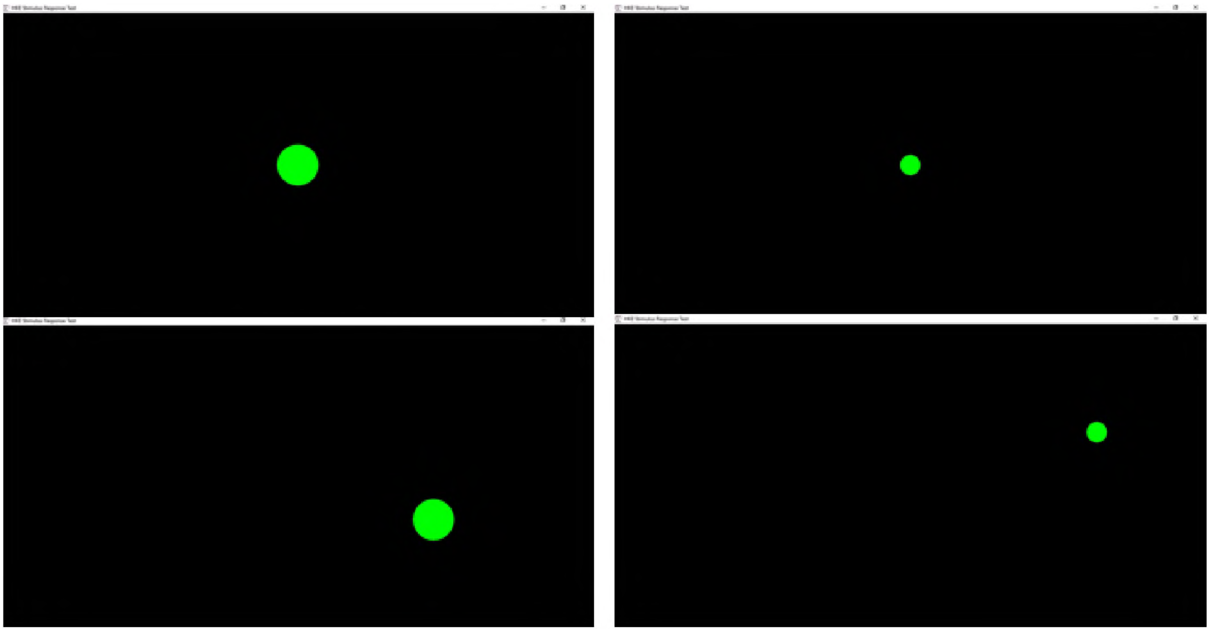


Figure 7: Screen shot of the psychomotor test showing the four possible scenarios: central-large (top left), central-small (top right), anywhere-large (bottom left) and anywhere-small (bottom right)

The psychomotor test (Figure 7) was comprised of both simple and complex elements, but in this instance, the two levels of complexity were amalgamated into one testing scenario. This test required participants to respond to stimuli (green dots on a black screen), by touching the stimulus on a Hewlett Packard (HP) 23" LCD touch screen in the shortest time possible using only their dominant hand. One of four stimuli would appear (one at a time) on a screen with a dimension of 550mm x 290mm.

Each stimulus was set to be presented in four varying scenarios, anywhere-large, central-large, anywhere-small and central-small. The large targets, irrespective of where they appeared, constituted the simple component, while the smaller targets, the more difficult component. More specifically, in instances of anywhere-large (24mm in diameter) and anywhere-small (12mm in diameter) targets, the stimulus would appear on the screen between −240mm and 240mm along the x-axis and −135mm and 135mm along the y-axis (anywhere on the screen). In instances of central-large (24mm in diameter) and central-small (12mm in diameter) targets, the stimulus would appear on the screen at −0mm and 0mm along the x-axis and −0mm and 0mm along the y-axis (the centre of the screen). The order of stimuli was alternated so that every second stimulus would appear at the centre of the screen. The duration of this test was set to 90 seconds, with a new stimulus appearing once the previous stimulus had been touched. Participants were placed at a set distance of 40cm from the touch screen. Furthermore, participants were instructed to use only their dominant hand to respond to the stimulus and to keep the hand in the same area of the screen once the stimulus had been responded to. This was done to ensure response time and motor programming time was not adversely affected. Response time (seconds) and target deviation (millimetres) were the measures of performance in this test.

3.3.2. Rating of perceived exertion

Subjective input was assessed in the form of Borg’s Rate of Perceived Exertion Scale (APPENDIX 1). This is a popular scale for ratings of exertion, as it is easy to use and understand (Borg, 1970). Borg’s (1970) Rate of Perceived Exertion Scale is a 15 point scale with verbal cues, ranging from 6 to 20, with 6 being “no exertion at all” to 20 being “maximal exertion”. A perceived exertion rating was recorded at the end of each condition, where the participant was asked to rate their perceived level of exertion required to perform the task. Perceived ratings of exertion were compared between conditions. These measures were not taken during the test battery at set intervals, as this may have affected the arousal and attention of the participants.

3.3.3. Heart rate frequency

The physiological responses of the different conditions were determined through heart rate frequency analysis. A Suunto® heart rate monitor was used to assess heart rate frequency. This equipment consisted of two units. The first unit was the Suunto® heart rate monitor and belt, to be placed on the participant’s chest. The second unit was the Suunto® docking station, which allows the recorded data to be downloaded from the heart rate monitor onto a computer. The data downloaded from the Suunto® heart rate monitor was stored by the Suunto Training Manager software. This data was analysed through the Human Kinetics and Ergonomics Department’s in-house data reduction tool.

3.4. Participant Characteristics

The participants ranged in age from 19 to 24 years and were a convenience sample of male and female Rhodes University students who were not habitual standing or sit-stand desk users, as the length of the implementation of sit-stand workstations have been shown to affect user comfort, which may in turn affect user performance (Karakolis *et al.*, 2014). The age range of 19 to 24 was chosen because according to Woods (1981) different age groups may have different responses to posture on cognitive performance. Participants volunteered to assist in this study for no remuneration.

Participants who reported having been diagnosed with attention deficit disorder (ADD), attention deficit hyperactivity disorder (ADHD) or any other disorder characterized primarily by inattentive concentration or a deficit of sustained attention were excluded from participation in this study. Furthermore, any participants with colour blindness were excluded from the study.

3.5. Ethical Consideration

3.5.1. Informed consent

Prior to testing, participants were verbally and in writing (APPENDIX 2) informed about the aims of the study, the procedures and what was required of them.

Participants were given the option of requesting that a female research assistant be present at the start and end of each session to fit and remove the heart rate monitor, if he/she did not feel comfortable with a male researcher fitting the heart rate monitor. After all participants were fully informed, consent forms (APPENDIX 3) were signed in order to agree to voluntarily participating in the study. This study was approved by the Human Kinetics and Ergonomics Ethics Committee prior to any testing taking place (APPENDIX 4).

3.5.2. Privacy and anonymity of results

All information was coded according to participant numbers, to ensure that data was kept confidential. Participants' data were kept until statistical analyses had been completed, after which it was deleted.

3.6. Experimental Procedure

Each participant was required to attend four laboratory sessions occurring at the same time of day, on four different days, at the Human Kinetics and Ergonomics Department. In the aim of maximal standardization of the procedure, the testing sessions were completed on separate days, to limit the accumulation of fatigue (Gutin, 1972) and at the same time of day for each participant, to limit the effects of the circadian rhythm (Becque *et al.*, 1993). The four laboratory sessions consisted of one habituation session and three testing sessions. A manually adjustable desk was used in this study and was adjusted for each participant to their body proportions and the recommended ergonomic guidelines (BIFMA, 2002).

3.6.1. Permutation

In order to account for a possible learning effect, the orders of the conditions were permutated between participants (APPENDIX 5). The order of the test battery was also permutated between participants, but the order remained the same for each of the conditions for each participant (APPENDIX 5).

3.6.2. Habituation session

Upon arrival to the habituation session, the researcher explained the protocol and the different conditions, ensuring that all participants understood what was required of them. A letter of information about the study and what was required before, during and after testing was also provided to all participants to read. Once each participant was fully informed and content with all the procedures, a letter of informed consent was signed. The participant was then introduced to the equipment (heart rate monitor, test battery, rating of perceived exertion scale and the adjustable workstation) and allowed to practice the test battery under all conditions, until he/she felt comfortable enough to perform the tests.

3.6.3. Testing sessions

Following the habituation session, the three experimental conditions were tested during three separate testing sessions. Upon arrival to each testing session, the participant was fitted with the Suunto® heart rate monitor. Once the heart rate monitor was placed on the participant, a five minute period of quiet sitting was provided in order to stabilise his/her heart rate. The participant then performed one of the three conditions. Participants were instructed to have no distractions (e.g. cell phones) with them in the testing laboratory and were instructed to remain silent during the testing protocol.

The researcher manually adjusted the workstation when a postural change was to be made. The participant performed the test battery for a duration of 60 minutes, after which the researcher terminated the testing session and removed the Suunto® heart rate monitor. The participant then had to rate his/her perceived exertion at the level at which he/she considered the task to be.

3.7. Data Processing

All data were imported into STATISTICA 8, where repeated analysis of variance (ANOVA) tests ($p<0.05$) were performed to identify significant differences in performance parameters, ratings of perceived exertion and physiological responses (heart rate frequency). Where appropriate, a Fisher post hoc analysis was performed in order to determine where the significance occurred. All data was analysed using the STATISTICA 8 software package to determine any significant differences, as well as graphically representing the findings.

3.8. Statistical Hypotheses

3.8.1. Condition effect

It is hypothesised that all measured parameters will be different between the three conditions.

H_0: μCondition 1 = μCondition 2 = μCondition 3
H_A: μCondition 1 ≠ μCondition 2 ≠ μCondition 3

3.8.2. Immediate postural effect

It is hypothesised that all measured parameters will be different between the immediate effects of the seated and standing posture.

H_0: μSeated = μStanding
H_A: μSeated ≠ μStanding

3.8.3. Delayed postural effect

It is hypothesised that all measured parameters will be different between the delayed effects of the seated and standing posture.

H_0: μSeated = μStanding
H_A: μSeated ≠ μStanding

3.8.4. Time-on-task effect

Time-on-task effects were not a main objective of this study; however, it is hypothesised that all measured parameters will be different between the four 15 minute intervals.

H_0: μQuarter 1 = μQuarter 2 = μQuarter 3 = μQuarter 4
H_A: μQuarter 1 ≠ μQuarter 2 ≠ μQuarter 3 ≠ μQuarter 4

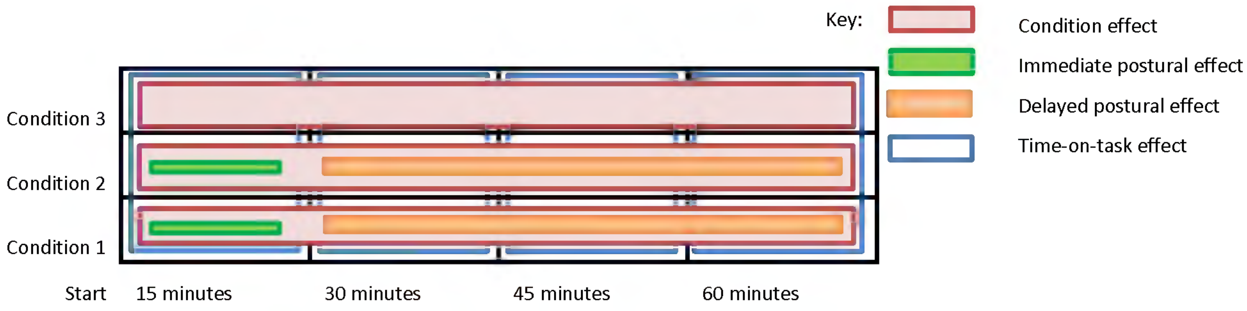


Figure 8: The condition effect, immediate postural effect, delayed postural effect and time-on-task effect hypotheses

Figure 8 illustrates the hypotheses, indicating the four effects: the condition effect, the immediate postural effect, the delayed postural effect and the time-on-task effect. Since the rating of perceived exertion was only measured at the end of each condition, no immediate postural effect, delayed postural effect and time-on-task effect were possible.

CHAPTER 4

RESULTS

For the purpose of this study, the dependent variables that were investigated included objective performance measures of a cognitive test battery including a simple response test, a choice response test, a recognition test, a working memory test and a psychomotor test. Subjective ratings of perceived exertion and physiological responses (heart rate frequency) were also investigated. The data of cognitive performance and physiological responses were statistically analysed in order to ascertain significance between conditions and over time, using an analysis of variance with three conditions and four 15 minute intervals as factors respectively. The three conditions tested were: Condition 1: 60 minutes seated, Condition 2: 15 minutes standing, followed by 45 minutes seated and Condition 3: 15 minutes seated, followed by 15 minutes standing, followed by 15 minutes seated, followed by 15 minutes standing. The categorical data for the rating of perceived exertion were statistically analysed in order to ascertain significance between the conditions, using an analysis of variance with three conditions. To account for the large interindividual variation in the data for cognitive performance and ratings of perceived exertion (APPENDIX 6: Table 14), values were normalized by dividing each participant's recorded value by the mean of that participant's values for the three conditions. While, in order to account for the large interindividual variation in the heart rate frequency data (APPENDIX 6: Table 14), values were normalized by subtracting each participant's mean resting heart rate frequency, as recorded for five minutes before the start of each of the three conditions. Finally, the immediate and the delayed postural effects on cognitive performance and physiological responses were also statistically analysed.

Statistical tables presented in this section are abridged versions, the full versions can be found in APPENDIX 6.

4.1. Cognitive Performance

4.1.1. Condition effect

One way ANOVAs revealed that the measures of simple response time, choice response time, choice response errors, recognition response time, recognition errors, working memory, psychomotor response time and psychomotor deviation were not significantly different between the three conditions (Table 1).

Table 1: Analysis of variance of the condition effect of the different cognitive performance tests (*significance p<0.05)

Cognitive test	**Measure**	**Degrees of Freedom**	**F**	**p**
Simple response test	response time	2, 58	1.55	0.22
Choice response test	response time	2, 58	1.20	0.31
	errors	2, 58	0.29	0.75
Recognition test	response time	2, 58	0.80	0.46
	errors	2, 58	0.74	0.48
Working memory test	correct strings	2, 58	1.87	0.16
Psychomotor test	response time	2, 58	1.17	0.32
	deviation	2, 58	0.16	0.85

4.1.2. Time-on-task effect

Although no significant condition effects were found between the three conditions, a significant time-on-task effect was found in three of the cognitive performance tests. One way ANOVAs revealed that measures of simple response time, choice response errors and working memory were significantly different over the four 15 minute intervals (Table 2).

Table 2: Analysis of variance of the time-on-task effect of the different cognitive performance tests (*significance p<0.05)

Cognitive test	**Measure**	**Degrees of Freedom**	**F**	**p**
Simple response test	response time	3, 87	4.32	**<0.01***
Choice response test	response time	3, 87	0.32	0.81
	errors	3, 87	7.46	**<0.01***
Recognition test	response time	3, 87	0.11	0.96
	errors	3, 87	0.23	0.87
Working memory test	correct strings	3, 87	5.65	**<0.01***
Psychomotor test	response time	3, 87	0.39	0.76
	deviation	3, 87	0.31	0.82

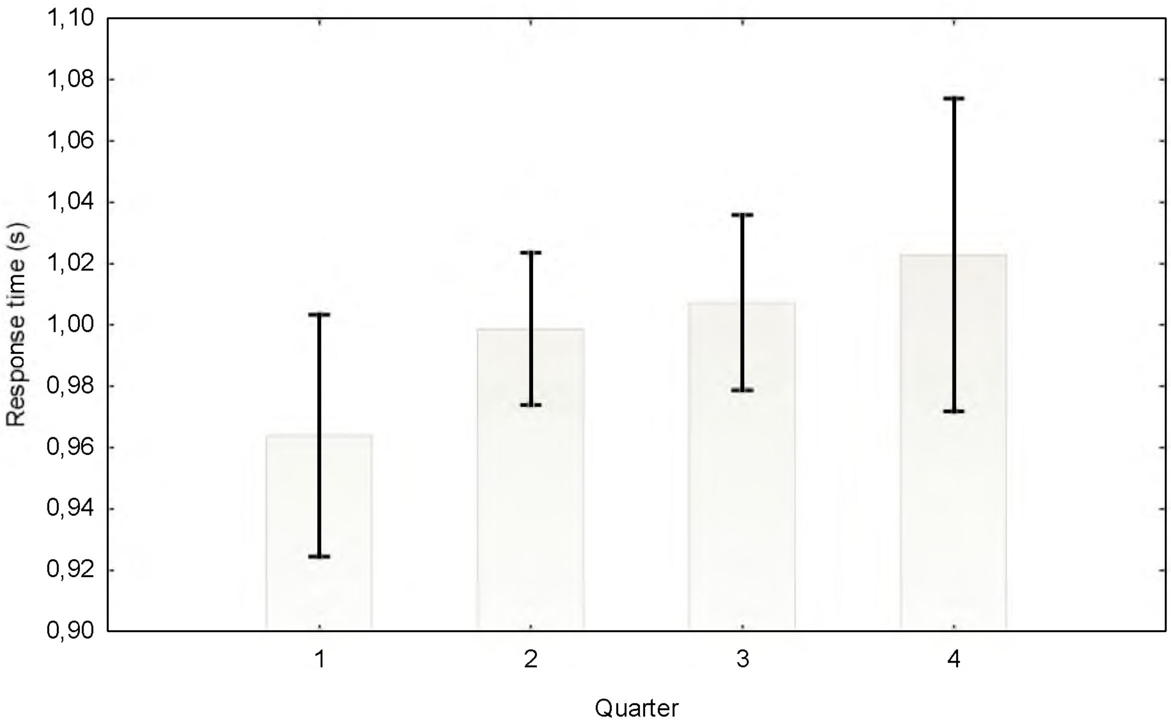


Figure 9: Comparison of the normalized simple response time in seconds over the four 15 minute intervals (Error bars denote 95% confidence intervals)

Figure 9 illustrates that there was a significant decrease in performance (increase in simple response time) over time. The first 15 minute interval presented the quickest response time, with a slowing of response time occurring with each subsequent 15 minute interval. A one way ANOVA (Table 2) revealed that simple response time was significantly different between the four 15 minute intervals (p< 0.01) and with the use of a Fisher post hoc test (Table 3), it was found that this difference was owing to Quarter 1 having a significantly quicker response time compared to Quarter 2 (p= 0.04), Quarter 3 (p= 0.01) and Quarter 4 (p<0.01).

Table 3: Fisher's least significant difference post hoc analysis of simple response time between the quarters (*significance p<0.05)

Quarter	**Q1**	**Q2**	**Q3**	**Q4**
Q1		**0.04***	**0.01***	**<0.01***
Q2	**0.04***		0.61	0.16
Q3	**0.01***	0.61		0.36
Q4	**<0.01***	0.16	0.36	

Unlike simple response time, choice response time was not significantly different over time; however, performance still deteriorated over time in terms of an increase in the percentage of choice response errors made.

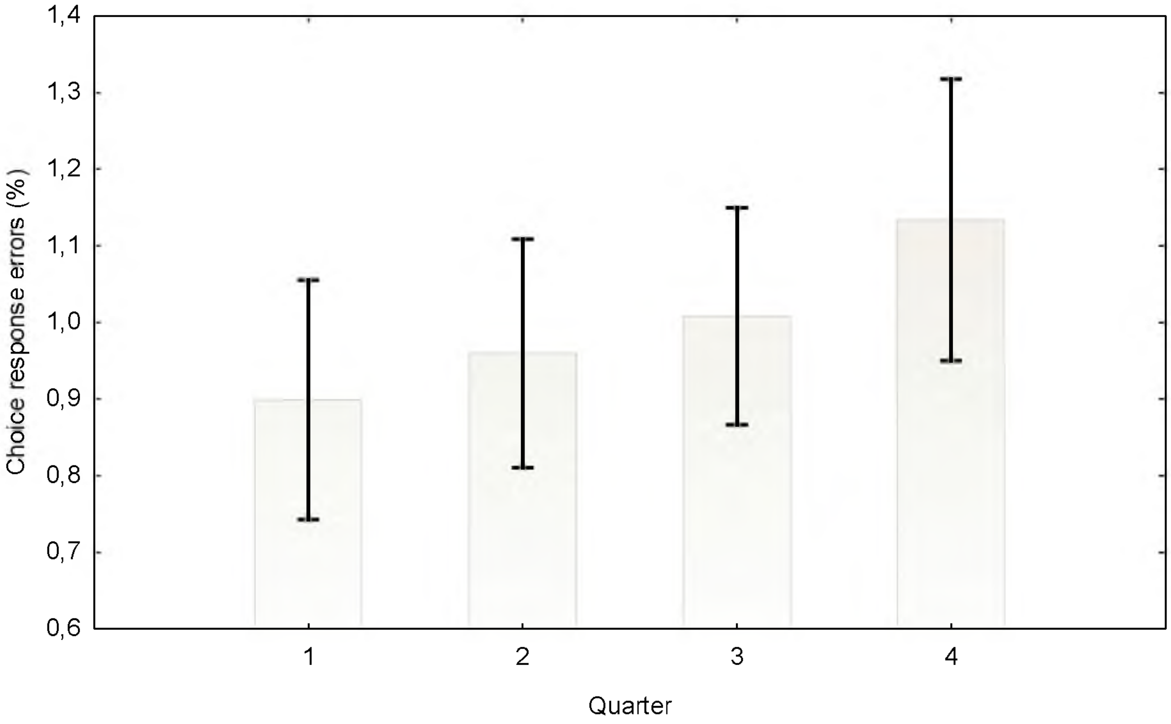


Figure 10: Comparison of the normalized percentage of choice response errors made over the four 15 minute intervals (Error bars denote 95% confidence intervals)

Figure 10 shows that over time there was a significant increase in the percentage of errors made. The first 15 minute interval presented the least errors made with an increase in errors occurring with each subsequent 15 minute interval. A one way ANOVA (Table 2) revealed that the percentage of errors made was significantly different between the four 15 minute intervals (p<0.01) and upon further inspection, with the use of a Fisher post hoc test (Table 4), it was found that this difference was owing to Quarter 4 having a significantly higher percentage of errors, compared to Quarter 1 (p<0.01), Quarter 2 (p<0.01) and Quarter 3 (p= 0.02), as well as Quarter 3 having a significantly higher percentage of errors compared to Quarter 1 (p= 0.04).

Table 4: Fisher's least significant difference post hoc analysis of the percentage of choice response errors made between the quarters (*significance p<0.05)

Quarter	**Q1**	**Q2**	**Q3**	**Q4**
Q1		0.24	**0.04***	**<0.01***
Q2	0.24		0.35	**<0.01***
Q3	**0.04***	0.35		**0.02***
Q4	**<0.01***	**<0.01***	**0.02***	

Unlike the performance decrement in the simple response test and choice response test over time, working memory performance improved over time.

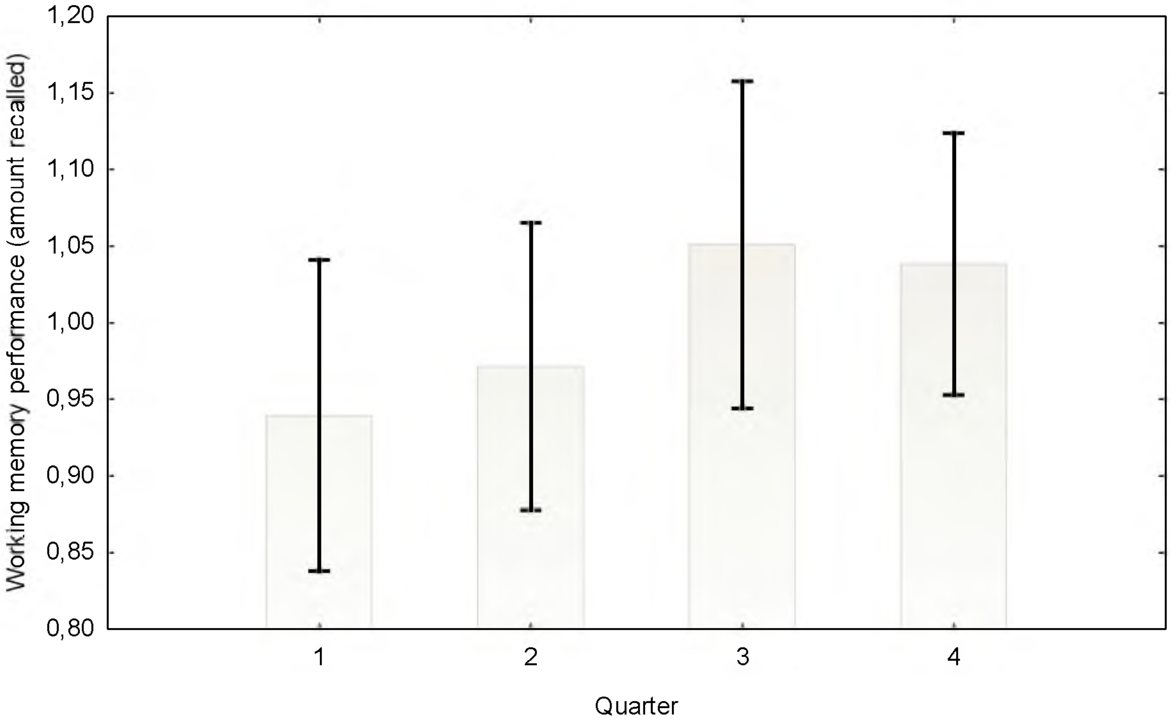


Figure 11: Comparison of the normalized number of correct strings memorized over the four 15 minute intervals (Error bars denote 95% confidence intervals)

Figure 11 illustrates that working memory performance was better during the second half of the task (Quarter 3 and Quarter 4) compared to the first half of the task (Quarter 1 and Quarter 2). A one way ANOVA (Table 2) revealed that number of correct strings memorized was significantly different between the four 15 minute intervals ($p<0.01$) and with the use of a Fisher post hoc test (Table 5), it was found that this difference was owing to Quarter 1 and Quarter 2 having significantly less correctly memorized strings compared to Quarter 3 ($p<0.01$ and $p= 0.01$ respectively) and Quarter 4 ($p<0.01$ and $p= 0.04$ respectively).

Table 5: Fisher's least significant difference post hoc analysis of working memory performance between the four 15 minute intervals (*significance $p<0.05$)

Quarter	**Q1**	**Q2**	**Q3**	**Q4**
Q1		0.32	**<0.01***	**<0.01***
Q2	0.32		**0.01***	**0.04***
Q3	**<0.01***	**0.01***		0.69
Q4	**<0.01***	**0.04***	0.69	

4.1.3. Postural effects

In order to determine the immediate effects of a standing posture versus a seated posture, the first 15 minute interval of Condition 1 (seated) and Condition 2 (standing) were statistically analysed. This was done to determine whether posture (seated or standing) had an immediate effect on cognitive performance. Only one cognitive performance test had a significant immediate postural effect.

Table 6: Analysis of variance of the immediate effect of posture on the different cognitive performance tests (*significance $p<0.05$)

Cognitive test	**Measure**	**Degrees of Freedom**	**F**	**p**
Simple response test	response time	1, 29	0.23	0.64
Choice response test	response time	1, 29	0.74	0.40
	errors	1, 29	0.05	0.82
Recognition test	response time	1, 29	<0.01	0.95
	errors	1, 29	0.01	0.92
Working memory test	correct strings	1, 29	0.02	0.90
Psychomotor test	response time	1, 29	6.59	**0.02***
	deviation	1, 29	3.68	0.06

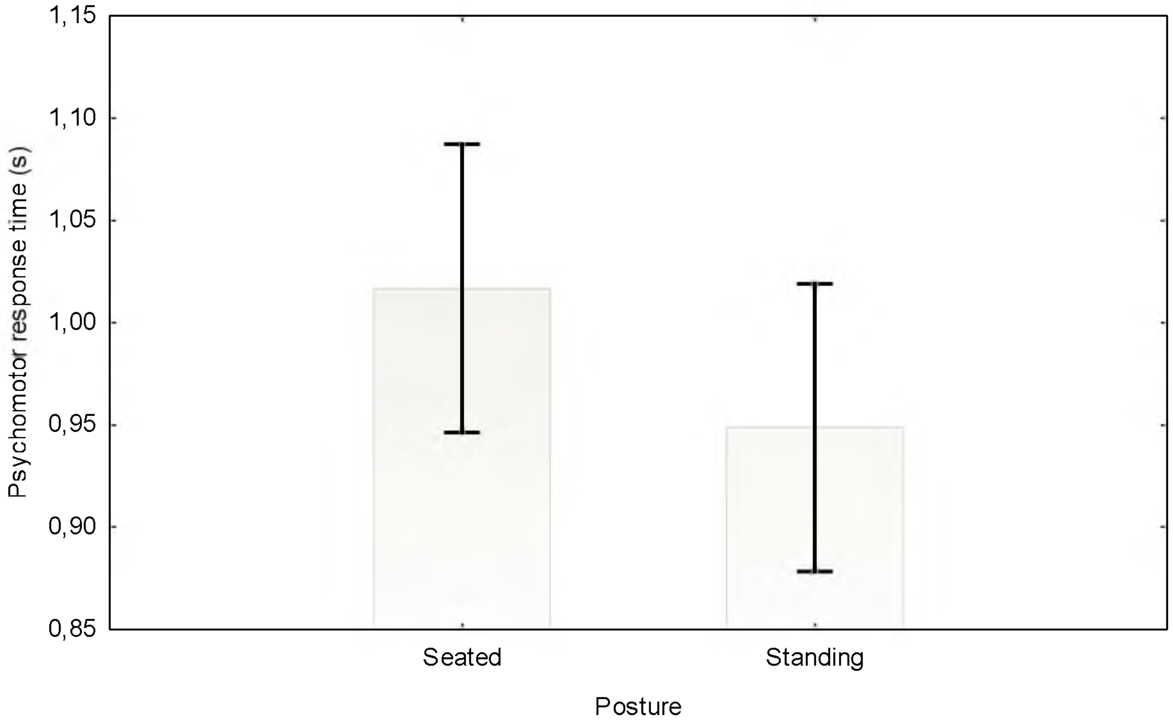


Figure 12: Comparison of the normalized psychomotor response time for seated and standing postures (Error bars denote 95% confidence intervals)

Figure 12 illustrates the immediate effect of posture on psychomotor response time. The psychomotor test found a better (quicker) response time while standing compared to while being seated. A one way ANOVA (Table 6) revealed that psychomotor response time was significantly different between the two postures (p= 0.02).

In order to determine the delayed (after) effects of the initial posture (standing versus seated), the remaining 45 minutes of Condition 1 and Condition 2 (where participants were both seated for the entire 45 minutes) were statistically analysed. The working memory test was the only cognitive test that found any significant delayed (after) effects of posture.

Table 7: Analysis of variance of the delayed effect of posture on the different cognitive performance tests (*significance p<0.05)

Cognitive test	**Measure**	**Degrees of Freedom**	**F**	**p**
Simple response test	response time	1, 29	2.45	0.13
Choice response test	response time	1, 29	<0.01	0.99
	errors	1, 29	0.63	0.43
Recognition test	response time	1, 29	1.37	0.25
	errors	1, 29	2.09	0.16
Working memory test	correct strings	1, 29	4.85	**0.04***
Psychomotor test	response time	1, 29	0.65	0.43
	deviation	1, 29	0.86	0.36

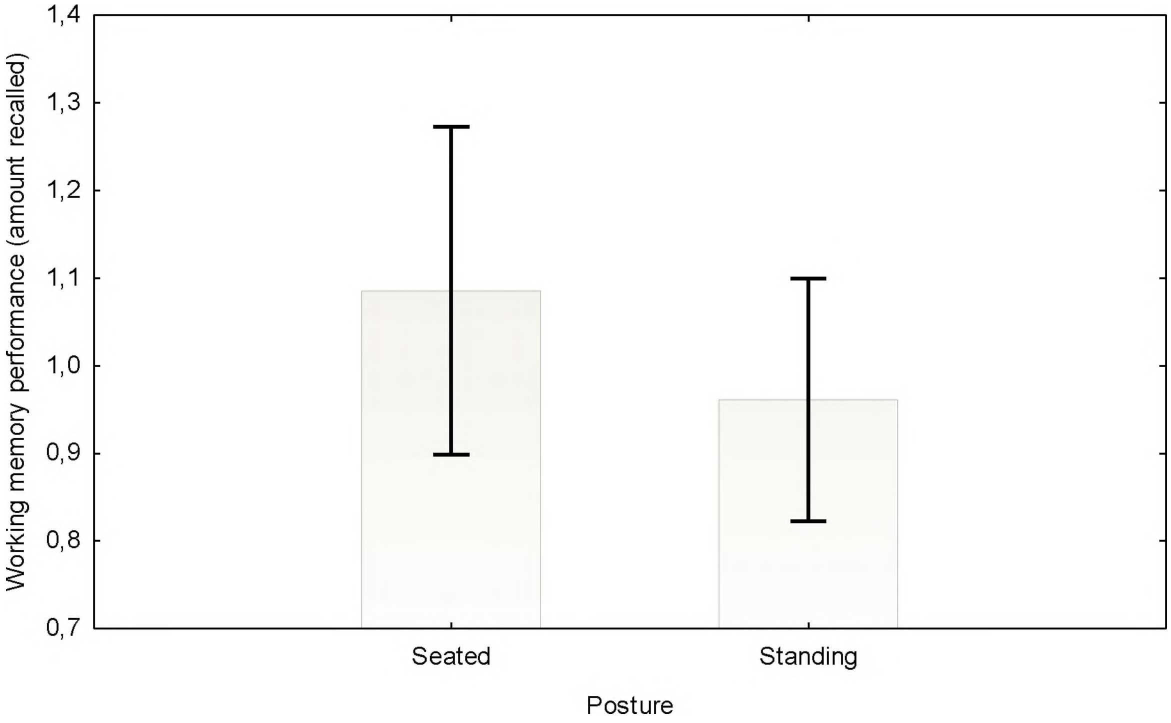


Figure 13: Comparison of the normalized working memory performance for the remaining 45 minutes seated, following the initial 15 minutes seated (left) and 15 minutes standing (right) (Error bars denote 95% confidence intervals)

Figure 13 illustrates that working memory performance was better for the remaining 45 minutes of being seated following 15 minutes of being seated, compared to following 15 minutes of standing. A one way ANOVA (Table 7) found that working memory performance during the remaining 45 minutes of being seated was significantly negatively affected by the initial 15 minutes of standing (p= 0.04).

4.2. Rating of Perceived Exertion

A perceived exertion rating was recorded at the end of each condition, where the participant was asked to rate their level of exertion required to perform the task. Perceived ratings of exertion were compared between conditions.

Table 8: Analysis of variance of the perceived rating of exertion between the three conditions (*significance p<0.05)

Effect	**Degrees of Freedom**	**F**	**p**
Condition	2, 58	4.84	**0.01***

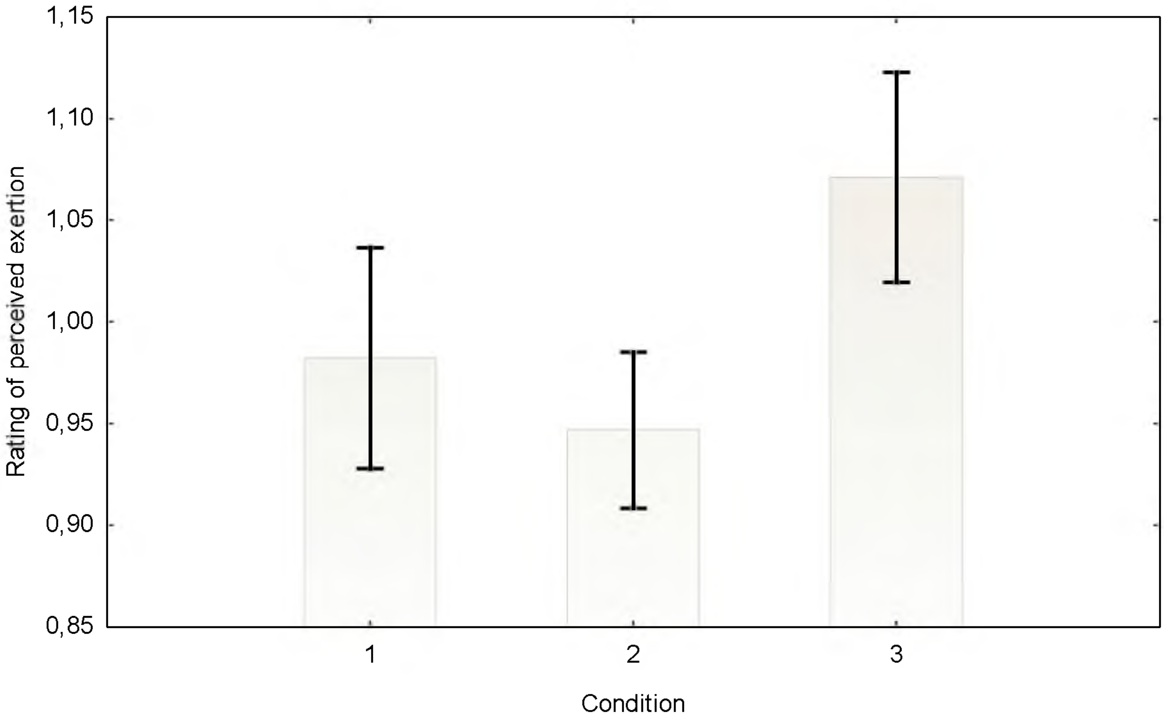


Figure 14: Comparison of the normalized perceived rating of exertion for the three conditions (Error bars denote 95% confidence intervals)

Figure 14 shows that the participants perceived Condition 3 as the most physically exerting, followed by Condition 1 and then Condition 2. A one way ANOVA (Table 8) revealed that the perceived rating of exertion was significantly different between the three conditions (p= 0.01) and with the use of a Fisher post hoc test (Table 9), it was found that this difference was owing to Condition 3 being rated significantly more physically exerting by the participants compared to Condition 1 (p= 0.03) and Condition 2 (p<0.01).

Table 9: Fisher's least significant difference post hoc analysis of the perceived rating of exertion between the three conditions (*significance p<0.05)

Condition	**1**	**2**	**3**
1		0.39	**0.03***
2	0.39		**<0.01***
3	**0.03***	**<0.01***	

4.3. Heart Rate Frequency

4.3.1. Condition effect

Heart rate frequency was continuously monitored and measured throughout each condition and an average of each minute was recorded. Mean heart rate frequency was found to be similar across all 3 conditions. A two way ANOVA (Table 10) revealed that heart rate frequency was not significantly different between the three conditions.

Table 10: Analysis of variance of heart rate frequency between the conditions and over time (*significance p<0.05)

Effect	**Degrees of Freedom**	**F**	**p**
Condition	2, 58	0.48	0.62
Time	59, 1711	5.15	**<0.01***
Condition*Time	118, 3422	6.35	**<0.01***

4.3.2. Time-on-task effect

There was a significant difference in heart rate frequency over time (p<0.01), but this can in all likelihood be attributed to the methodological design of employing different postures during the same 15 minute intervals. For example in the first 15 minute interval, the participant was seated in Condition 1, standing in Condition 2 and seated in Condition 3.

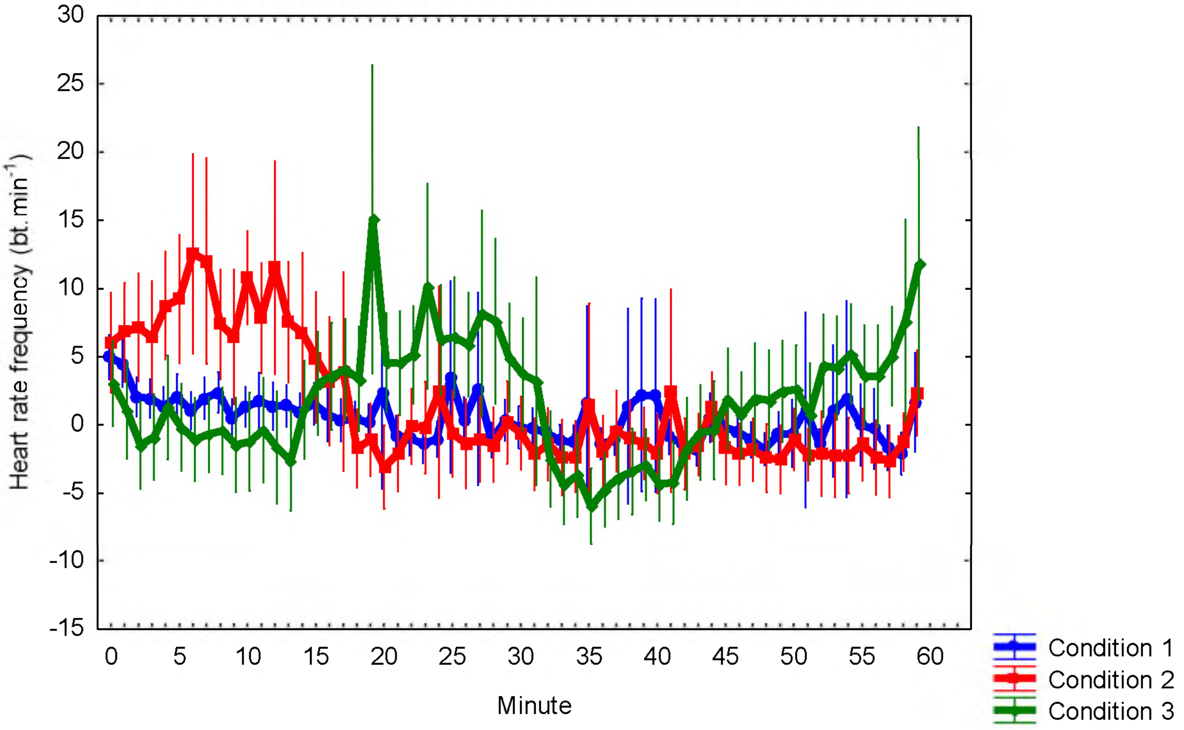


Figure 15: Comparison of the normalized heart rate frequency in beats per minute (bt.min^{-1}) for the three conditions over the task duration of 60 minutes (Error bars denote 95% confidence intervals)

Figure 15 illustrates heart rate frequency for the entire 60 minute task duration for the three conditions. It shows that the seated posture in all the conditions elicited a lower heart rate frequency compared to the standing posture. A two way ANOVA, as illustrated in Table 10, revealed that heart rate frequency was significantly different between conditions over time ($p<0.01$).

4.3.3. Postural effects

In order to determine the immediate effects on heart rate frequency of a standing posture versus a seated posture, the first 15 minute interval of Condition 1 (seated) and Condition 2 (standing) were statistically analysed. This was done to determine whether the immediate posture (seated or standing) had an effect on the physiological responses.

Table 11: Analysis of variance of the immediate effect of posture on heart rate frequency (*significance p<0.05)

Effect	**Degrees of Freedom**	**F**	**p**
Posture	1, 29	15.86	**<0.01***

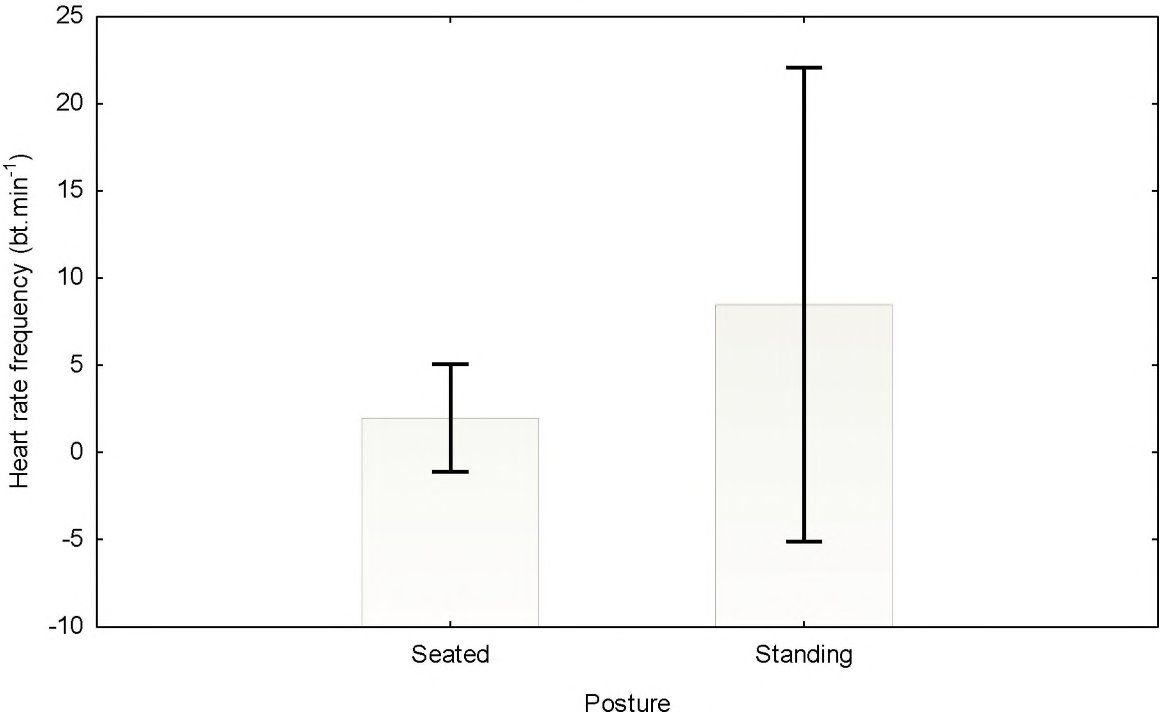


Figure 16: Comparison of the normalized heart rate frequency in beats per minute (bt.min-1) for the seated and standing postures (Error bars denote 95% confidence intervals)

Figure 16 illustrates the immediate effect of posture on heart rate frequency for the seated and standing postures and shows that the seated posture elicited a lower heart rate frequency compared to the standing posture. A one way ANOVA, as illustrated in Table 11, revealed that heart rate frequency was significantly different between seated and standing postures (p<0.01).

In order to determine the delayed (after) effects of the initial posture (standing versus seated), the remaining 45 minutes of Condition 1 and Condition 2 (where participants were both seated for the entire 45 minutes) were statistically analysed. No significant delayed postural effects were found (Table 12).

Table 12: Analysis of variance of the delayed effect of posture on heart rate frequency (*significance $p<0.05$)

Effect	**Degrees of Freedom**	**F**	**p**
Posture	1, 29	0.44	0.51

4.4. Summary of Results

Table 13 summarizes all condition effects, time-on-task effects and immediate and delayed postural effects on cognitive performance, perceived rating of exertion and physiological responses.

Table 13: Summary table of results (blank cells indicate no significant difference)

Dependant variable	**Condition effect**	**Time effect**	**Immediate postural effect**	**Delayed postural effect**
Simple response test		↓response time		
Choice response test		↑errors		
Recognition test				
Working memory test		↑correct strings		seated>standing (correct strings)
Psychomotor test			standing>seated (response time)	
Rating of perceived exertion	Condition3> Condition1 Condition3> Condition2	N/A	N/A	N/A
Heart rate frequency			standing>seated	

4.5. Response to Hypotheses

4.5.1. Condition effect

It was hypothesised that all measured parameters would be different between the three conditions; hence all null hypotheses failed to be rejected, except for the rating of perceived exertion where the null hypothesis was rejected, as a significant difference was found between conditions.

4.5.2. Immediate postural effect

It was hypothesised that all measured parameters would be different for the immediate effects of seated and standing postures; hence the null hypotheses failed to be rejected, except for psychomotor response time and heart rate frequency where the null hypothesis was rejected, as a significant difference was found between the immediate postures.

4.5.3. Delayed postural effect

It was hypothesised that all measured parameters would be different for the delayed effects of seated and standing postures; hence the null hypotheses failed to be rejected, except for working memory performance where the null hypothesis was rejected, as a significant difference was found.

4.5.4. Time-on-task effect

It was hypothesised that all measured parameters would be different between the four 15 minute intervals, hence the null hypotheses failed to be rejected, except for simple response time, choice response errors and working memory performance where the null hypothesis was rejected, as a significant difference was found between the four 15 minute intervals.

CHAPTER 5

DISCUSSION

This study outlined a number of hypotheses aimed at assessing the effect of two different sit-stand regimes (of different total standing duration) on cognitive task performance, physiological responses and the subjective rating of perceived exertion. This chapter critically analyses the data presented in the results. It focuses on the cognitive performance measures between the different conditions. It further looks at the physiological responses obtained during testing and attempts to find and link possible explanations for all results obtained. The subjective rating of perceived exertion of the participants will also be compared between the conditions.

Although time-on-task effects were noted during a majority of the measured variables, analysing the findings and drawing conclusions on time-on-task effects independently was not a main objective of this study. Therefore, these effects will only be discussed briefly. Since each condition was performed over a one hour period, time-on-task effects are an integral part of determining how whole shifts should be arranged. Therefore, the role that time-on-task plays in cognitive task performance, physiological responses and subjective ratings of perceived exertion cannot be underestimated.

5.1. Cognitive Performance

5.1.1. Condition effect

No significant differences in cognitive performance were found between Condition 1, Condition 2 and Condition 3. These findings are in agreement to a study by Schraefel *et al*. (2012), comparing the effect of two different body postures on six cognitive executive function domains. The six cognitive executive function domains included: executive function, complex attention, cognitive flexibility, psychomotor speed, response time and processing speed. Only complex attention (measured by working memory performance) had a significant difference between the standing and seated conditions, with the seated condition having a more favourable outcome.

These findings are also consistent with the findings of Bantoft *et al.* (2016) where no effect of being seated or standing during a 60 minute test duration was found on measures of working memory, selective and sustained attention and information-processing speed. These findings are also in agreement with several other studies on young adults performing cognitive tasks that report no occurrence of dual-task cost while standing (Jamet *et al.*, 2007; Lindenberger *et al.*, 2000; Marsh and Geel, 2000; Redfern *et al.*, 2001).

5.1.2. Time-on-task effect

A significant time-on-task effect was found in three of the cognitive performance tests. The simple response time, choice response errors and working memory measures were significantly different over the four 15 minute intervals. The cognitive performance data of both the simple response test and the choice response test indicated a decline in performance over time. The response time measure of the simple response test increased with time-on-task, while the response time measure of the choice response test did not show a significant difference over time; however, errors in responding correctly (left click for a green circle and right click for a red square) to the stimulus presented increased with time-on-task. Research has indicated that tasks that require effort ultimately result in fatigue (Schmidt, 1982). Time induces fatigue simply because any activity carried out for long enough periods will result in an increased difficulty maintaining the activity (Lal and Craig, 2001). This is why performance decreases as a function of time-on-task. Working memory performance however, showed an improvement with time-on-task, with a greater amount of correct strings of numbers recalled in Quarter 3 and Quarter 4 compared to Quarter 1 and Quarter 2. This can be explained by Van Dongen and Dinges (2000), who reported that task performance reliability was limited by the practice effect which tended to result in cognitive performance improvement the more a task was repeated.

5.1.3. Postural effect

Only one cognitive performance test had a significant immediate postural effect (standing posture versus a seated posture). The psychomotor test found a significantly better (quicker) response time while standing compared to being seated. This is in contradiction to Commissaris *et al.* (2014), where a psychomotor test that required fine motor actions of the hands (mouse pointing and clicking) was negatively affected by the use of a standing workstation.

The working memory test was the only cognitive test that found any significant delayed (after) effects of posture. Working memory performance was better for the remaining 45 minutes of being seated following 15 minutes of being seated, compared to following 15 minutes of standing. John *et al.* (2009) found that while walking on a treadmill, math problem solving performance decreased. This impact on math problem solving is consistent with the resource theory prediction that arousal impedes working memory (John *et al.*, 2009). This finding is also in agreement with a sitting versus standing study, where the low-arousal position of sitting gave the expected working memory advantage (Schraefel *et al.*, 2012).

5.2. Rating of Perceived Exertion

Subjective input was assessed in the form of Borg's Rate of Perceived Exertion scale. A perceived exertion rating was recorded at the end of each condition, where the participant was asked to rate the level of exertion required to perform the task. Prolonged standing in the workplace has also been shown to cause body discomfort and muscle fatigue (Halim *et al.*, 2012), but with the suggestion of Karakolis *et al.* (2014) to limit standing to 15 minutes for newly implemented sit-stand workstations, (which is below the initiation time point for low back pain development) it would be expected that body discomfort and muscle fatigue should not occur at any greater rate than sitting, where standing is limited to 15 minutes.

The participants perceived Condition 3 as the most physically exerting of the three conditions, but their subjective rating of perceived exertion may have been influenced by the fact that they were not habitual standing or sit-stand desk users. This finding is in contradiction to Halim *et al.* (2012) who proposed that standing with intermittent sitting would be the best solution to minimize discomfort and muscle fatigue associated with prolonged tasks. In agreement with this finding, Ebara *et al.* (2008) found that the use of sit-stand workstations had an adverse effect in light of musculoskeletal discomfort. Condition 3 had the longest total duration of standing and the greatest number of sit-to-stand/stand-to-sit transitions. By having the rating of perceived exertion only measured at the end of each condition, may have influenced participants to base their subjective rating on the posture employed for the last 15 minutes of the condition. Therefore, it is not possible to determine whether the greater number of transitions, the longer duration of total standing time or a combination of factors elicited this perception of the participants.

Condition 2 was perceived by the participants as the least exerting, even compared to Condition 1, where participants were seated for the entire 60 minute task duration. In contradiction to these findings, Chester *et al.* (2002) found that workers subjectively preferred sitting for 90 minutes, compared to standing or using a sit-stand chair. Therefore the recommendations of Corlett (1978) and Beach *et al.* (2005) that work spaces should be arranged so that work may be done in either a seated or standing position (as the combinations of postures are useful in reducing the workload and the monotonous feelings in a repetitive task) was found to be true in this study, but only for Condition 2 (15 minutes standing, followed by 45 minutes seated) and not for Condition 3 (15 minutes seated, followed by 15 minutes standing, followed by 15 minutes seated, followed by 15 minutes standing).

5.3. Heart Rate Frequency

5.3.1. Condition effect

Standing is accompanied by an automatic increase in heart rate frequency (Grubb and Karabin, 2008) and it has been shown to be possible to estimate energy expenditure from heart rate frequency in a group of individuals (Keytel *et al.*, 2005). Heart rate frequency was found to be not significantly different between the three conditions, indicating that energy expenditure was also not significantly different between the conditions. Although there are studies (Ainsworth *et al.*, 2000; Reiff *et al.*, 2012 and Miles-Chan *et al.*, 2013) which have compared solely standing energy expenditure to solely seated energy expenditure, it is to the best of the author's knowledge that no studies have been done to compare mean seated energy expenditure and mean standing energy expenditure to a mean combination sit-stand energy expenditure (for a set duration). However, a study by Júdice *et al.* (2016) determined the metabolic cost of a single sit-stand transition and found it to be about 0.32 kcal (35% above sitting) and suggested that workers should frequently interrupt sitting with standing, as the accumulative effects of the energy expenditure of sit-stand transitions may be beneficial. Although Condition 3 had two sit-stand transitions, no significant differences in heart rate frequency were found between this and Condition 2 (one sit-stand transition) and Condition 1 (no sit-stand transitions). It may be that a study of longer duration is needed in order to determine the credibility of this suggestion.

5.3.2. Postural effect

The mean data shows that the seated posture had a significantly lower heart rate frequency compared to the standing posture. This therefore indicates that standing elicits greater energy expenditure, while being seated elicits lower energy expenditure. This finding would be expected as a greater heart rate has been found to be an indicator of greater physical exertion (Gamberale, 1972) and this can be explained in terms of the higher demands on the metabolism and circulation during standing compared to sitting (Wilks *et al.*, 2006). This finding is in agreement with studies by Ainsworth *et al.*, (2000), Reiff *et al.* (2012) and Miles-Chan *et al.* (2013) which found that mean standing energy expenditure was significantly higher compared to mean sitting energy expenditure.

Heart rate frequency in the standing posture had a greater degree of variation compared to the seated posture. This is in accordance with Miles-Chan *et al.* (2013) who found three distinct phenotypes based on the magnitude and time-course of the energy expenditure response to steady-state standing. These findings challenge the recommendation that implementing standing at work can be used as a blanket strategy to increase energy expenditure in all individuals. Individual differences that may impact energy expenditure need to be considered.

5.4. Resource Theory

The results of this study will now be interpreted using the resource theory of human cognitive processing. Since human cognitive processing resources are limited, the effectiveness of performing cognitive work while standing can differ from that of performing cognitive work while seated (Kahnemann, 1973). Despite the high degree of automaticity, postural control processes may still require motor preparatory attention to facilitate multi-sensory integration and the generation of motor commands. A highly automated task (like standing) usually needs low information processing (Regnaux *et al.*, 2005). Highly automated tasks compete for the same resources, but dual-task costs should be low given that few resources are taken up (Beilock *et al.*, 2002). Therefore in a sit-stand workstation paradigm there may be competition for the same resources, which might lead to a reduction in cognitive performance (Husemann *et al.*, 2009). Dietrich and Sparling (2004) suggested that performing physical movement might not only consume cognitive resources, but also generate cognitive resources.

This study found no indication that either sit-stand regime (Condition 2 or Condition 3) had any dual-task costs (compared to the seated condition), but an indication of a dual-task cost was found after 15 minutes of standing, when working memory performance for the remaining 45 minutes of being seated was worse than the remaining 45 minutes of being seated after 15 minutes of being seated. Standing in the first 15 minutes may have consumed more cognitive resources than it generated.

There was no indication that the immediate posture of standing had any dual-task costs. A better response time in the psychomotor test occurred while standing, indicating that standing actually generated more cognitive resources than it consumed.

Apart from the potential occurrence of a dual-task cost, the cognitive task was interrupted by a short break when changing work positions (Husemann *et al.*, 2009). It has been suggested that this break may possibly lead to reduced efficiency or, alternatively, to improved cognitive performance because of activation of the cardiovascular system (Watanabe *et al.*, 2007) and increased stimulation and awareness (Caldwell *et al.*, 2003). The cardiovascular activation may have led to a better psychomotor response time while standing.

5.5. Arousal Theory

The results of this study will now be interpreted using the arousal theory. The ascending reticular activating system is thought to be responsible for maintaining a state of arousal and it has been found that standing stimulates the reticular activating system more than sitting (Lee and Dan, 2012). As the act of standing increases physiological arousal, it would be expected that a change from a seated position to a standing position would result in an improvement of performance in tasks requiring higher levels of arousal. Research has found that different tasks require different levels of arousal for optimal performance (Diamond *et al.*, 2007) and it appears that increased levels of arousal can improve performance on information processing tasks in instances when the individual is initially functioning in a physiological state of under-arousal.

The immediate standing posture produced a better response time in the psychomotor test, indicating that the increased level of arousal of standing improved performance; while on the other hand, a low level of arousal following 15 minutes seated, led to a better working memory performance for the remaining 45 minutes of being seated, compared to the remaining 45 minutes of being seated after 15 minutes of standing. This is in agreement with Diamond *et al.* (2007) who stated that different tasks require different levels of arousal for optimal performance.

5.6. Reflection on Methodology

This study had some inherent delimitations and limitations, which may have affected the results and thus findings.

5.6.1. Delimitations

The sample used in this study was delimited to a convenient sample of Rhodes University students. Both males and females were used in this investigation. Exclusion criteria for participation in the study included: participants who have been diagnosed with attention deficit disorder or any other disorder characterized primarily by inattentive concentration or a deficit of sustained attention.

Participants were informed prior to testing to please adhere to certain requirements hours prior to testing. Participants were required to have good night’s sleep, no alcohol or stimulating/sedating medications 24 hours prior to testing and no coffee/caffeine or (strenuous) exercise 12 hours prior to testing. It was taken by the participant’s word whether or not they followed these requirements.

Data collection took place in a controlled laboratory setting, to ensure that the protocol was consistent among participants. The study was limited to three conditions. The three conditions had to be permutated to prevent the order of effects impacting on the results. Participants were required to be tested at the same time of day for each condition on all three occasions to prevent the time of day being an influencing variable on their performance.

5.6.2. Limitations

This experimental investigation aimed to control all variables that could potentially confound on the final results. However, due to the many causes and factors affecting heart rate, performance and perceived exertion, certain limitations present in this investigation could not be eliminated.

The participants used in the study were only Rhodes University students who volunteered to participate. However, they were representative of the general population of this particular age group.

The experiment was conducted in laboratory settings in order to control environmental factors and therefore mental fatigue was induced in the participants rather than it occurring due to a real life working situation. The laboratory settings may also have affected the degree of effort the participants expended in completing the protocol as opposed to if testing occurred in the field.

The duration of the protocol was limited due to time constraints therefore the results may differ for a longer duration.

The testing protocol was repeated on three separate days and this may have caused a learning effect or boredom to occur, as participants become more familiar with the procedures and tests conducted.

CHAPTER 6

CONCLUSION

This study focused on determining the effect of two different sit-stand regimes on cognitive task performance, physiological responses and the subjective rating of perceived exertion. The findings from this study show that even though the two different sit-stand regimes did not result in a significant impact on cognitive task performance, an immediate postural effect for psychomotor response time and a delayed postural effect for working memory were found.

The participants perceived Condition 3 (15 minutes seated, followed by 15 minutes standing, followed by 15 minutes seated, followed by 15 minutes standing) as the most physically exerting condition. This subjective rating may have been influenced by the fact that the participants were not habitual standing or sit-stand desk users and by only having the rating of perceived exertion measured at the end of each condition. It was not possible to determine whether the greater number of transitions, the longer duration of total standing time or a combination of factors elicited this perception of the participants.

Heart rate frequency was not significantly different between the conditions. The seated posture had a significantly lower heart rate frequency compared to the standing posture; this indicates that standing elicits greater energy expenditure than being seated. Heart rate frequency while standing had a greater degree of variation compared to being seated.

Taking these findings into account, it is recommended that: one should be seated when performing this type of working memory task, should be standing when performing this type of psychomotor task, that the recommendation that implementing standing at work can be used as a blanket strategy to increase energy expenditure in all individuals needs to be explored further and that individual differences may impact energy expenditure.

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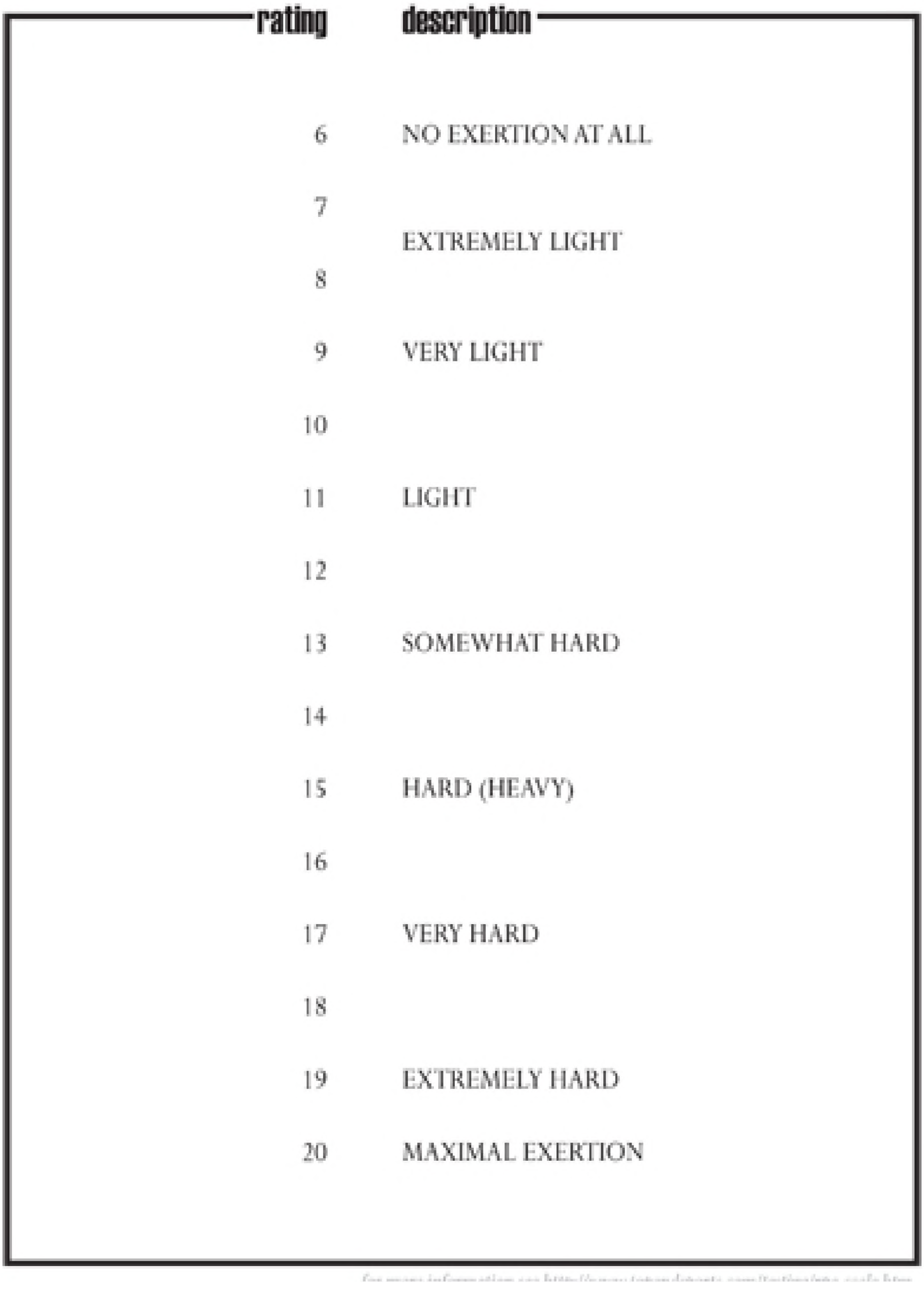
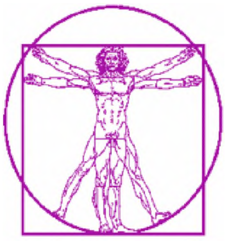
APPENDIX 1

RATING OF PERCEIVED EXERTION SCALE



rating	description
6	NO EXERTION AT ALL
7	
	EXTREMELY LIGHT
8	
9	VERY LIGHT
10	
11	LIGHT
12	
13	SOMEWHAT HARD
14	
15	HARD (HEAVY)
16	
17	VERY HARD
18	
19	EXTREMELY HARD
20	MAXIMAL EXERTION

APPENDIX 2



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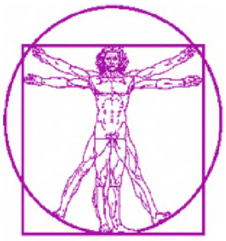


INFORMATION TO PARTICIPANTS

Thank you for participating as a participant in my Masters project entitled, “The effect of sit-stand regimes on cognitive task performance”. Your time and effort is much appreciated and is invaluable to me as a researcher.

Aim of the study

Desk and computer work have traditionally been performed while being seated (Wilks *et al*., 2006), but the introduction of non-sedentary work configurations, which encourage standing rather than sitting, have become more popular in organizations (Knight and Baer, 2014). Standing may be a practical working position for workers handling heavy equipment, as the processes require frequent movements and large degree of freedom (Halim *et al*., 2012), but office workers tend to prefer being seated to perform tasks, as sitting uses less energy than standing and because standing becomes increasingly uncomfortable after a period of time (Lehman *et al*., 2001). When it comes to cognitive performance and executive function, the benefits of standing or sitting are less clear. Performance effects need to be determined, as improvements in the workplace, working posture and discomfort need to be justified in terms of improvements in work performance (Liao and Drury, 2000).

The aim of the study is to investigate and assess the effect of physiological arousal associated with sit-stand regimes, on cognitive task performance. Furthermore, the effect of fast versus slow cycling between sitting and standing will also be investigated. Throughout the course of the testing protocol, heart rate as well as heart rate variability will be measured and performance measures will be recorded.

Additionally you will be asked to rate your subjective feeling of fatigue at the end of each session.

Sample characteristics

Male and female participants between the ages of 19 to 24 years, whom are not habitual standing or sit-stand desk users, will be eligible for this study.

Procedures

You will be required to attend four laboratory sessions at the Human Kinetics and Ergonomics Department. Each session will last approximately one hour and twenty minutes. In the initial session (habituation session) you will be introduced to the equipment (heart rate monitor), setup (standing and seated conditions) and procedures, as well as being allowed to practice the task on the computer, until you feel comfortable enough to perform the task. I will explain the protocol to you in detail, after which you will be required to sign an informed consent form. You will be required to attend these four sessions at the same time on four different days. If you feel uncomfortable with a male researcher fitting the heart rate monitor, you can request that a female research assistant be present at the start and end of each session to fit and remove the monitor.

The second, third and fourth sessions will entail you completing a test battery for 60 minutes. Three conditions will be tested: Condition 1: 60 minutes seated, Condition 2: 15 minutes standing and 45 minutes seated, Condition 3: 60 minutes intermittent seated and standing (15 minutes seated, 15 minutes standing, 15 minutes seated and 15 minutes standing).

Graphic showing postures during conditions

The heart rate monitor will be attached and worn by you throughout the procedure. A perceived effort rating will also be asked at the end of each condition, where you will be asked to rate the difficulty of performing the task on a scale of 6 (no exertion at all) to 20 (maximal exertion).

Your anonymity will be protected at all times. Your data will be associated with a participant code and not your name (e.g. Participant 001). The researcher will have a separate list of participants' names and their corresponding number code during testing, after which this list will be destroyed. With your permission, I will be taking some photographs during the testing session which will be used solely for the purpose of my research and will be destroyed on completion of my research. If the photo is used in the printed copy of my research, I will blank out your face, ensuring your anonymity.

Risks and benefits

It is unlikely that you will experience any injuries during this study, as the procedures are not considered harmful in any way. The risks associated with this study are no greater than working at a desk while seated or standing for a period of time. If you feel uncomfortable and unable to complete the protocol please note that you may request to stop the test at any point. Due to the nature of the task, mental fatigue is a possibility. Mental fatigue is a temporary inability to maintain optimal cognitive performance. The onset of mental fatigue during any cognitive activity is gradual and depends upon your cognitive ability, level of sleep and overall health. Mental fatigue could provide further risk if a highly cognitive, attention demanding task is performed post testing, such as driving long distances or operating heavy machinery. Physical fatigue may occur, as new sit-stand workstation users may not be used to standing for longer periods of time. It is for this reason that continuous standing is limited to 15 minutes.

Benefits derived from this study include exposure to equipment and technology which may otherwise be difficult to encounter, for example the test battery. You will also contribute to an improved understanding of the demands placed on individuals in a wide array of work situations.

PLEASE TAKE NOTE OF THE FOLLOWING REQUIREMENTS BEFORE YOUR TESTING SESSION:

- A good night's sleep before testing
- No alcohol 24 hours prior to testing
- No coffee/caffeine at least 1 hour prior to testing, and no more than 2 cups within the last 12 hours
- No (strenuous) exercise 12 hours prior to testing
- No stimulating/sedating medications are to be taken 24hrs prior to testing

Please contact the researcher if you are unsure of any of these requirements.

Please inform the researcher about any medication you are currently taking, which might possibly have a stimulating or sedating effect.

Upon completion of the project, brief relevant feedback on the research findings will be made available to you if you like, in the form of a PDF.

Thank you for showing an interest in this study. I hope you will learn a lot from this and that you will enjoy the experience. If you have any further questions please do not hesitate to contact me directly.

Yours sincerely

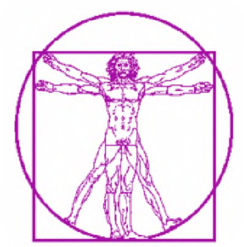
Ethan Berndt

(Masters student – Department of Human Kinetics and Ergonomics)

Tel: 0814434399

Email: g10b1890@campus.ru.ac.za

APPENDIX 3



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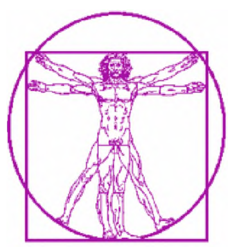

Human Kinetics and Ergonomics Department
INFORMED CONSENT AND INDEMNITY
For research involving human participants

I, …………………………………………… have been fully informed of the research project entitled; "*The Effect of Sit-Stand Regimes on Cognitive Task Performance*".

I have read the information sheet and understand the testing procedure that will take place. All testing procedures, associated risks and the benefits from partaking in this study have been verbally explained to me as well as in writing [*letter of information appended to this document*]. I have had ample opportunity to ask questions and to clarify any concerns or misunderstandings. I am satisfied that these have been answered satisfactorily. I understand that all data collected for publication purposes will be kept anonymous and all information gained in this regard will be treated confidentially. Furthermore, I consent to photographs, knowing that these will be altered to ensure my anonymity. I understand that I am able to withdraw from the study at any point, irrespective of external influences placed on me by the researcher.

In agreeing to participate in this research study I waive any legal recourse against the researchers from the Department of Human Kinetics and Ergonomics (HKE), Rhodes University, from claims resulting from personal injuries sustained whilst participating in the above mentioned research. I am aware and fully understand that the Department of Human Kinetics and Ergonomics is not responsible for any injuries due to my personal negligence and non-compliance with instructions. This waiver shall be binding upon my heirs and personal representatives.

I have read and understood the above information, as well as the information provided in the letter accompanying this form. I therefore consent to voluntarily participate in this research project.

PARTICIPANT PROVIDING CONSENT:

______________________________	____________________	____________________
(Print name)	(Signed)	(Date)

WITNESS:

______________________________	____________________	____________________
(Print name)	(Signed)	(Date)

PRINCIPAL RESEARCHER:

______________________________	____________________	____________________
(Print name)	(Signed)	(Date)

APPENDIX 4

Human Kinetics and Ergonomics Ethics Committee Report

RHODES UNIVERSITY
Where leaders learn

Student Name: Ethan Berndt

Code: HKE-2015-23
Type of Research: MSc
Project Title: The effect of sit-stand regimes on cognitive task performance
Supervisor: Dr. Swantje Zschernack
Application received: 23 November 2015
Resubmitted on: 27 February 2016
Report Compiled: 30 March 2016

Dear Ethan,

Your resubmission has been successful – the reviewers have approved your modifications. You may therefore continue with your experimental testing.

Approved ✓	Approved, on condition that suggestions have been effected	Request for rework and resubmission	Rejected

On behalf of the HKE Ethics Committee I wish you all the best with your study.

Signed

Miriam Mattison.

MC Mattison
Chair: Human Kinetics and Ergonomics Ethics Committee

APPENDIX 5

PERMUTATION SCHEDULE

Participant code	Order of test battery	Order of conditions
001	Response time Recognition Memory Psychomotor	123
002	Response time Recognition Psychomotor Memory	132
003	Response time Psychomotor Memory Recognition	213
004	Response time Psychomotor Recognition Memory	231
005	Response time Memory Psychomotor Recognition	312
006	Response time Memory Recognition Psychomotor	321
007	Recognition Response time Memory Psychomotor	123
008	Recognition Response time Psychomotor Memory	132
009	Recognition Psychomotor Memory Response time	213
010	Recognition Psychomotor Response time Memory	231
011	Recognition Memory Psychomotor Response time	312
012	Recognition Memory Response time Psychomotor	321
013	Memory Response time Recognition Psychomotor	123
014	Memory Response time Psychomotor Recognition	132
015	Memory Recognition Psychomotor Response time	213
016	Memory Recognition Response time Psychomotor	231
017	Memory Psychomotor Response time Recognition	312
018	Memory Psychomotor Recognition Response time	321
019	Psychomotor Response time Recognition Memory	123
020	Psychomotor Response time Memory Recognition	132
021	Psychomotor Recognition Memory Response time	213
022	Psychomotor Recognition Response time Memory	231
023	Psychomotor Memory Recognition Response time	312
024	Psychomotor Memory Response time Recognition	321
025	Response time Recognition Memory Psychomotor	123
026	Response time Recognition Psychomotor Memory	132
027	Response time Psychomotor Memory Recognition	213
028	Response time Psychomotor Recognition Memory	231
029	Response time Memory Psychomotor Recognition	312
030	Response time Memory Recognition Psychomotor	321

APPENDIX 6

STATISTICAL TABLES

Table 14: Absolute means, standard deviation and coefficient of variation (percent) for all measured parameters

Dependent variable	**Measure**	**Mean**	**Standard deviation**	**Coefficient of variation**
Simple response test	response time	0.33s	0.04s	13.62%
Choice response test	response time	0.47s	0.06s	13.07%
	errors	4.81%	2.74%	56.93%
Recognition test	response time	0.59s	0.06s	10.54%
	errors	35.96%	4.61%	52.09%
Memory test	correct strings	3.86	0.71	21.52%
Psychomotor test	response time	1.00s	0.21s	20.72%
	deviation	5.00mm	1.47mm	29,43%
Rate of perceived exertion		8.57	1.48	17.29%
Heart rate frequency		78.48 bt.min^{-1}	12.89 bt.min^{-1}	16.42%

Table 15: Analysis of variance of the simple response time between conditions and over time (15 minute intervals) (*significance p<0.05)

Effect	**Degrees of Freedom**	**F**	**p**
Condition	2, 58	1.55	0.22
Quarter	3, 87	4.32	<0.01*
Condition*Quarter	6, 174	1.35	0.24

Table 16: Analysis of variance of the choice response time between the two stimuli, three conditions and over time (15 minute intervals) (*significance p<0.05)

Effect	**Degrees of Freedom**	**F**	**p**
Stimulus	1, 29	2.87	0.10
Condition	2, 58	1.20	0.31
Quarter	3, 87	0.32	0.81
Stimulus*Condition	2, 58	0.20	0.82
Stimulus*Quarter	3, 87	1.48	0.23
Condition*Quarter	6, 174	1.09	0.37
Stimulus*Condition*Quarter	6, 174	3.12	<0.01*

Table 17: Analysis of variance of the percentage of choice response errors made between the two stimuli, three conditions and over time (15 minute intervals) (*significance p<0.05)

Effect	**Degrees of Freedom**	**F**	**p**
Stimulus	1, 29	<0.01	0.97
Condition	2, 58	0.29	0.75
Quarter	3, 87	7.46	<0.01*
Stimulus*Condition	2, 58	0.10	0.90
Stimulus*Quarter	3, 87	3.67	0.02*
Condition*Quarter	6, 174	2.82	0.01*
Stimulus*Condition*Quarter	6, 174	0.57	0.75

Table 18: Analysis of variance of the recognition response time between conditions and over time (15 minute intervals) (*significance p<0.05)

Effect	**Degrees of Freedom**	**F**	**p**
Condition	2, 58	0.80	0.46
Quarter	3, 87	0.11	0.96
Condition*Quarter	6, 174	0.78	0.59

Table 19: Analysis of variance of the percentage of recognition errors made between the two types of errors, three conditions and over time (15 minute intervals) (*significance p<0.05)

Effect	**Degrees of Freedom**	**F**	**p**
Type of error	1, 29	2.07	0.16
Condition	2, 58	0.74	0.48
Quarter	3, 87	0.23	0.87
Type of error*Condition	2, 58	0.83	0.44
Type of error*Quarter	3, 87	0.10	0.96
Condition*Quarter	6, 174	0.57	0.75
Type of error*Condition*Quarter	6, 174	0.88	0.51

Table 20: Analysis of variance of the number of correct strings memorized between the two length of strings, three conditions and over time (15 minute intervals) (*significance p<0.05)

Effect	**Degrees of Freedom**	**F**	**p**
Length of string	1, 29	348.85	<0.01*
Condition	2, 58	1.87	0.16
Quarter	3, 87	5.65	<0.01*
Length of string *Condition	2, 58	1.69	0.19
Length of string *Quarter	3, 87	4.22	<0.01*
Condition*Quarter	6, 174	1.04	0.40
Length of string *Condition*Quarter	6, 174	0.47	0.83

Table 21: Analysis of variance of the psychomotor response time between the two stimuli locations, two stimuli sizes, three conditions and over time (15 minute intervals) (*significance $p<0.05$)

Effect	**Degrees of Freedom**	**F**	**p**
Location	1, 29	36.60	<0.01*
Size	1, 29	63.84	<0.01*
Condition	2, 58	1.17	0.32
Quarter	3, 87	0.39	0.76
Location*Size	1, 29	6.14	0.02*
Location*Condition	2, 58	1.07	0.35
Size*Condition	2, 58	3.22	0.05*
Location*Quarter	3, 87	1.00	0.40
Size*Quarter	3, 87	1.26	0.29
Condition*Quarter	6, 174	0.51	0.80
Location*Size*Condition	2, 58	2.58	0.09
Location*Size*Quarter	3, 87	0.90	0.44
Location*Condition*Quarter	6, 174	0.71	0.64
Size*Condition*Quarter	6, 174	1.39	0.22
Location*Size*Condition*Quarter	6, 174	0.38	0.89

Table 22: Analysis of variance of the psychomotor deviation between the two stimuli locations, two stimuli sizes, three conditions and over time (15 minute intervals) (*significance $p<0.05$)

Effect	**Degrees of Freedom**	**F**	**p**
Location	1, 29	15129.12	<0.01*
Size	1, 29	48.54	<0.01*
Condition	2, 58	0.16	0.85
Quarter	3, 87	0.31	0.82
Location*Size	1, 29	557.58	<0.01*
Location*Condition	2, 58	1.66	0.20
Size*Condition	2, 58	0.29	0.75
Location*Quarter	3, 87	3.78	0.01*
Size*Quarter	3, 87	0.09	0.96
Condition*Quarter	6, 174	1.40	0.22
Location*Size*Condition	2, 58	2.32	0.11
Location*Size*Quarter	3, 87	1.49	0.22
Location*Condition*Quarter	6, 174	0.73	0.63
Size*Condition*Quarter	6, 174	1.44	0.20
Location*Size*Condition*Quarter	6, 174	1.15	0.33