The effects of distraction on threat-related changes in attention focus and postural control

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ABSTRACT

The purpose of this thesis was to investigate whether threat-related changes in attention focus and postural control could be modified using distraction. Healthy young adults (N=21) stood without (No Threat) and with (Threat) the possibility of receiving an unpredictable anterior or posterior support surface translation under conditions in which they were required to perform or not perform a distractor task. The results of the thesis showed significant threat-related changes in attention focus and postural control independent of distraction. When performing with distraction compared to without, threat-related changes in high-frequency sway (1.0-2.5 Hz) were significantly reduced, and threat-related changes in attention focus to self-regulatory strategies tended to be reduced. These findings suggest that distraction may modify threat-related changes in attention focus and postural control.

Keywords: postural control, threat, emotion, attention focus, distraction

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List of Abbreviations

COM – Centre of mass

COP – Centre of pressure

BOS – Base of support

CNS – Central nervous system

AP – Anterior-posterior

ML – Medial-lateral

MSRS – Movement-specific reinvestment scale

STAI – State-trait anxiety inventory

DOSPERT – Domain-specific risk-taking inventory

MP – Movement processes

SRS – Self-regulatory strategies

TRS – Threat-related stimuli

TII – Task irrelevant information

TO – Task objectives

DTO –Distractor task objectives

SNS – Single number sequence

LS – Letter sequence

PPV – Phobic postural vertigo

SE – Standard error

SD – Standard deviation

CHAPTER ONE: LITERATURE REVIEW

1.1 Postural control

Postural control is a requirement for the independent and safe performance of many daily activities. The postural control system involves a complex interaction of sensory (i.e., visual, vestibular, and somatosensory) and motor processes that work together to maintain the body's alignment, and balance (Horak, 2006). The primary goal of the postural control system is to control the body's centre of mass (COM) within its base of support (BOS). The COM is defined as the point in space at which the total body mass is located (Winter, 1995). The BOS is defined as the area of the body that is in contact with the environment (e.g., feet on the ground) allowing for the generation of ground reaction forces that act to control the movement of the COM (Winter, 1995). The centre of pressure (COP) is defined as the location of the weighted average of these ground reaction forces and represents the adjustments of the central nervous system (CNS) to control the COM (Winter, 1995). Thus, postural control can be considered a complex motor skill that is made more challenging by individual, task, and environmental constraints (Horak, 2006; Huxham, Goldie, & Patla, 2001).

To maintain balance and avoid falling, the postural control system must be able to adapt to meet the demands of the task and the challenge of the environment in which the task must be carried out. Postural tasks may require the COM to be maintained within a stationary BOS (e.g., during quiet standing), or controlled within a moving BOS (e.g., during walking; Winter, 1995). Standing tasks can be made more difficult by reducing the size of the BOS (e.g., two-leg to one leg stance) or altering the quality of the BOS (e.g., firm to foam support surface). Walking tasks can be made more challenging by altering the temporal (e.g., walk at a preferred pace or as fast as possible) or spatial (e.g., navigate a wide versus narrow travel path) characteristics associated with the task. In addition, walking through a cluttered and unpredictable environment (e.g., in a busy mall) will be much more demanding than navigating through an uncluttered and fully predictable environment. During the performance of these static and dynamic postural tasks, the postural control system must be able to anticipate and react to disturbances to the COM, such as a push to the trunk, or a step onto an unstable support surface. As well, these postural tasks may have to be carried out while concurrently performing other motor and cognitive tasks which can place further demands on information processing and postural control resources (Huxham et al., 2001; Woollacott & Shumway-Cook, 2002). The postural control strategies observed in response to specific task and environmental constraints can vary with individual constraints such as biological age (Sturnieks, St George, & Lord, 2008) or pathology (e.g., Parkinson's disease; Adkin, Bloem, & Allum, 2005). Thus, a complex and dynamic interaction between individual, task, and environmental constraints will influence the strategy the CNS uses to maintain postural control and avoid falling (Huxham et al., 2001).

1.2 Emotions and postural control

Emotions, such as anxiety or fear, may also constrain the postural control system. Several review papers have been written that highlight the research that has established a relationship between emotions and postural control (Hadjistavropoulos, Delbaere, & Fitzgerald, 2011; Legters, 2002; Staab, Balaban, & Furman, 2013; Young & Williams, 2015). Research has revealed differences in postural control between anxious and non-anxious individuals (Bolmont, Gangloff, Vouriot, & Perrin, 2002; Ohno, Wada, Saitoh, Sunaga, & Nagai, 2004; Perna, Dario, Caldirola, Stefania, Cesarani, & Bellodi, 2001; Wada, Sunaga, & Nagai, 2001), and between individuals who report a fear of falling and those who do not report this fear (Friedman, Munoz, West, Rubin, & Fried, 2002; Li, Fisher, Harmer, McAuley, & Wilson, 2003; Maki, Holliday, & Topper, 1991; Maki, Holliday, & Topper, 1994; Viljanen, Kulmala, Rantakokko, Koskenvuo, Kaprio, & Rantanen, 2012). For example, increased postural sway on standing tasks is observed in both anxious (Perna et al., 2001) and fearful individuals (Maki et al., 1991), compared to their non-anxious and non-fearful counterparts, respectively. Another line of research to suggest a relationship between emotions and postural control are the studies that show changes in postural control (i.e., stiffening response) when viewing images that evoke strong negative emotions (Azevedo et al., 2005; Facchinetti, Imbiriba, Azevedo, Vargas, & Volchan, 2006). Neuroanatomical evidence also provides a basis for this relationship as emotional structures in the brain (i.e., parabrachial nucleus and amygdala) project to the vestibular system, cerebellum, and basal ganglia, all important structures within the postural control system (Balaban, 2002; Staab et al., 2013). Taken together, these studies provide evidence of a link between emotions and postural control. Given this evidence, as well as the elevated levels of fear of falling reported in older adults (Legters, 2002) and individuals with balance problems (Adkin, Frank, & Jog, 2003), it is important to examine emotional constraints on postural control as these constraints may confound the assessment and treatment of postural control problems.

1.2 Postural threat models

Researchers have studied the effects of emotions, such as anxiety and fear, on static and dynamic postural control by manipulating the level of postural threat experienced by the participants. This type of experimental manipulation allows postural control strategies to be compared between non-threatening and more threatening conditions. The two primary postural threat models that have been used in the literature are the 1) surface height threat model and 2) postural perturbation (anticipation) threat model. The results of studies that use these types of experimental postural threat manipulations to understand the relationship between emotions and postural control will be discussed next.

1.3.1 Surface height threat model

Researchers have used a surface height threat model to examine the effects of anxiety and fear on static and dynamic postural control. In these experiments, researchers have manipulated the level of postural threat by having participants stand, for example, at ground level and at different surface heights above the ground (e.g., Adkin, Frank, Carpenter, & Peysar, 2000; Brown, Polych, & Doan, 2006; Carpenter, Adkin, Brawley, & Frank, 2006; Carpenter, Frank, & Silcher, 1999; Carpenter, Frank, Silcher, & Peysar, 2001; Zaback, Cleworth, Carpenter, & Adkin, 2015). When standing on an elevated surface, researchers who first used this model argued that the postural threat, or the risk of injury associated with falling, was increased, providing an opportunity to examine anxiety and fear effects on postural control (Brown & Frank, 1997). The efficacy of this model has been confirmed as converging evidence shows that participants report feeling more anxious, more fearful of falling, less confident, and less stable when standing at height (e.g., Carpenter et al., 2006; Davis, Campbell, Adkin, & Carpenter, 2009; Huffman, Horslen, Carpenter, & Adkin, 2009; Zaback et al., 2015). In addition, physiological arousal levels have been shown to be elevated, as indicated by increased skin conductance (Brown et al., 2006; Davis et al., 2009; Huffman et al., 2009; Zaback et al., 2015) and increased blood pressure (Carpenter et al., 2006), when standing at height.

The surface height threat model has primarily been used in healthy young adults to isolate the effects of anxiety and fear on postural control without the confounds of age or pathology. The most common postural task that has been studied is standing postural control. Typically, healthy young adults lean away from the edge of the elevated surface (as indicated by a shift in the mean position or average location of the COP), and demonstrate reduced amplitude of COP adjustments (as indicated by lower root-mean square or standard deviation values) coupled with an increased frequency of COP adjustments (as indicated by higher mean power frequency values) when standing at heights ranging from 0.8-m to 3.2-m above the ground (Adkin et al., 2000; Brown et al., 2006; Carpenter et al., 1999; Carpenter et al., 2006; Cleworth, Horslen, & Carpenter, 2012; Zaback et al., 2015; Cleworth & Carpenter, 2016). The changes are strongest in the anterior-posterior (AP) direction, or the direction of the imposed postural threat (Adkin et al., 2000). The combination of decreased amplitude and increased frequency of postural adjustments suggests the adoption of an ankle stiffening strategy (Winter, Patla, Prince, Ishac, & Gielo-Perczak, 1998). With the body modeled as an inverted pendulum when quietly standing, increased muscle activity around the ankle joints would act to tighten control of the COM within the limits of the BOS (Winter, 1995; Winter et al., 1998). This was experimentally confirmed by Carpenter and colleagues as healthy young adults demonstrated increased ankle muscle stiffness when standing at height (Carpenter et al., 2001). Furthermore, these threat-related changes in standing postural control have been shown to scale to the level of postural threat; for example, progressive increases in frequency and decreases in amplitude have been observed with progressive increases in surface height (Adkin et al., 2000; Davis et al., 2009).

The changes in mean position and frequency measures during standing when threatened are consistently reported. However, the effect of postural threat on the amplitude of postural adjustments has been shown to be less consistent. Although many studies have reported decreased amplitude of postural adjustments (Adkin et al., 2000; Carpenter et al., 1999, Carpenter et al., 2006; Zaback et al., 2015), others have reported no change (Huffman et al., 2009), and yet, others have reported increased amplitude of postural adjustments. For example, when individuals stand at more extreme surface heights (over 9-m; Nakahara, Takemori, & Tsuruoka, 2000; Simeonov & Hsiao, 2001), self-report a significant fear of falling (Davis et al., 2009), or self-report a greater tendency to reinvest in movement (Zaback et al., 2015), amplitude of postural adjustments is increased.

The surface height threat model has also reveal changes in postural control beyond changes in standing postural control. Research has shown changes in anticipatory postural control (Adkin, Frank, Carpenter, & Peysar, 2002; Gendre, Yiou, Gélat, Honeine, & Deroche, 2016; Zaback et al., 2015), reactive postural control (Brown & Frank, 1997; Carpenter, Frank, Adkin, Paton, & Allum, 2004), functional balance tasks (e.g., one leg stance; Hauck, Carpenter, & Frank, 2008), and normal and adaptive gait (Brown, Gage, Polych, Sleik, & Winder, 2002; McKenzie & Brown, 2004) when threatened by elevated surface height. In general, the CNS adopts strategies that provide increased caution when threatened. For example, when rising on to the toes, the anticipatory postural adjustment which acts to move the COM forward toward the edge of the platform is smaller and slower resulting in a smaller and slower forward displacement of the COM. This strategy ensures that failure on the task would result in a rocking back on to the heels instead of losing balance over the edge of the platform (Adkin et al., 2002). When responding to an external perturbation on an elevated surface, muscle activity in leg and trunk muscles is larger, and muscle activity in the arms is larger and earlier, suggestive of a strategy to limit COM movement (Brown & Frank, 1997; Carpenter et al., 2004). Individuals have a slower walking velocity, shorter stride length, and spend longer time in double support when walking at elevated surface heights (Brown et al., 2002). Reduced lead and trail limb velocity and clearance has also been observed when stepping over an obstacle in a height-related threat condition (McKenzie & Brown, 2004). This evidence across a range of postural tasks shows that when threatened with a change in surface height, the CNS adopts strategies to limit movement of the COM to provide greater safety.

The surface height threat model has also been used to examine the effects of emotions on postural control in different populations. For the most part, similar threat-related changes in quiet standing, including decreased amplitude and increased frequency of postural adjustments have been observed in older adults (Brown et al., 2006; Carpenter et al., 2006) and individuals with Parkinson’s disease (Pasman, Murnaghan, Bloem, & Carpenter, 2011).

1.3.2 Postural perturbation (anticipation) threat model

Researchers have also used a postural perturbation (anticipation) threat model to study the effect of anxiety and fear on postural control. In these experiments, researchers have manipulated the level of postural threat by having participants stand with no possibility of receiving an external postural perturbation (i.e., no threat condition) and with the possibility of receiving an external perturbation (i.e., threat condition). The perturbation has been delivered in the form of a push or pull to the upper trunk (Shaw, Stefanyk, Frank, Jog, & Adkin, 2012) or a translation of the support surface (Johnson, Zaback, Tokuno, Carpenter, & Adkin, 2017; Phanthanourak, Cleworth, Adkin, Carpenter, & Tokuno, 2016). Similar to the surface height threat model, converging evidence has also demonstrated the efficacy of this model to study the effects of anxiety and fear on postural control as participants have reported more anxiety and had elevated physiological arousal levels as indicated by increased skin conductance when standing under the expectation of a postural perturbation (Johnson et al., 2017).

Contrary to standing at elevated surface heights, the threat of receiving a postural perturbation appears to generate a different postural control strategy suggesting that threat-related changes may depend on the nature of the threat. For example, an increase in trunk sway angle and angular velocity in both roll and pitch directions has been observed in healthy young adults when standing with the threat of an AP trunk perturbation compared to without this threat (Shaw et al., 2012). With the threat in the form of an AP support surface translation, individuals adopted a forward lean, and demonstrated increased amplitude and increased frequency of COP postural adjustments (Johnson et al., 2017). A difference in postural control strategy using this type of threat compared to surface height threat has also been observed in an anticipatory postural control task. Phanthanourak and colleagues (2016) found that individuals increased the magnitude of the anticipatory postural adjustment during a rise to toes task under the threat of a medial-lateral support surface translation. This is opposite to the reduction in the magnitude of the anticipatory postural adjustment observed when rising on to the toes at height (Adkin et al., 2002; Zaback et al., 2015). The results of these three studies suggest that there is a need to consider how the nature or context of the threat can differentially influence postural control and highlights the need to explore postural control responses under different threat scenarios.

The postural perturbation threat model has also been used to study behaviour in healthy older adults and individuals with Parkinson's Disease (Shaw et al., 2012). Compared to healthy young adults who increased trunk sway when expecting a perturbation, older adults decreased trunk sway in the roll direction, while patients with Parkinson's disease did not change trunk sway when standing and expecting to receive a perturbation to the trunk (Shaw et al., 2012).

1.1 Mechanisms underlying threat-related changes in postural control

As reviewed above, research has shown that postural control is altered when faced with a threatening situation. Although this relationship is well-established, the underlying mechanisms that may contribute to, or explain these threat-related changes in postural control are less understood. Threat-related changes in physiological arousal and perceived anxiety, fear, balance confidence, and stability have been consistently reported (Brown et al., 2002; Brown et al., 2006; Carpenter et al., 2006; Davis et al., 2009; Gage, Sleik, Polych, McKenzie, & Brown, 2003; Hauck et al., 2008; Huffman et al., 2009; Pasman et al., 2011; Sturnieks, Delbaere, Brodie, & Lord, 2016; Zaback et al., 2015). Associations between these threat-related changes and threat-related changes in postural control have also been observed. For example, increased balance confidence has been shown to be associated with a decreased frequency of postural adjustments (Hauck et al., 2008;

Huffman et al., 2009), while increases in perceived stability have been shown to be associated with an increased amplitude of postural adjustments (Hauck et al., 2008). Research has also revealed threat-related changes in sensory system function (Davis et al., 2011; Horslen, Dakin, Inglis, Blouin, & Carpenter, 2014; Horslen, Murnaghan, Inglis, Chua, & Carpenter, 2013; Naranjo, Allum, Inglis, & Carpenter, 2015), as well as threat-related changes in cortical responses to unpredictable trunk perturbations (Adkin, Campbell, Chua, & Carpenter, 2008) suggesting these factors as potential mechanisms that may contribute to threat-related postural changes. In addition, changes in the allocation of attention resources when threatened may also contribute to threat-related postural changes (Huffman et al., 2009; Johnson et al., 2017; Zaback et al., 2015), and is the focus of this thesis.

1.4.1 Attention focus

When threatened, individuals may alter where they choose to direct their attention resources contributing to changes in how they control their balance. Research has shown threat-related changes in the allocation of attention resources, with these changes associated with specific modifications in postural control (Huffman et al., 2009; Johnson et al., 2017; Zaback et al., 2015, Zaback, Carpenter, & Adkin, 2016). Zaback and colleagues showed that an individuals' tendency to reinvest attention in their movement, as assessed with the Movement-Specific Reinvestment Scale (MSRS; Masters & Maxwell, 2008), was associated with threat-related changes in postural control (Zaback et al., 2015). Individuals who had a greater tendency to consciously control their movements (i.e., higher score on the conscious motor processing subscale of the MSRS) were more likely to lean further away from the edge and have larger amplitude of postural adjustments when standing on an elevated surface. Individuals who had a greater tendency to be more self-conscious of their movement appearance (i.e., higher score on the movement self-conscious subscale of the MSRS) were more likely to have smaller amplitude of postural adjustments. Research has also shown that individuals report higher state levels of conscious motor processing and movement self-consciousness using a modified state version of the MSRS when quietly standing at an elevated surface height (Huffman et al., 2009; Zaback et al., 2015). It has been observed that individuals who reported higher levels of conscious motor processing were more likely to lean further away from the edge on an elevated support surface (Huffman et al., 2009).

Research has also reported additional threat-related changes in attention focus beyond those associated with focusing on controlling and monitoring postural control. Zaback and colleagues asked individuals an open-ended question to report where they directed their attention when quietly standing under non-threatening and threatening conditions using the surface height threat model (Zaback et al., 2016). These researchers found that five attention focus categories emerged. These categories were attention focus to 1) movement processes, 2) task objectives, 3) threat-related stimuli, 4) self-regulatory (coping) strategies, and 5) task-irrelevant information. When standing at a high compared to low surface height, individuals directed more attention to movement processes, threat-related stimuli, and self-regulatory strategies, and less attention to task objectives and task-irrelevant information. Additionally, threat-related changes in attention focus were associated with threat-related changes in postural control. For example, individuals who directed more attention toward movement processes were more likely to demonstrate increases in frequency of postural adjustments and decreases in amplitude of postural adjustments when directing less attention to this category (Zaback et al., 2016). Also, participants that reported increased attention focus to self-regulatory (coping) strategies were more likely to show greater decreases in amplitude of postural adjustments (Zaback et al., 2016). Johnson and colleagues reported similar broad changes in attention focus between non-threatening and threatening conditions using the postural perturbation (anticipation) threat model (Johnson et al., 2017). When threatened, individuals directed more attention focus to movement processes, threat-related stimuli, and self-regulatory strategies, less attention focus to task-irrelevant information, and no change in attention focus to task objectives (Johnson et al., 2017). Associations were also observed between threat-related changes in attention focus and postural control but only for the condition in which participants had previous experience with responding to the postural perturbation. With this experience, increases in attention focus to movement processes were associated with leaning further forward and increases in amplitude of postural adjustments (Johnson et al., 2017). Increases in attention focus to self-regulatory strategies were associated with greater increases in the frequency of postural adjustments with experience (Johnson et al., 2017).

Considering these broad threat-related changes in attention focus and their association with threat-related changes in postural control, it is important to consider different strategies that could be used to modify attention focus when faced with a threatening condition. It is important to consider that a shift in attention focus when threatened may or may not be beneficial. For example, leaning further away from the edge of a high platform which has been associated with a more conscious control of posture would be considered a protective strategy (Huffman et al., 2009), but other research has shown that postural control was less efficient when participants were instructed to actively control their posture (Vuillerme & Nafati, 2007).

1.4.2 Distracting attention

Research has shown that instructions concerning the attention focus an individual should adopt when performing a motor skill can have a powerful effect on motor performance and learning (Wulf, 2013). In general, this research compares the effects of providing external attention focus instructions (i.e., directed to the effects of one's movements), internal attention focus instructions (i.e., directed to the mechanics of one's movements), or no specific attention focus instructions at all (control condition) on performance. The definition of an internal attention focus strategy is also consistent with directing attention to movement processes (Zaback et al., 2016). Across diverse types of motor skills, including postural tasks, an external attention focus has been shown to provide a benefit to performance compared to an internal attention focus or no specific attention focus instructions (Chiviacowsky, Wulf, & Wally, 2010; Landers, Wulf, Wallmann, & Guadagnoli, 2005; Wulf, 2013; Wulf, Landers, Lewthwaite, & Töllner, 2009). These findings are explained within the constrained action hypothesis which suggests that an external focus of attention promotes automaticity whereas an internal focus of attention interferes with automatic movement processes (Wulf, 2013).

Vuillerme & Nafati, (2007) instructed healthy young adults to focus attention on body sway and to actively intervene in controlling their posture when standing. Compared to a no instruction condition, this instructional set increased amplitude and frequency of postural adjustments in both AP and medial-lateral (ML) directions, which was interpreted as less efficient postural control. The findings of this study provide support for the negative effects of an internal attention focus on balance (Wulf, 2013). In a subsequent study, these researchers compared standing when performing a cognitive short-term memory task (i.e., recalling a series of digits in the correct order) to standing without performing this task in healthy young adults. The cognitive task was employed to determine if distracting attention away from posture influenced its control. Participants decreased amplitude and increased frequency of postural adjustments when performing the cognitive task (Nafati & Vuillerme, 2011). The researchers argued that the decrease in attention focus to postural control by having to concurrently perform an attention-demanding task allowed for the adoption of a more automated and unconstrained postural control strategy.

Research has used different cognitive tasks to distract attention away from the control of posture. The addition of a cognitive task has been shown to benefit postural control in healthy young adults (Nafati & Vuillerme, 2011; Polskaia, Richer, Dionne, & Lajoie, 2015; Richer, Saunders, Polskaia, & Lajoie, 2017a), and healthy older adults (Richer, Polskaia, & Lajoie, 2017b; Potvin-Desrochers, Richer, & Lajoie, 2017). In general, these studies have revealed that the concurrent performance of a cognitive task distracts attention away from the body thereby promoting a more automated control of posture presumably by limiting attention to posture itself.

Taken together, using an external attention focus or a concurrent cognitive task appears to promote a more automated control of posture (Nafati & Vuillerme, 2011; Polskaia et al., 2015; Richer et al., 2017a; Richer et al., 2017b; Potvin-Desrochers et al., 2017). Research has explored the effects of different cognitive tasks (specifically related to task difficulty) on postural control, as well as directly comparing whether specific attention focus instructions provide a greater benefit to posture compared to a concurrent cognitive task. Potvin-Desrochers and colleagues (2017) examined the effects of continuous and discrete cognitive tasks on postural control. They observed that performing a continuous task (mentally counting the occurrence of a pre-selected digit in an auditory sequence) increased automaticity (as evidenced by a lower standard deviation of COP postural adjustments) beyond any of the discrete tasks, when compared to performing no task at all. Other researchers compared this type of continuous task with internal and external attention focus instructions on standing postural control in healthy young (Polskaia et al., 2015; Richer et al., 2017a) and older adults (Richer et al., 2017b; Potvin-Desrochers et al., 2017). Compared to when directing attention externally towards reducing the movement of markers attached to the ankle (Richer et al., 2017a) or hips (Richer et al., 2017b), greater benefits to postural control (i.e., reduced amplitude and increased frequency of COP) were found when performing the continuous cognitive task.

This approach (i.e., cognitive task distraction) has also been used in people with phobic postural vertigo (PPV; Wuehr, Brandt, & Schniepp, 2016). When standing, individuals diagnosed with PPV have increased sway frequency, especially high-frequency sway (>0.1 Hz; Holmberg, Tjernström, Karlberg, Fransson, & Magnusson, 2009), and increased amplitude of postural adjustments (Wuehr et al., 2016) compared to healthy controls. These postural differences in people with PPV are suggested to result from a more conscious control of posture due to an anxiety related to postural control. Wuehr and colleagues (2016) revealed a normalization of postural control for people with PPV to that of healthy controls by having them perform a cognitive task (e.g., naming items from a given category) when standing. The researchers suggested that these changes were a result of distracting attention away from the anxious conscious control of posture.

Taken together, this body of research reinforces the potential benefit of using a relatively simple concurrent cognitive task to distract attention away from postural control, and as such forms the focus of this thesis. As individuals direct more attention to posture, as well as other loci of attention focus, when threatened and with these changes in attention focus associated with changes in postural control (Johnson et al., 2017; Zaback et al., 2015), there is a potential utility for using a cognitive task to distract attention away from broad changes in attention focus to modify the influence of postural threat on postural control.

CHAPTER TWO: RATIONALE & PURPOSE

2.1 Rationale

Emotions such as fear and anxiety have been shown to influence postural control (Hadjistavropoulos et al., 2011; Legters, 2002; Staab et al., 2013; Young & Williams, 2015). Fear related to falling is prevalent in older adults (Legters, 2002), and individuals who report a fear of falling have demonstrated changes in postural control (Maki et al., 1991). Therefore, there is a need to understand emotional effects on postural control.

One way that researchers have studied the effects of emotions on postural control is by using a postural threat model, such as raising the height of the support surface on which individuals stand (Brown & Frank, 1997). Height-related changes in anxiety and fear have been reported allowing for an investigation of the effects of these emotions on postural control. Height-related changes in standing (Adkin et al., 2000; Brown et al., 2006; Carpenter et al., 1999; Carpenter et al., 2001; Carpenter et al., 2006; Zaback et al., 2015), anticipatory (Adkin et al., 2002; Gendre et al., 2016; Zaback et al., 2015) and reactive postural control (Brown & Frank, 1997; Carpenter et al., 2004) as well as normal and adaptive gait (Brown et al., 2002; McKenzie & Brown, 2004) have been observed. Typically, these changes are described as cautious and protective as they act to limit body movement when threatened. However, the nature of threat appears to influence threat-related changes in postural control. For example, while expecting to receive an external perturbation (i.e., anticipation threat models), compared to not expecting a perturbation, different postural control changes have been observed (i.e., anterior lean and increased COP amplitude; Johnson et al., 2017) compared to those seen using the surface height threat model (i.e., forward lean and decreased COP amplitude; Carpenter et al., 1999; Adkin et al., 2000; Brown et al., 2006; Carpenter et al., 2006; Zaback et al., 2015).

Given these threat-related changes in postural control, researchers have explored various mechanisms that could help to explain these changes. For instance, changes in vestibular and somatosensory function (Davis et al., 2011; Horslen et al., 2014; Horslen et al., 2013; Naranjo et al., 2015) as well as cortical responses (Adkin et al., 2008) have been observed when threatened. Other researchers have looked at attention as a possible mechanism underlying these changes. When threatened, research has shown more reinvestment in movement and more attention directed to a variety of different categories (Huffman et al., 2009; Zaback et al., 2015, 2016; Johnson et al., 2017). Broad attentional changes have been reported when threatened, including more attention to movement processes, threat-related stimuli and self-regulatory (coping) strategies (Johnson et al., 2017; Zaback et al., 2015). Threat-related changes in attention focus have also been associated with threat-related postural changes (Johnson et al., 2017; Zaback et al., 2015). For example, when anticipating an AP support surface translation, individuals lean further forward and increase COP amplitude when they direct more attention to movement processes, where as increases in attention focus to self-regulatory strategies have been associated with greater increases in the frequency of postural adjustments (Johnson et al., 2017). When standing at an elevated surface height, individuals who directed more attention toward movement processes were more likely to demonstrate increases in frequency of postural adjustments and decreases in amplitude of postural adjustments when directing less attention to this category (Zaback et al., 2016).

As research suggests a broad impairment in attention when threatened, it is important to determine if distracting attention away from posture can modify threat-related attention focus and postural changes. Other research has shown that adopting an external attention focus promotes a more automatic control of posture compared to an internal attention focus, which seems to interfere with this type of control (Wulf, 2013). Moreover, focusing on the conscious control of posture has been shown to decrease efficiency of postural performance for a standing task (Vuillerme & Nafati, 2007). One way to shift attention away from posture and increase automaticity (as evidenced by increased frequency, decreased amplitude) is to simultaneously perform a relatively simple cognitive task when quietly standing in non-threatening conditions (Nafati & Vuillerme, 2011; Polskaia et al., 2015; Richer et al., 2017a; Richer et al., 2017b; Potvin-Desrochers et al., 2017). This dual task approach has also been used in people with PPV and has been shown to normalize postural control in these individuals relative to healthy controls (Wuehr et al., 2016). No research has examined the effects of this type of distraction task on threat-related attention focus and postural responses using a postural perturbation threat model.

2.2 Purpose

The purpose of this thesis is to investigate whether a cognitive distractor task can be used to modify threat-related changes in attention focus and postural control.

2.3 Hypothesis

When threatened with the expectation of a support surface translation (without distraction), it was expected that individuals would increase arousal and perceived anxiety, direct more attention to movement processes, threat-related stimuli, and self-regulatory (coping) strategies, and less attention to task objectives and task irrelevant information, lean further forward, and display a larger COP amplitude and higher COP frequency of postural adjustments (Johnson et al., 2017), especially high frequency sway (>0.1 Hz; Wuehr et al., 2016).

When threatened with the expectation of a support surface translation (with compared to without distraction), it was expected that individuals would show no change in arousal and anxiety, direct more attention to the distractor task and less attention to movement processes, threat-related stimuli, self-regulatory (coping) strategies, task objectives, and task-irrelevant information, not lean as far forward, and display lower COP amplitude and COP frequency of postural adjustments, especially high frequency sway (>0.1 Hz; Wuehr et al., 2016). It was also expected that the changes in attention focus and postural control would be greater when performing a more compared to less challenging distractor task (Polskaia & Lajoie, 2016).

CHAPTER THREE: METHODS

3.1 Participants

A total of 23 participants were collected, but outliers resulted in 21 being analyzed (11 females, 10 males; mean ± standard deviation = 22.81 ± 2.42 years). All participants had no self-reported neurological, or musculoskeletal condition(s) that could influence their balance. Participants were recruited from the undergraduate and graduate student population at Brock University through word of mouth, announcements made in class, and posters placed around the university campus. Participants provided written informed consent prior to the start of any of the experimental procedures.

3.2 Procedure

The Brock University Biosciences Research Ethics Board approved all experimental procedures (BREB#17-355; Appendix A). Testing was conducted in the Biomechanics and Motor Control Laboratory at Brock University. For all experimental conditions, participants were instructed to stand on a force plate (OR6-7, AMTI, Watertown, MA, USA). The force plate was surrounded by a wooden platform (0.9m x 1.6m) fitted flush with its surface. The force plate and wooden platform were affixed to a 4.3m linear positioning stage (H2W Technologies Inc., Valencia, CA, USA). Participants were instructed to stand with bare-feet, adopt a stance width equal to their foot length, have their arms relaxed at the sides, and focus their gaze on an eye-level target located in front of them 4-m away, these instructions were consistent across all trials. A trace of the participants' feet was made on the force plate in order to keep stance position consistent across all experimental conditions. To ensure safety throughout the experiment, participants wore a harness that was attached to a track secured to the ceiling. The harness only provided support to the participant in the event of a fall.

3.2.1 Distractor task manipulation

Participants were asked to stand while performing three distractor task conditions: Control (i.e., no task), Single Number Sequence (SNS; Polskaia et al., 2015; Richer et al., 2017a; Richer et al., 2017b; Potvin-Desrochers et al., 2017), and Letter Sequence (LS; Polskaia & Lajoie, 2016). For all task conditions, participants received the same instructions related to the task objectives; 1) to stand quietly; 2) to have their arms relaxed at their sides; and 3) to have their gaze focused on an eye-level target located in front of them 4-m away. These instructions are typically provided for quiet standing tasks (e.g., Johnson et al., 2017) and were referred to as task objective instructions in this thesis. In the Control task condition, participants stood quietly and were not required to perform any additional task. In the SNS task condition, participants stood quietly, and mentally counted the occurrence of a pre-selected digit in an auditory sequence of 3-digit numbers presented every 3-s (i.e., 3-2-4, 5-8-0, 1-4-3, etc). In the LS task condition, participants stood quietly and mentally counted the occurrence of a pre-selected letter in an auditory sequence of letters presented every 2-seconds (i.e., A-J-K-V-C-D, etc). Participants were instructed to prioritize the distractor task in the LS and SNS conditions. The tasks were selected based on: 1) their low difficulty level (to minimize increases in physiological arousal that could influence postural measures; Maki & McIlroy, 1996); 2) continuous nature (to maximize distraction throughout the trial); and 3) the lack of articulation during the trial (to avoid articulation effects on postural measures; Dault, Yardley, & Frank, 2003).

3.2.2 Postural threat manipulation

Postural threat was manipulated by having participants stand with no possibility of receiving an external postural perturbation (No Threat) and with the possibility of receiving an external postural perturbation (Threat). The perturbation was an unpredictable support surface translation in the forward or backward direction (displacement = 0.20 m, peak velocity = 0.5 m/s, peak acceleration = 0.7 m/s^2). This type of perturbation has been used in previous research to manipulate the level of postural threat and elicit a step response (Johnson et al., 2017; Phanthanourak et al., 2016). Additionally, as perturbation experience has been shown to modify threat-related postural responses (Johnson et al., 2017), participants were exposed to the postural threat before measuring their standing response to anticipating the perturbation. As such, participants experienced the perturbation in both directions before performing the 62-s Threat trial that was analyzed (Table 1).

3.2.3 Procedures

Upon arrival, participants first completed a demographic and health questionnaire to assess age, biological sex, and health status (Appendix B). Next, participants completed a series of questionnaires to assess level of trait anxiety, physical risk-taking, and movement reinvestment. These questionnaires were randomly presented to each participant. Trait anxiety was measured using the State-Trait Anxiety Index (STAI; Spielberger, Gorsuch, Lushene, Vagg, & Jacobs, 1983). This questionnaire consists of 20 items and reflects the level of anxiety experienced on a regular basis. Participants rated on a 4-point Likert scale ranging from 1 (“almost never”) to 4 (“almost always”) how they felt in general about each item (Appendix C). Higher scores on the STAI reflect higher levels of trait anxiety. Risk taking was measured using the Domain-Specific Risk-Taking (DOSPERT; Blais & Weber, 2006). The DOSPERT consists of 30 items and evaluates willingness to engage in risky behaviours across 5 content domains (ethical, social, health and safety, financial, and recreational). Each item was rated on a 7-point Likert scale from 1 (“extremely unlikely”) to 7 (“extremely likely”; Appendix D). Higher scores reflect more risk-taking behavior. Movement reinvestment was measured using the Movement Specific Reinvestment Scale (MSRS; Masters, Eves, & Maxwell, 2005). The MSRS consists of 10 items and assesses propensity for controlling and/or monitoring movement. The MSRS has 2 subscales; conscious motor processing (tendency to consciously control movement) and movement self-consciousness (tendency to monitor movement style). Participants rated how they felt on a 6-point scale ranging from “strongly disagree” to “strongly agree” for each item (Appendix E). Higher scores reflect more reinvestment in movement. Following the completion of the questionnaires, anthropometric measures, including height, weight, foot length, and heel-to-ankle length were obtained (Appendix B).

Participants stood under three task conditions (Control, LS, and SNS). Within each task condition, participants stood in No Threat and Threat conditions. The order of experimental conditions is outlined in Table 1.

First, all participants completed a single 62-s quiet standing trial with no possibility of a perturbation. For this trial, all participants received the task objective instructions (i.e., stand quietly, arms at sides, eyes focused on target). This trial was designated as ‘practice’ and used to address potential first trial effects (Adkin et al., 2000), and prime participants for all state questionnaires (Johnson et al., 2017).

Table 1: Order of experimental conditions

Distraction	**Threat**	**Duration(s)**	**Perturbation**	**State Questionnaires**
Control	Practice	62	None	Yes
Control	No Threat	62	None	Yes
Forward and backward platform movement was demonstrated				
Control	Threat	5	Forward	No
Control	Threat	30	Backward	No
Control	Threat	62	Forward	Yes
Distractor task performed (60-s each) while seated				
Distractor-SNS	No Threat	62	None	Yes
Distractor-SNS	Threat	30	Backward	No
Distractor-SNS	Threat	62	Forward	Yes
Distractor-SNS	Threat	15	Forward	No
Distractor task performed (60-s each) while seated				
Distractor-LS	No Threat	62	None	Yes
Distractor-LS	Threat	45	Backward	No
Distractor-LS	Threat	30	Forward	No
Distractor-LS	Threat	62	Forward	Yes

Note: SNS=single number sequence; LS=letter sequence; Control condition always performed first. SNS and LS conditions were counter-balanced.

Participants always completed the Control task condition first to assess the initial effect of postural threat without confounds of performing the distractor tasks. In the Control condition, participants stood quietly with no distractor task, for 4 trials: 1) No Threat (62-s; no perturbation), 2) Threat (perturbation after 5-s of quiet standing), 3) Threat (perturbation after 30-s of quiet standing), and 4) Threat (perturbation after 62-s of quiet standing). Trial 1 (No Threat) was identical to the practice trial in terms of: 1) no distractor task; 2) postural threat (i.e., no possibility of a perturbation); 3) instructions (i.e., stand quietly, arms at sides, eyes focused on target); and 4) duration (i.e., 62-s).

Following Trial 1 (No Threat), platform movement in the forward and backward directions was demonstrated. Only quiet standing data prior to the perturbation from trials 1 and 4 (62-s standing trials) were analyzed.

The following two task conditions were similar to the Control condition (Table 1) in terms of postural threat, and instructions provided (i.e., stand quietly, arms at sides, eyes focused on target). The only difference was participants were required to perform a distractor task (SNS or LS). An instructor explained how to perform each task and had them practice the task for 62-s in a seated position prior to the respective conditions. In the SNS condition, 4 trials were performed: 1) No Threat (62-s; no perturbation), 2) Threat (perturbation after 30-s of quiet standing), 3) Threat (perturbation after 62-s of quiet standing), and 4) Threat (perturbation after 15-s of quiet standing). As in the Control condition, only quiet standing data prior to the perturbation from the 62-s trials were analyzed. The LS condition also consisted of 4 trials: 1) No Threat (62-s; no perturbation), 2) Threat (perturbation after 45-s of quiet standing), 3) Threat (perturbation after 30-s of quiet standing), and 4) No Threat (perturbation after 62-s of quiet standing). As in the Control condition, only quiet standing data prior to the perturbation from the 62-s trials were analyzed. The SNS and LS task conditions were presented in a counter-balanced order.

Physiological arousal and postural measures were obtained during each 62-s No Threat and Threat trial. Following each of the 62-s No Threat and Threat trials (Table 1), participants were seated at a location off the moving platform and completed a series of state questionnaires to assess: worry-related and somatic anxiety (Appendix F, Johnson et al., 2017), and attention focus (Appendix G, Johnson et al., 2017; Zaback et al., 2016).

3.3 Dependent measures

3.3.1 Arousal

Changes in physiological arousal during each 62-s standing trial were estimated through electrodermal activity (EDA100C, BIOPAC Systems Inc., Goleta, USA). Two Ag/AgCl electrodes were placed on the thenar and hypothenar eminences of the non-dominant hand (Fowles et al., 1981). The placement location ensured participants could answer questionnaires without disturbing the electrode placements. Electrodermal activity data was recorded using Spike2 software (CED, Cambridge, UK) and A-D sampled at 1000Hz (Micro1401, CED, Cambridge, UK). The measure used to summarize this signal was the total number of phasic responses over the duration of the trial (electrodermal response, EDR). EDRs represent a tonic measurement of electrodermal activity and were defined as a peak greater than 0.08mS/s that remained greater than 0.04mS/s for at least 400ms to either side of the peak (Boucsein et al., 2012)

3.3.2 Perceived anxiety

After each 62-s standing trial, participants completed a questionnaire assessing their worry-related and somatic-related perceived anxiety (Appendix F). Each question was rated on a scale ranging from 0 (“Not at all worried”; “Not at all anxious”) to 9 (“Very worried”; “Very anxious”), respectively (Smith, Smoll, & Schutz, 1990). Responses to these two questions were averaged to provide a single measure of anxiety (Johnson et al., 2017).

3.3.3 Attention focus

Following each 62-s standing trial, participants were asked to rate how much they focused on movement processes (MP), task objectives (TO), threat-related stimuli (TRS), self-regulatory strategies (SRS), and task-irrelevant information (TII; Zaback et al., 2015; Johnson et al., 2017). A category called distractor task objectives (DTO) was added as a manipulation check to ensure participants were adequately attending to the cognitive tasks. A 9-point Likert scale from 1 (“Not at all”) to 9 (“Very much so”) was used to assess how much attention was allocated to the categories listed above (Appendix F).

3.3.4 Postural control

Ground reaction forces and moments from the force plate were sampled at 1000Hz (matched EDR collection frequency), and low-pass filtered offline using a dual-pass second order Butterworth filter with a cut-off frequency of 5Hz. The COP, which reflects the weighted average of pressure applied by the feet on the force plate, was calculated from this data. For each 62-s standing trial, COP mean position (MPOS), root mean square (RMS), and mean power frequency (MPF) summary measures was calculated in the anterior-posterior (AP) direction as COP changes are strongest in the direction of the imposed threat (Adkin et al., 2000; Johnson et al., 2017). COP-MPOS reflects the average location of the COP as referenced to the ankle joint and how far individuals leaned away from this reference point (Johnson et al., 2017). MPF-COP reflects the average frequency contained within a power spectrum following Fast Fourier Transformation (FFT) which bins the power amplitude at each frequency (Winter & Patla, 1997). COP-RMS reflects the amplitude variability in relation to COP-MPOS. FFT was also performed on multiple, non-overlapping frequency bins which were isolated and examined to see significant differences in COP power across the frequency band (Reynolds, 2010). These measures were defined COP power within 0-0.1 Hz, 0.1-1.0 Hz, 1.0-2.5 Hz, 2.5-5.0 Hz. Following the FFT, the total amount of sway within these frequency bins was calculated as a sum in millimeters.

3.4 Statistical analysis

Descriptive statistics were calculated for demographic (i.e., age, height, weight) and personality trait measures (i.e., STAI, DOSPERT-physical risk taking, MSRS-CMP, MSRS-MSC). As well, descriptive statistics were calculated for physiological arousal, perceived anxiety, attention focus, and postural control measures for each distractor task and threat condition. Descriptive statistics were also calculated for the percentage of errors made when performing the distractor tasks in each threat condition.

A 2 (task: SNS, LS) x 2 (threat: No Threat, Threat) repeated measures analysis of variance (RM-ANOVA) was conducted for the percentage of errors made when performing the distractor tasks. A significant interaction effect was explored by examining follow-up comparisons for each task between No Threat and Threat conditions.

A 3 (task) x 2 (threat) RM-ANOVA procedure was conducted for each physiological arousal, perceived anxiety, attention focus and postural control measure. The tasks consisted of three levels: Control, LS, and SNS. The threat consisted of two levels: Threat and No Threat conditions. Mauchly's test was performed to ensure sphericity, or the amount of variance between conditions, was equal. If Mauchly's test was significant, the Greenhouse-Geisser correction was used to adjust degrees of freedom and determine if any main, or interaction effects were found following the correction. Significance level was set to $p<0.05$. Significance values between 0.05 and 0.10 were considered trends (Pritschet, Powell, & Horne, 2016). Post-hoc pairwise comparisons were conducted if significant task main effects were found to investigate differences between Control, LS, and SNS tasks. Any significant interaction effect was explored by examining the effect of task in the No Threat condition and Threat condition separately.

CHAPTER FOUR: RESULTS

4.1 Data screening and statistical assumptions

4.1.2 Outliers

Two of the 23 participants who volunteered were not included in the final statistical analysis due to excessively small RMS-COP values that could not be resolved, or too many outlying variables. Therefore, the total sample size was reduced to 21 participants (10 males; mean age ± standard deviation = 22.81 ± 2.42 years) for the remainder of the statistical analysis. For this sample of healthy young adults, personality trait scores (Table 6) revealed similar levels of trait anxiety, physical risk taking, movement reinvestment, and movement self-consciousness to past research (Zaback et al., 2015).

All variables were screened for univariate outliers. This included all individual characteristics in addition to No Threat and Threat values gathered for all psychological, physiological, attention focus, and postural control measures while performing the SNS, LS, and Control distractor conditions. To check for univariate outliers, data for these variables were converted to standardized z-scores. A z-score greater or less than ± 3.29 was identified as a univariate outlier. If a variable fit this criteria it was replaced by a value ± 3 standard deviations of the mean in the direction it was previously outlying. After replacements for each variable were made, data was screened again, and any new outliers were replaced using the same method (Tabachnick & Fidell, 2007). This procedure was repeated until no new outliers emerged. The final mean and standard error values for all measures are presented in Table 6 and Table 7.

4.1.3 Normality

Normality was assessed for all variables. This included all individual characteristics, in addition to Threat and No Threat values in the SNS, LS, and Control task conditions for all psychological, physiological, attention focus, and postural control measures. Normality was assessed by examining the skewness and kurtosis statistics for each variable with significance set at $p<0.001$. Significance was determined by converting each skewness and kurtosis statistic to a z-score by dividing each value by its own standard error. Any values greater or less than ±3.29 were considered significantly skewed or kurtotic (Field, 2013). A log10 transformation was performed on all significantly skewed and kurtotic measures, but because there was no major change to the results original values were kept for the analysis. Furthermore, it has also been suggested that if the values presented by the measures are deemed to be meaningful that a transformation is not recommended (Tabachnick & Fidell, 2007). As such, no transformations were used for the analysis. See Table(s) 2-5 for a summary skewed and kurtotic data.

Table 2: Skewness and kurtosis statistics for personality trait measures

	Skewness	Kurtosis
ANX-T	0.36	-0.37
PRT	-0.24	-0.62
CMP-T	-0.33	-1.12
MSC-T	0.44	-0.31

Note: ANX-T=state-trait anxiety inventory; PRT=domain specific risk-taking scale; CMP-T=conscious motor processing scale; MSC-T=movement self-consciousness scale. Bold font indicates significant skewness or kurtosis with p<0.001.

Table 3: Skewness and kurtosis statistics for physiological and psychological measures

	No Threat		Threat	
	Skewness	Kurtosis	Skewness	Kurtosis
		Control		
ANX-S	1.58	2.92	-0.72	0.76
EDR	-0.53	-0.52	-0.01	-0.83
		LS		
ANX-S	0.55	-1.11	-0.36	-0.18
EDR	0.12	-1.19	0.62	-0.66
		SNS		
ANX-S	1.16	0.69	-0.20	-1.00
EDR	0.06	-1.64	0.05	-0.78

Note: LS=letter sequence; SNS=single number sequence; *ANX-S=self-reported anxiety; EDR=electrodermal response. Bold font indicates significant skewness or kurtosis with p<0.001.*

Table 4: Skewness and kurtosis statistics for attention focus measures

	No Threat		Threat	
	Skewness	Kurtosis	Skewness	Kurtosis
		Control		
MP	0.91	0.27	-0.67	0.10
TO	0.28	-1.20	0.26	-0.40
TRS	1.41	1.63	-0.27	-0.10
SRS	0.49	-0.53	-0.09	0.07
TII	-0.14	-1.34	0.91	-0.53
DTO	-	-	-	-
		LS		
MP	1.66	**4.31**	0.17	-1.34
TO	0.79	-0.22	0.20	-0.88
TRS	1.49	0.80	-0.08	-0.65
SRS	0.44	-1.41	0.39	-0.82
TII	0.88	-0.74	0.69	-1.06
DTO	-0.55	1.24	-0.82	1.06
		SNS		
MP	**1.65**	2.51	0.45	-1.10
TO	0.85	-0.19	0.40	-1.00
TRS	**1.71**	1.90	0.23	-1.31
SRS	0.64	-0.75	-0.003	-1.35
TII	1.17	-0.17	1.17	-0.34
DTO	-0.35	0.25	-0.99	0.33

Note: LS=letter sequence; SNS=single number sequence; MP=movement processes; TO=task objectives; TRS=threat-related stimuli; SRS=self-regulatory strategies; TII=task irrelevant information; DTO=distractor task objectives. Bold font indicates significant skewness or kurtosis with p<0.001.

Table 5: Skewness and kurtosis statistics for postural control measures

	No Threat		Threat	
	Skewness	Kurtosis	Skewness	Kurtosis
		Control		
MPOS-COP	1.12	2.11	0.26	0.42
RMS-COP	0.93	1.34	1.41	2.77
MPF-COP	0.87	0.08	1.37	3.01
0-0.1 Hz	1.24	1.19	1.49	1.74
0.1-1.0 Hz	0.70	-0.46	1.57	1.48
1.0-2.5 Hz	0.83	-0.33	**2.18**	**4.21**
2.5-5.0 Hz	1.37	1.42	**1.83**	2.75
		LS		
MPOS-COP	0.75	0.61	0.88	2.02
RMS-COP	0.23	-1.54	0.12	-0.70
MPF-COP	0.43	-0.87	0.31	-0.35
0-0.1 Hz	**1.89**	**4.58**	**2.11**	**5.02**
0.1-1.0 Hz	1.04	1.00	0.32	-0.62
1.0-2.5 Hz	0.50	-0.65	0.03	-1.43
2.5-5.0 Hz	**1.74**	**4.18**	**1.87**	**4.47**
		SNS		
MPOS-COP	0.66	0.14	0.33	-0.72
RMS-COP	1.28	2.29	1.46	**5.22**
MPF-COP	1.26	1.40	1.20	0.70
0-0.1 Hz	**1.98**	**4.62**	**1.72**	**4.66**
0.1-1.0 Hz	0.79	0.37	1.45	1.27
1.0-2.5 Hz	**2.47**	**6.18**	0.23	-0.70
2.5-5.0 Hz	**1.85**	**3.36**	1.37	1.82

Note: COP=center of pressure; LS=letter sequence; SNS=single number sequence; MPOS=mean position; MPF=mean power frequency; RMS =root mean square. Bold font indicates significant skewness or kurtosis with $p<0.001$.

4.1.4 Assumption of sphericity

Mauchly's test was used to assess sphericity. If a violation occurred, the Greenhouse-Geisser correction was used to adjust the degrees of freedom and create a more conservative F-ratio. According to Field (2013), if the Greenhouse-Geisser estimate is above 0.75 the correction is too conservative and the Huynh-Feldt correction should be used instead. There was only one case where this occurred (ε=0.758), but in the Huynh-Feldt was even more conservative (ε=0.807), so the Greenhouse-Geisser corrected values were used. Therefore, there were only two cases of which sphericity was violated and the Greenhouse-Geisser correction was used; task effects for 1.0-2.5 Hz sway and interaction effects for 1.0-2.5 Hz sway.

4.2 Experimental results

Descriptive statistics for personality trait measures (i.e., STAI, DOSPERT-physical risk taking, MSRS-CMP, MSRS-MSC) are presented in Table 6. Descriptive statistics for physiological and psychological measures, attention focus measures, and postural control measures for each distractor task and threat condition are presented in Table 7; a summary of the 3 (task) by 2 (threat) RM-ANOVAs for these measures is presented in Table 8. Descriptive statistics for the percentage of errors made when performing the distractor tasks in each threat condition are presented in Table 9.

Table 6: Mean and standard deviation (SD) values for all personality trait measures

	Mean	SD	Min.	Max.
Personality Trait Measures				
ANX-T	41.14	9.41	27	62
PRT	25.29	9.07	8	40
CMP-T	20.05	4.16	12	26
MSC-T	16.67	5.29	7	28

Note: ANX-T=state-trait anxiety inventory; PRT=domain specific risk-taking scale; CMP-T=conscious motor processing scale; MSC-T=movement self-consciousness scale.

Table 7: Mean and standard error (SE) values for all physiological, psychological, attention focus, and postural control measures for all experimental conditions

	Control		LS		SNS	
	No Threat	*Threat*	*No Threat*	*Threat*	*No Threat*	*Threat*
Physiological & Psychological Measures						
EDR (µS)	9.14 (0.95)	13.86 (0.95)	8.57 (1.13)	12.29 (1.06)	8.24 (1.32)	11.95 (1.24)
ANX-S (sum)	2.45 (0.33)	5.50 (0.36)	2.62 (0.34)	5.60 (0.44)	2.79 (0.43)	5.45 (0.50)
*Attention Focus Measures**						
MP (sum)	3.76 (0.48)	5.85 (0.41)	3.24 (0.40)	4.52 (0.55)	2.81 (0.45)	4.81 (0.50)
TO (sum)	4.90 (0.52)	6.19 (0.32)	4.48 (0.42)	5.62 (0.45)	4.24 (0.51)	5.33 (0.48)
TRS (sum)	2.00 (0.31)	5.48 (0.43)	2.10 (0.36)	5.14 (0.50)	1.90 (0.33)	5.00 (0.55)
SRS (sum)	3.38 (0.36)	5.24 (0.41)	3.33 (0.48)	4.19 (0.50)	3.19 (0.43)	4.33 (0.46)
TII (sum)	4.29 (0.49)	3.10 (0.46)	3.19 (0.53)	3.24 (0.51)	2.76 (0.50)	2.71 (0.50)
DTO (sum)	-	-	7.62 (0.21)	7.67 (0.22)	7.67 (0.23)	8.24 (0.19)
Postural Control Measures						
MPOS-COP (mm)	33.20 (3.85)	40.70 (4.15)	32.20 (3.63)	36.90 (3.50)	34.30 (3.67)	39.80 (3.96)
RMS-COP (mm)	5.06 (0.36)	5.41 (0.34)	4.37 (0.25)	4.49 (0.30)	4.39 (0.31)	5.10 (0.35)
MPF-COP (Hz)	0.15 (0.015)	0.26 (0.022)	0.18 (0.016)	0.26 (0.027)	0.19 (0.022)	0.24 (0.026)
0-0.1 Hz (mm)	158.20 (28.33)	112.50 (19.33)	90.80 (16.48)	80.90 (17.96)	97.40 (20.9)	125.20 (20.66)
0.1-1.0 Hz (mm)	6.49 (0.85)	10.92 (1.59)	5.45 (0.66)	6.26 (0.65)	5.99 (0.76)	8.62 (1.08)
1.0-2.5 Hz (mm)	0.201 (0.029)	0.826 (0.18)	0.212 (0.032)	0.451 (0.058)	0.254 (0.066)	0.568 (0.076)
2.5-5.0 Hz (mm)	0.007 (0.0011)	0.021 (0.0037)	0.005 (0.0007)	0.014 (0.0024)	0.006 (0.0009)	0.022 (0.0038)

*Note: LS=letter sequence; SNS=single number sequence; EDR=electrodermal response; ANX-S=perceived state anxiety; MP=movement processes; TO=task objectives; TRS=threat-related stimuli; SRS=self-regulatory strategies; TII=task irrelevant information; DTO=distractor task objectives; COP=center of pressure; MPOS=mean position; RMS=root mean square; MPF=mean power frequency. * Questions used to assess attention focus are presented in Appendix G.*

Table 8: Summary of 3 (task) by 2 (threat) RM-ANOVA

	Threat			Task			Task x Threat		
	F-ratio	*P-value*	ηp^2	*F-ratio*	*P-value*	ηp^2	*F-ratio*	*P-value*	ηp^2
Physiological & Psychological Measures									
EDR	**38.60**	**<0.001**	**0.659**	2.52	0.093	0.112	0.77	0.487	0.035
ANX-S	**70.45**	**<0.001**	**0.779**	0.19	0.822	0.010	0.35	0.710	0.017
Attention Focus Measures									
MP	**23.25**	**<0.001**	**0.538**	**10.35**	**<0.001**	**0.341**	2.06	0.141	0.093
TO	**14.76**	**0.001**	**0.425**	2.23	0.121	0.100	0.07	0.937	0.003
TRS	**48.16**	**<0.001**	**0.492**	0.79	0.459	0.038	0.49	0.563	0.024
SRS	**19.37**	**<0.001**	**0.987**	**4.31**	**0.020**	**0.177**	3.00	0.061	0.131
TII	1.81	0.194	0.083	**3.65**	**0.035**	**0.154**	**3.93**	**0.028**	**0.164**
Postural Control Measures									
MPOS-COP	**14.15**	**0.001**	**0.414**	2.00	0.149	0.091	0.91	0.413	0.043
RMS-COP	1.75	0.201	0.081	**4.98**	**0.012**	**0.199**	0.83	0.444	0.040
MPF-COP	**13.10**	**0.002**	**0.396**	0.27	0.765	0.013	2.13	0.133	0.096
0-0.1 Hz	0.25	0.623	0.012	**3.27**	**0.049**	**0.140**	2.16	0.129	0.097
0.1-1.0 Hz	**7.68**	**0.012**	**0.277**	**8.14**	**0.001**	**0.289**	2.40	0.104	0.107
1.0-2.5 Hz	**15.73**	**0.001**	**0.440**	3.75	0.053	0.158	**4.03**	**0.038**	**0.168**
2.5-5.0 Hz	**23.55**	**<0.001**	**0.541**	**3.53**	**0.039**	**0.150**	2.25	0.118	0.101

Note: EDR=electrodermal response; ANX-S=perceived state anxiety; MP=movement processes; TO=task objectives; TRS=threat-related stimuli; SRS=self-regulatory strategies; TII=task irrelevant information; COP=center of pressure; MPOS=mean position; RMS=root mean square; MPF=mean power frequency. Significant differences (p<0.05) are highlighted in bold font.

4.2.1 Task performance

A significant task main effect was revealed for percentage of errors made in distractor task performance ($F_{(1, 20)}$=15.84, *p*=0.001, ηp^2=0.442). Participants made significantly more errors when performing the SNS compared to the LS distractor task. The threat main effect and task by threat interaction were not significant. Table 9 displays the percentage of errors made in distractor task performance across task and threat conditions.

Table 9: Mean and standard error values for percentage of errors made in distractor task performance

	Seated	No Threat	Threat
SNS	0.95% (0.66)	8.57% (1.59)	8.10% (1.64)
LS	2.38% (1.18)	3.33% (1.26)	2.38% (1.18)

Note: SNS=single number sequence; LS=letter sequence.

4.2.2 Physiological and psychological measures

There was a significant main effect of threat for EDR ($F_{(1, 20)}$=38.60, *p*<0.001, ηp^2 =0.659). Independent of task conditions, EDR was significantly higher in the Threat compared to No Threat condition (Figure 1A). There was a trend for a main effect of task for EDR ($F_{(1, 20)}$=2.52, *p*=0.093, ηp^2 =0.112). Follow-up comparisons revealed that individuals had a higher EDR in the Control (11.50 ± 0.791) compared to SNS (10.09 ± 1.217, *p*=0.059) and LS (10.43 ± 1.04, *p*=0.118) conditions. The task by threat interaction was not significant (Table 8).

A significant threat main effect was observed for perceived anxiety ($F_{(1, 20)}$=70.45, p<0.001, ηp^2 =0.779). Independent of task conditions, participants reported higher levels of anxiety in the Threat compared to No Threat condition (Figure 1B). The task main effect and task by threat interaction was not significant (Table 8).

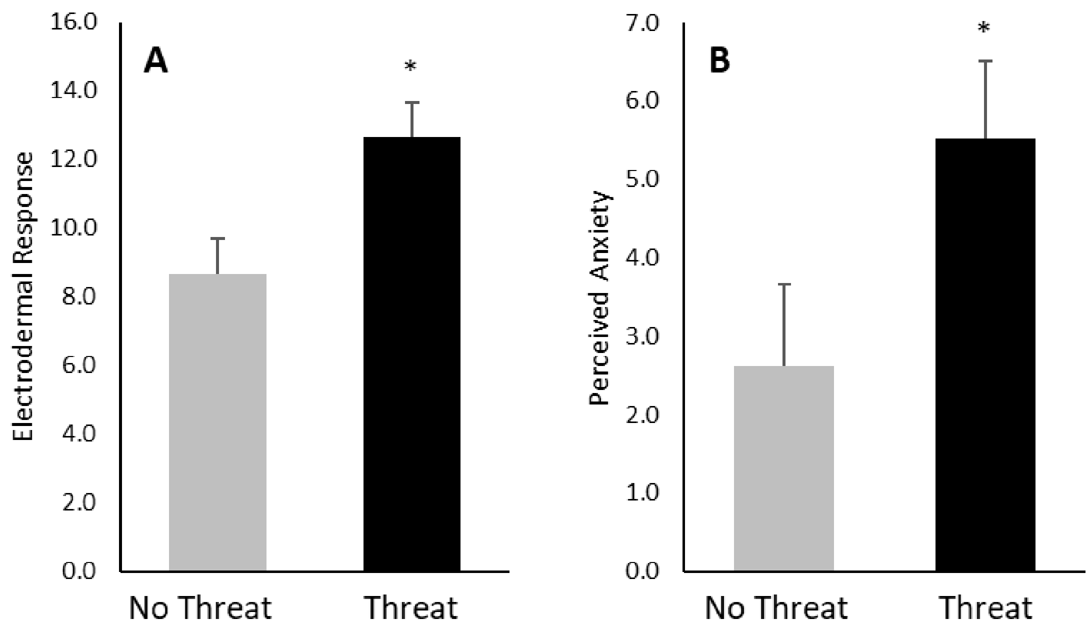

Figure 1: Threat main effects for physiological and psychological measures. (A) electrodermal response (µS), (B) self-reported perceived anxiety. Bars represent mean values while error bars represent 1 standard error. *Indicates a significant difference (p<0.05) from the No Threat condition.

4.2.3 Attention focus measures

There was a significant main effect of threat for attention focus to MP ($F_{(1, 20)}$=23.25, p<0.001, ηp^2 =0.538,). Independent of task conditions, individuals directed more attention to MP in the Threat compared to No Threat condition (Figure 2A). A significant task main effect was also observed for attention focus to MP ($F_{(2, 40)}$=10.35, p<0.001, ηp^2=0.341). Follow-up comparisons showed that individuals directed more attention to MP in the Control (4.81 ± 0.40) compared to the LS (3.88 ± 0.42, p=0.002) and SNS

(3.81 ± 0.41, $p<0.001$) task conditions; no significant difference was observed between the LS and SNS tasks ($p=0.780$). A significant task by threat interaction was not observed (Table 8).

There was a significant threat main effect for attention focus to TO ($F_{(1, 20)}=23.25$, $p<0.001$, $\eta p^2=0.538$,). Independent of task conditions, individuals directed more attention to TO in the Threat compared to No Threat condition (Figure 2B). The task main effect and task by threat interaction were not significant (Table 8).

There was a significant main effect of threat for attention focus to TRS ($F_{(1, 20)}=48.16$, $p<0.001$, $\eta p^2=0.707$). Independent of task conditions, individuals directed more attention to TRS in the Threat compared to No Threat condition (Figure 2C). The task main effect and task by threat interaction were not significant (Table 8).

There was a significant main effect of threat for attention focus to SRS ($F_{(1, 20)}=19.37$, $p<0.001$, $\eta p^2=0.492$). Independent of task conditions, individuals directed more attention to SRS in the Threat compared to No Threat condition (Figure 2D). A significant task main effect was also observed for attention focus to SRS ($F_{(2, 40)}=4.31$, $p=0.020$, $\eta p^2=0.177$). Follow-up comparisons showed that individuals directed more attention to SRS in the Control (4.31 ± 0.34) compared to the SNS (3.76 ± 0.41, $p=0.008$) task conditions; no significant difference was observed between the LS and SNS tasks ($p=1.000$). Of note, there was a trend observed for the task by threat interaction for attention focus to SRS ($F_{(2, 40)}=3.00$, $p=0.061$, $\eta p^2=0.131$; Figure 3A), which would have superseded the threat and task main effects. Follow-up comparisons revealed no significant differences between the three tasks in the No Threat condition (all p's > 0.31). In the Threat condition, there was a decrease in attention focus to SRS for the LS (*p*=0.014) and SNS (p=0.004) tasks compared to the Control task while there was no difference between the LS and SNS tasks (*p*=0.658).

A significant task by threat interaction was observed for TII ($F_{(2, 40)}$=3.93, *p*=0.028, ηp^2=0.164; Figure 3B). Follow-up comparisons revealed that in the No Threat condition, attention focus to task irrelevant information was lower in the LS (*p*=0.009) and SNS (*p*=0.002) tasks compared to the Control task; there was no difference between the LS and SNS tasks (*p*=0.353). There was no difference between the three tasks in the Threat condition (all *p*'s >0.305)

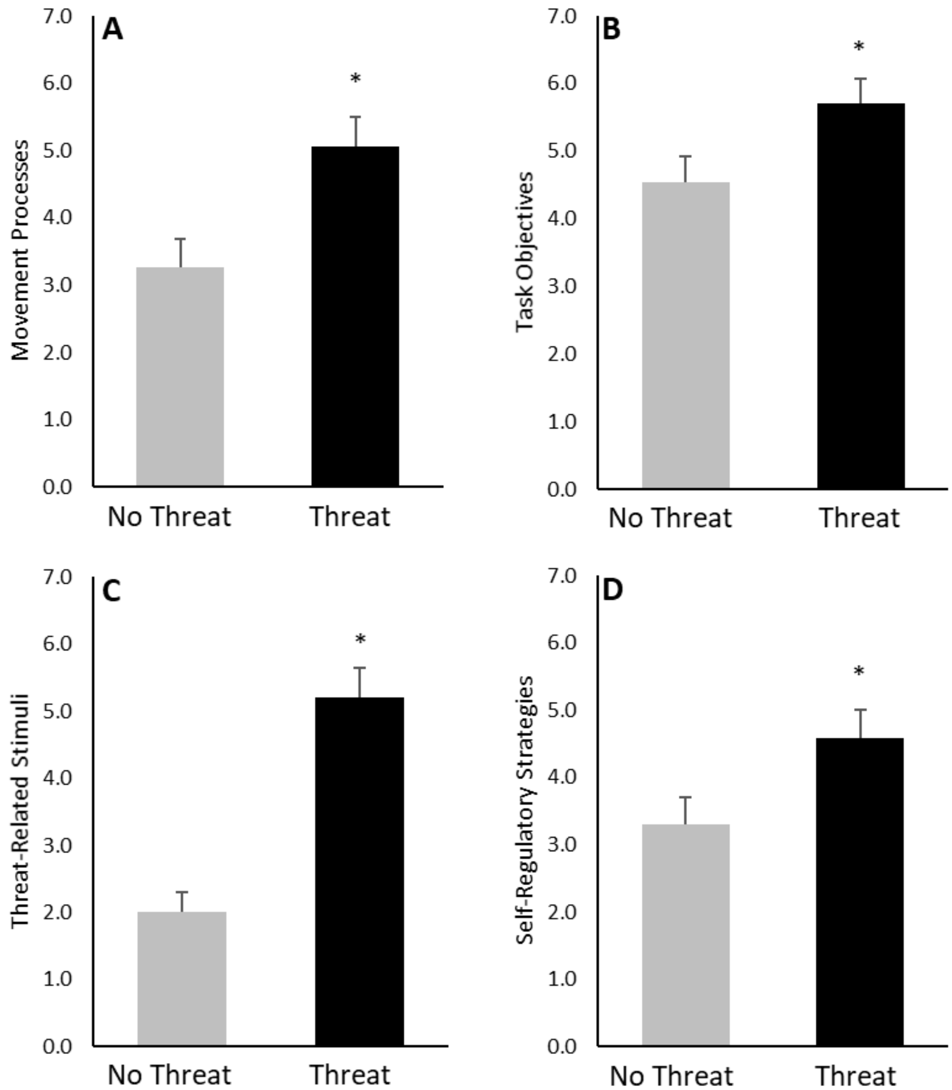

Figure 2: Threat main effects for attention focus measures to (A) movement processes, (B) task objectives, (C) threat-related stimuli, and (D) self-regulatory strategies. All figures represent mean ± 1 standard error values based on a 9-point Likert scale. *Indicates a significant difference ($p<0.05$) from the No Threat condition

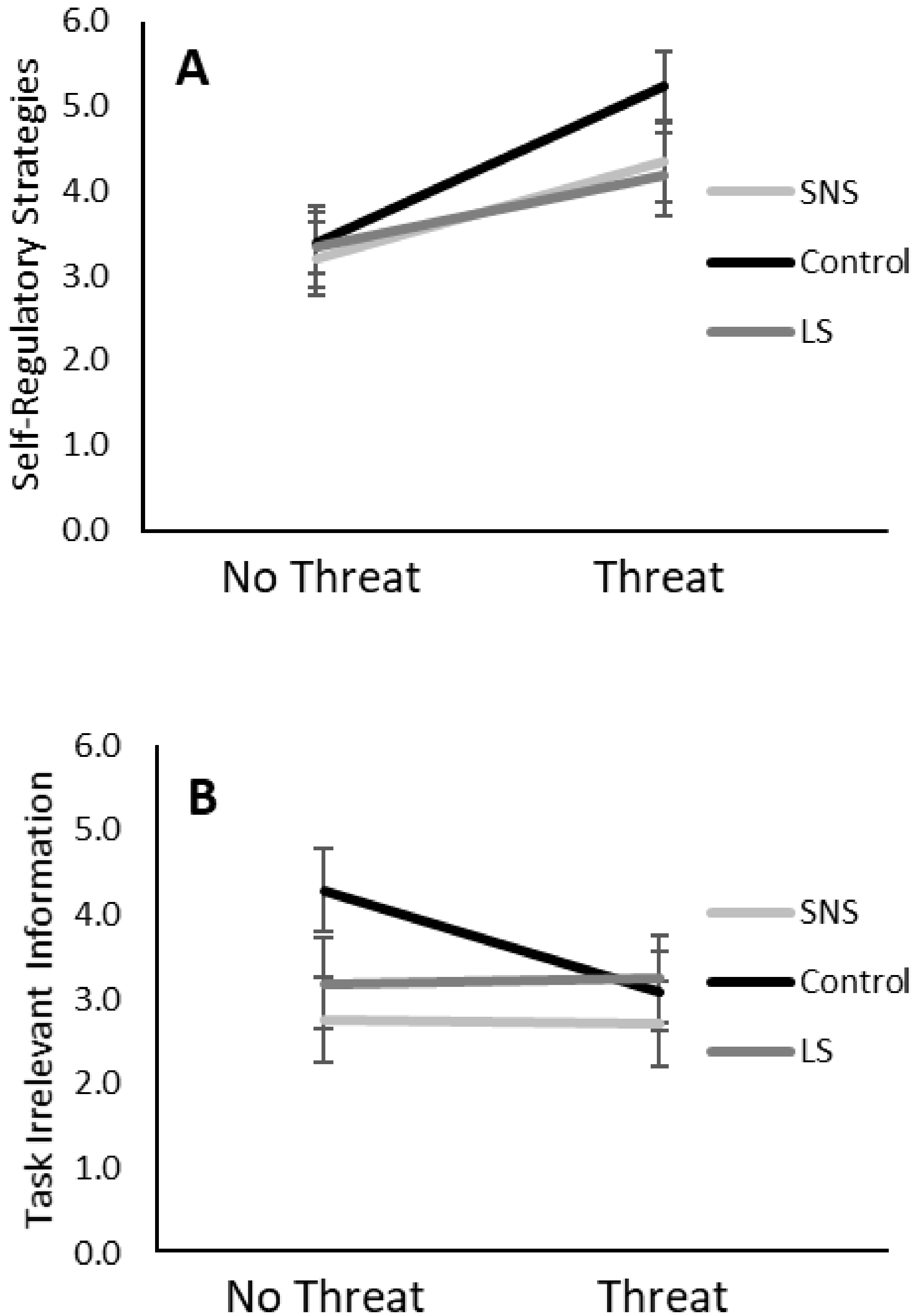

Figure 3: Task by threat interaction effects for attention focus to (A) self-regulatory strategies (trend; p=0.061) and (B) task-irrelevant information (p=0.028). Both figures represent mean ± 1 standard error values based on a 9-point Likert scale. *Note: SNS=single number sequence; LS=letter sequence.*

4.2.4 Postural control measures

There was a significant main effect of threat for MPOS-COP ($F_{(1, 20)}$=14.15, p=0.001, ηp^2=0.414). Independent of task conditions, individuals leaned further forward in the Threat compared to No Threat condition (Figure 4A). The task main effect and the task by threat interaction were not significant (Table 8).

There was no significant main effect of threat for RMS-COP (Figure 4B). There was a significant task main effect revealed for RMS-COP ($F_{(2, 40)}$=4.98, p=0.012, ηp^2=0.199). Follow-up comparisons showed that RMS-COP was significantly greater in the Control (5.23 ± 0.25) compared to the LS (4.43 ± 0.24, p=0.003) task condition, but was not different from the SNS (4.74 ± 0.26, p=0.074) task. There was no difference in RMS-COP between the LS and SNS (p=0.257) task conditions. A significant task by threat interaction was not observed (Table 8).

There was a significant main effect of threat for MPF-COP ($F_{(1, 20)}$=13.10, p=0.002, ηp^2=0.396). Independent of task conditions, MPF-COP increased in the Threat compared to No Threat condition (Figure 4C). The task main effect and task by threat interaction were not significant (Table 8).

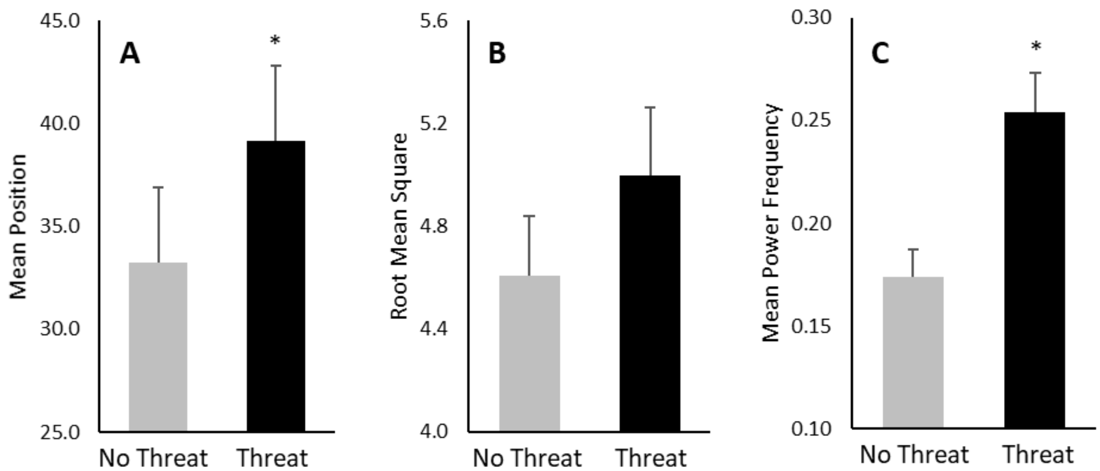

Figure 4: Threat main effects for postural control measures (A) mean position (mm) referenced to the ankle joint, (B) root mean square amplitude (mm), and (C) mean power frequency (Hz) of centre of pressure (COP). All figures represent mean ± 1 standard error values. *Indicates a significant difference ($p<0.05$) from the No Threat condition.

There was no significant main effect of threat for COP power within 0-0.1 Hz (Figure 5A). A significant task main effect was observed for COP power within 0-0.1 Hz ($F_{(2, 40)}=3.26$, $p=0.049$, $\eta p^2=0.140$). Follow-up comparisons revealed COP power within 0-0.1 Hz to be significantly greater in the Control (135.32 ± 17.24) compared to the LS (85.87 ± 14.48, $p=0.019$) task but not different from the SNS (111.30 ± 14.48, $p=0.141$) task. There was also no difference between the LS and SNS ($p=0.271$) tasks for COP power within 0-0.1 Hz. A significant task by threat interaction was not observed (Table 8).

There was a significant main effect of threat for COP power within 0.1-1.0 Hz ($F_{(1, 20)}=7.68$, $p=0.012$, $\eta p^2=0.277$). Independent of task, individuals COP power within 0.1-1.0 Hz was greater in the Threat compared to No Threat condition (Figure 5B). A significant task main effect was also observed for COP power within 0.1-1.0 Hz ($F_{(2, 40)}=8.14$, $p=0.001$, $\eta p^2=0.289$). Follow-up comparisons showed that COP power within 0.1-1.0 Hz was significantly greater in Control (8.71 ± 0.94, $p=0.001$) and SNS (7.31 ±

0.65, p=0.012) compared to the LS (5.85 ± 0.52) task condition, but no significant difference between the Control and SNS (p=0.103) task was observed. A significant task by threat interaction was not observed (Table 8).

There was a significant task by threat interaction revealed for COP power within 1.0-2.5 Hz ($F_{(1.516, 30.327)}$=4.03, p=0.038, ηp^2=0.168). The interaction effect is displayed in Figure 6. Follow-up comparisons revealed no significant differences between the three tasks in the No Threat condition (all p's > 0.506). In the Threat condition, there was a decrease in COP power within 1.0-2.5 Hz for the LS (p=0.032) and SNS (trend; p=0.090) tasks compared to the Control task while there was also a reduction in this measure for the LS compared to SNS task (trend; p=0.078).

There was a significant main effect of threat for COP power within 2.5-5.0 Hz ($F_{(1, 20)}$=23.55, p<0.001, ηp^2=0.541). Independent of task, COP power within 2.5-5.0 Hz was higher in the Threat condition compared to the No Threat condition (Figure 5D). A significant task main effect was also observed for COP power within 2.5-5.0 Hz ($F_{(2, 40)}$=3.53, p=0.039, ηp^2=0.150). Follow-up comparisons showed significantly greater COP power within 2.5-5.0 Hz for the Control (0.014 ± 0.002, p=0.021) and SNS (0.014 ± 0.002, p=0.024) compared to the LS (0.009 ± 0.001) task condition. No differences were found between the Control and SNS (p=0.959) distractor task conditions. A significant task by threat interaction was not observed (Table 8).

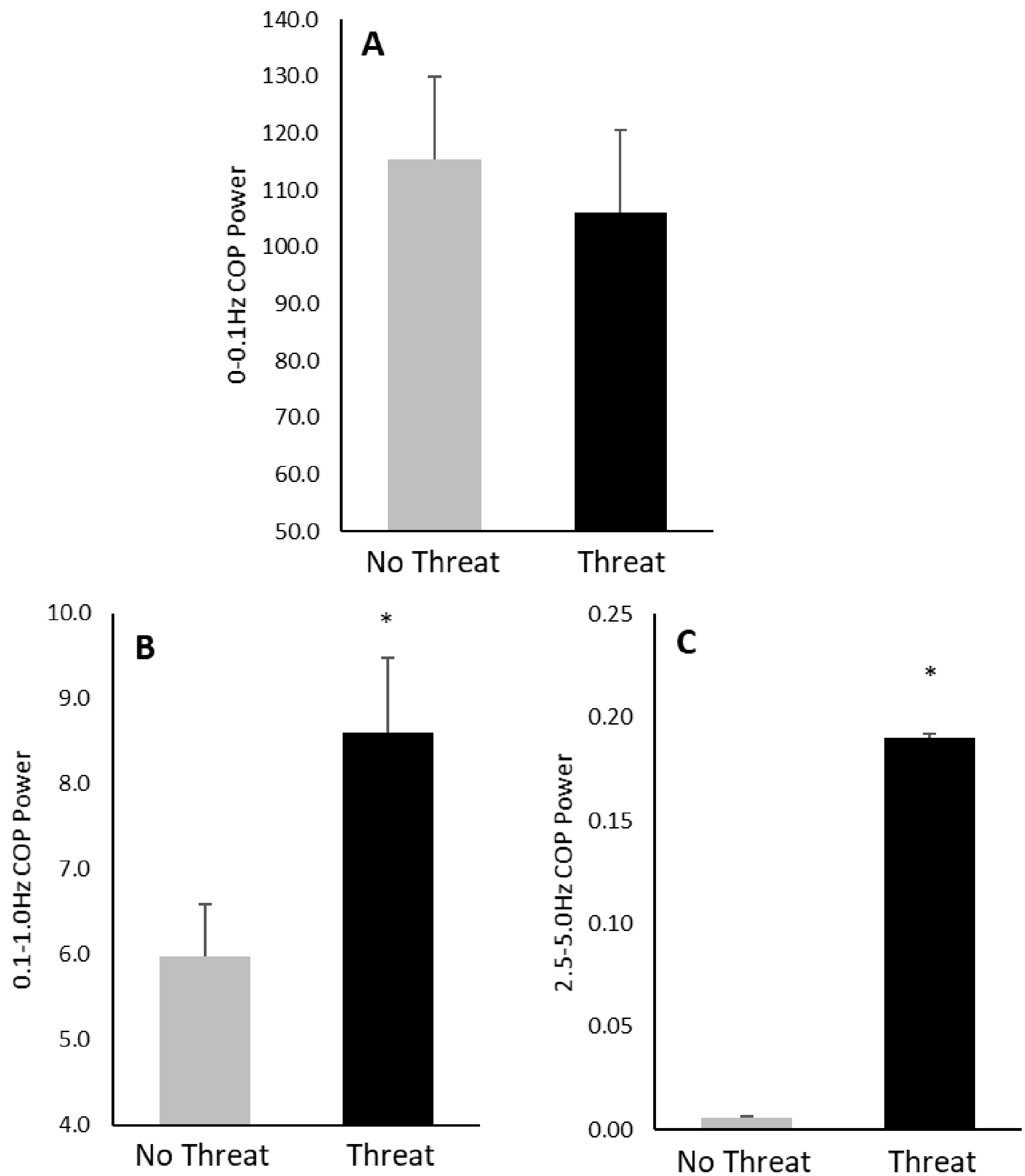

Figure 5: Threat effects for COP power within (A) 0-0.1Hz, (B) 0.1-1.0Hz, and (C) 2.5-5.0Hz. All figures represent mean ± 1 standard error values. *Indicates significant difference (p<0.05) from the No Threat condition.

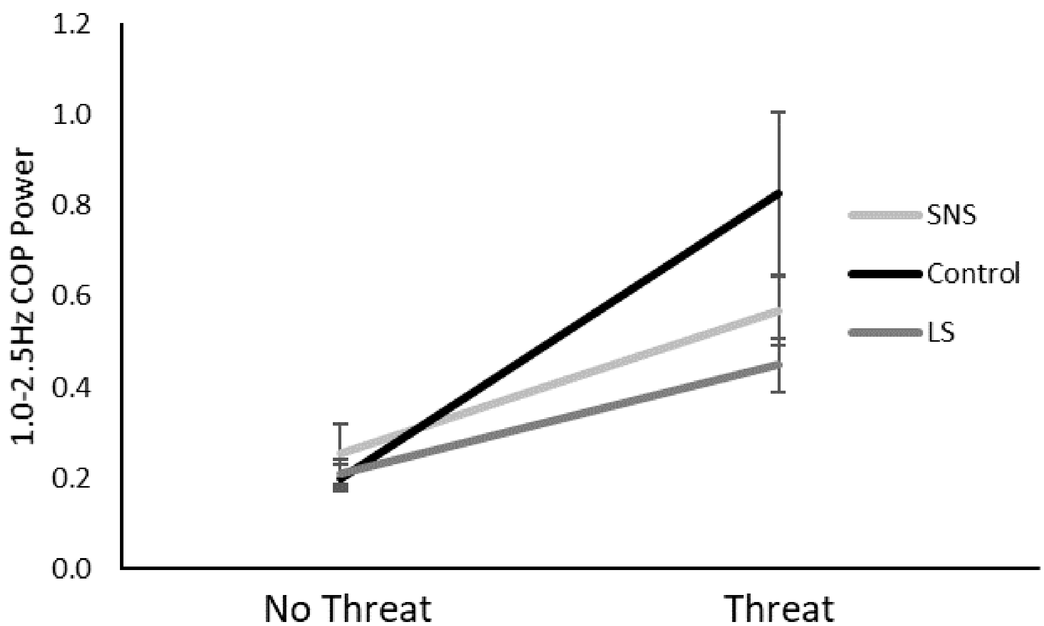

Figure 6: Significant task by threat interaction of COP power within 1.0-2.5Hz. This figure represents mean ± 1 standard error values. *Note: SNS=single number sequence; LS=letter sequence.*

CHAPTER FIVE: DISCUSSION

The purpose of this thesis was to investigate whether threat-related changes in attention focus and postural control could be modified by distracting attention away from posture by having participants perform a cognitive distractor task. A postural perturbation (anticipation) threat model known to generate threat-related changes in emotions, attention focus, and postural control was used (Johnson et al., 2017). The novel manipulation employed in this thesis was to compare threat-related changes in attention focus and postural control between conditions in which participants performed no additional task or a distractor task. The tasks, mentally counting the occurrence of a pre-selected letter in a sequence of letters or a pre-selected number in a sequence of numbers, were selected to distract participants from directing attention to movement processes (posture), or other loci of attention focus (e.g., threat-related stimuli, self-regulatory strategies, movement processes, etc.) when threatened, while requiring minimal cognitive load and limiting increases in arousal that might interfere with or confound postural control.

The results of the thesis showed significant changes in attention focus and postural control when threatened; the threat was confirmed by a significant increase in self-reported perceived anxiety as well as a significant increase in physiological arousal (as indicated by an increased number of electrodermal responses). When threatened, participants directed more attention to movement processes (posture), self-regulatory (coping) strategies, task objectives, and threat-related stimuli, and demonstrated changes in postural control which included leaning further forward and increasing frequency of COP displacements, especially higher frequency sway (>0.1 Hz). The introduction of the distractor tasks only significantly influenced COP power within 1.0-2.5 Hz, with a smaller threat-related increase observed when performing the tasks, specifically the letter sequence, compared to not having to perform the tasks. Contrary to the hypotheses, the addition of the distractor tasks did not significantly modify attention focus. However, there was a trend (p=0.061) for a reduction in threat-related attention focus to self-regulatory strategies (e.g., tactics employed to remain confident, calm, or focused) when the distractor tasks were added. The results of the thesis were, for the most part, able to replicate but also extend the work (i.e., findings related to threat-related changes in higher frequency sway components) of Johnson and colleagues (2017). The findings of the thesis also provide some evidence that the performance of a distractor task can modify aspects of sway frequency, and albeit not significantly, threat-related changes in attention focus (i.e., self-regulatory strategies). Future research is needed to examine whether broad threat-related changes in attention focus can be modified by other types of purposeful distraction with the resultant changes in attention focus associated with postural changes.

5.1 Psychological and physiological response

The postural perturbation (anticipation) threat model has been used in the past to study the effects of postural threat on attention focus and postural control (Johnson et al., 2017). These researchers confirmed the efficacy of this threat model by reporting psychological (e.g., increased self-reported perceived anxiety) and physiological (e.g., increased electrodermal activity) changes when standing with, compared to without, the possibility of receiving a postural perturbation in the form of a support surface translation. This postural threat model was employed for this thesis, and the results reinforced that this type of threat was able to generate a significant psychological and physiological response. Participants reported significantly higher levels of perceived anxiety and had an elevated number of electrodermal responses when standing with, compared to without, the possibility of receiving a forward or backward support surface translation. The threat-related psychological and physiological changes were observed independent of the task condition, suggesting that the performance of a distractor task, whether the letter or number sequence, did not significantly alter this response. To avoid potential confounds of arousal on postural control (Maki & McIlroy, 1996), the letter and number sequence tasks, which were considered less challenging tasks (Polskaia & Lajoie, 2016), were used to only distract attention away from movement processes (posture) or other attention focus loci such as self-regulatory strategies or threat-related stimuli, while not further increasing physiological arousal levels.

5.2 Attention focus

The results of this thesis revealed that individuals directed more attention focus to movement processes (posture), threat-related stimuli, task objectives, and self-regulatory strategies when threatened with the possibility of a postural perturbation, independent of the task condition. This broad shift in attention focus to multiple loci is, for the most part, in line with past research that has examined postural threat effects on attention focus. For example, a shift to a more conscious control of posture (Huffman et al., 2009; Zaback et al., 2015), as well as broad changes in attention focus (e.g., more attention to movement processes, self-regulatory strategies and threat-related stimuli; Johnson et al., 2017; Zaback et al., 2016) have been reported when standing on an elevated surface and when standing in anticipation of a postural perturbation. In contrast with a decrease (Zaback et al., 2016) or no change (Johnson et al., 2017) in attention focus to task objectives when threatened, the results of this thesis showed an increase in attention focus to task objectives. These differences may result from the different context associated with the threat or the duration of the quiet standing period prior to the perturbation threat, respectively.

Contrary to the hypotheses, threat-related changes in attention focus to movement processes (posture), self-regulatory strategies, task objectives, and threat-related stimuli were not significantly modified by the addition of the distractor cognitive tasks. The only loci of attention focus that was influenced by the distractor tasks, as evidenced by a significant task by threat interaction, was attention focus to task-irrelevant information. When quietly standing without distraction, participants directed less attention to task-irrelevant information in the Threat compared to No Threat condition. This threat-related decrease in attention focus for this measure was not observed when a distraction was present; the interaction was due to less attention being directed to task-irrelevant information when distracted in the No Threat conditions. As expected, when not threatened and not required to perform a distractor task, participants reported directing more attention focus to thoughts unrelated to the task at hand. It appears that an added postural threat and/or distractor task results in a reduction in attention focus to task-irrelevant information most likely due to attentional resources being directed to more task relevant information.

The results of the thesis suggest that the distractor tasks selected did not influence threat-related changes in attention focus. The lack of threat-related changes observed in these attention focus measures with distraction may have resulted from the challenge posed by the distractor tasks. As the difficulty associated with both the letter and number sequence tasks was thought to be low (Polskaia & Lajoie, 2016), it is possible that participants were still able to direct attention focus to movement processes (posture) as well as other loci of attention foci when threatened. To support this view, participants made few errors when completing the task in both No Threat (Mean ± SE; LS=3.33 ± 1.26 %, SNS=8.57 ± 0.16%), and Threat (Mean ± SE; LS=2.38 ± 1.18%, SNS=8.10 ± 1.64%) conditions and self-reported directing high amounts of attention focus to the cognitive task in both No Threat (Mean ± SE; LS=7.62 ± 0.21, SNS=7.67 ± 0.23) and Threat (Mean ± SE; LS=7.67 ± 0.22,SNS=8.24 ± 0.19) conditions. Even though the distractor tasks were to be prioritized and these observations suggest that participants in fact did adhere to this instruction, participants may have been able to successfully perform the distractor tasks and still have the available cognitive resources to direct attention to other loci when threatened resulting in the lack of threat-related changes in attention focus. This interpretation suggests a ceiling effect on threat-related changes in attention focus and postural control when performing these distractor tasks. Along these lines, Brown et al. (2002) discovered that healthy young adults enhanced performance on the Brooks' spatial letter task when standing in a threatening compared to non-threatening condition suggesting that cognitive resources were not exceeded in this scenario. The assessment of attention focus may have been further confounded by the self-report nature of the attention focus questionnaire used, and its susceptibility to expectation and desirability bias across threat and distractor task conditions.

Despite the lack of significant differences in the attention focus measures with distraction, the influence of distraction on attention focus to self regulatory strategies will be discussed. There was a trend (*p*=0.061) for a reduction in threat-related attention to self-regulatory strategies when individuals performed the distractor tasks. This attention focus question probed strategies that participants used to remain confident, calm, and/or focused (Johnson et al., 2017; Zaback et al., 2016). Thus, participants when threatened and not distracted may have engaged in specific coping strategies in an effort to remain confident, calm, and/or focused. With the addition of a distractor task, it appears that participants were less able to direct attention to these coping strategies when threatened (Figure 3A). This could be because the use of coping strategies may be susceptible to distraction as research has shown that practice is needed to effectively implement this type of strategy (Wilson, 2008).

The primary objective of the thesis was to determine if a distractor task could act to shift attention away from the control of posture (Wuehr et al., 2016; Polskaia & Lajoie, 2016). The results of this thesis were not able to demonstrate that the distractor task was able to influence threat-related changes in attention to movement processes (posture). An examination of the means for attention focus to movement processes reveals non-significant reductions in threat-related attention focus directed to movement processes when performing a distractor task (*p*=0.141). Again, the nature of the cognitive task may have resulted in the lack of expected differences. Wuehr and colleagues (2016) employed a similar type of distraction paradigm in patients with PPV but used a word categorization task; this type of task may have provided a greater distraction to shift attention from posture or other loci when threatened. Alternatively, it is possible that the attention focus question related to movement processes did not capture specific aspects of posture (e.g., even weight displacement over BOS, muscle contractions, actively controlling sway, etc.) that if assessed individually may have been influenced by the distractor task.

In summary, broad changes in attention focus similar to past research were observed in response to anticipating a postural threat in the form of an anterior-posterior support surface translation. The distractor tasks employed in this study did not appear to influence these threat-related attention focus changes.

5.3 Postural control

The results of the thesis were, for the most part, able to replicate the work of Johnson et al. (2017) showing threat-related postural changes using the postural perturbation model. When standing and anticipating a perturbation in the anterior-posterior direction, participants leaned further forward and demonstrated increases in frequency of COP displacements. However, whereas Johnson and colleagues showed an increase in amplitude of COP displacement, the current thesis showed no change in this measure when threatened. The sample duration used in the current thesis (60s) compared to the sample duration (30s) used by Johnson and colleagues (2017) may explain the incongruent findings. Research suggests that sample durations of 60s or longer provide a more reliable representation of amplitude-based measures and that comparisons should be limited to comparable sample durations (Carpenter et al., 2001; van der Kooij, Campbell, & Carpenter, 2011). In addition, studies using surface height threat models have shown less consistent threat-related amplitude changes compared to the more consistently observed changes in frequency-based measures or leaning (Huffman et al., 2009). Moreover, when performing a secondary task (e.g., Brooks' spatial letter task), increases in surface height were found to have no significant effect on postural control in healthy young adults, but improvements in secondary task performance were found instead (Brown et al., 2002). This suggests that healthy young adults can prioritize a relatively simple secondary task under postural threat without significantly influencing their control of posture. Although, it is possible that these findings would change if the difficulty of the task and challenge of the context increased.

The results of this thesis also extend the work of Johnson and colleagues by reporting threat-related changes in high frequency sway (i.e., range 0.1 to 5.0 Hz). Most postural threat studies have reported increases in frequency as evidenced by increases in mean power frequency. An examination of the higher frequency ranges was prompted by research in more anxious populations (e.g., patients with PPV exhibiting differences in higher frequency sway compared to controls; Krafczyk, Schlamp, Dieterich, Haberhauer, & Brandt, 1999). The results provide support in healthy individuals that a postural threat that induces changes in perceived anxiety generates an increase in higher frequency sway. Research suggests that higher frequency postural sway (>0.1 Hz) is characteristic of an anxious control of posture (i.e., people with PPV; Holmberg et al., 2009; Wuehr et al., 2016), which has been experimentally confirmed by Krafczyk et al. (1999) who specified significant increases in COP power within 3.53-8 Hz. The current thesis extends this research as evidenced by healthy individuals increasing high frequency sway (>0.1 Hz) when exposed to an anxiety inducing situation characterized as the anticipation of a support surface translation.

The results of this thesis also showed that most of the threat-related postural changes described above were not influenced by the distractor task. The one exception was COP power within 1.0-2.5 Hz. The results showed a reduction in threat-related increases in

COP power within 1.0-2.5 Hz when performing a distractor task compared to no task. The results support the hypothesis that the distractor task would reduce the threat-related changes of COP power within 1.0-2.5 Hz. This work partially supports Wuehr and colleagues (2016) who identified a normalization of postural control for people with PPV to that of healthy controls by having them perform a concurrent cognitive task (i.e., naming items from a given category). These findings suggest that the ability to reduce aspects of high frequency sway with a distraction is not limited to chronically anxious populations (e.g., people with PPV) and may have the potential to influence high frequency sway in other populations where emotions confound postural control.

Thus, the results of this thesis show threat-related reductions in high frequency sway and a trend toward reductions in attention focus to self-regulatory strategies. Limited research has reported associations with changes in attention focus and changes in postural control in response to a postural threat (Zaback et al., 2016; Johnson et al., 2017). This work has reported an association between attention focus to self-regulatory strategies and mean power frequency (Zaback et al., 2016; Johnson et al., 2017); directing more attention to self-regulatory strategies was related to greater increases in mean power frequency. Thus, it is possible that the reductions in attention focus to self-regulatory strategies when distracted, albeit non-significant, may underlie the threat related reduction in aspects of high frequency sway when distracted.

5.4 Distractor task effects

There were no significant differences between distractor task conditions, independent of threat condition, for the psychological and physiological response. There was a trend (p=0.093) for lower physiological arousal levels when performing the distractor tasks specifically the single number sequence. As arousal has been shown to influence postural control, this result may suggest that it is necessary to consider the potential influence of changes in arousal when using distractor tasks.

Some differences between task conditions were observed for the attention focus measures. Specifically, differences were observed for attention focus to movement processes, and self-regulatory strategies. Irrespective of threat conditions, participants directed significantly less attention to these categories when performing both the LS and SNS when compared to the Control task. This suggests that past research was correct in their prediction that performing a concurrent cognitive task can effectively direct attention way from the conscious control of posture (Wuehr et al., 2016), in addition to the other attention categories, but this was independent of the threat condition.

Results of this thesis also revealed differences in postural control measures between task conditions, including: RMS amplitude, 0-0.1 Hz, 0.1-1.0 Hz, and 2.5-5.0 Hz COP power, regardless of the threat condition. Interestingly, these measures were significantly lower when performing a distractor task compared to performing no task, albeit the LS demonstrated the greatest difference compared to the SNS. These results could be explained by the corresponding decreases in attention focus to self-regulatory strategies and movement processes when performing a cognitive task compared to performing no task. To elaborate, more attention to these categories has been previously associated with increases in amplitude and frequency of postural adjustments, respectively (Johnson et al., 2017). It is possible that the decreased attention to these categories in the current thesis could be driving the reduction in higher frequencies of postural sway and RMS when performing these distractor tasks. Alternatively, lower RMS values when performing the distractor tasks, independent of threat condition, could be attributed to the introduction of the distractor tasks; similar effects have been previously reported when standing and performing a concurrent cognitive task (Polskaia et al., 2015; Richer et al., 2017a; Richer et al., 2017b; Potvin-Desrochers et al., 2017). Although most postural and attention focus measures did not reveal any significant interactions, these measures are moving in the direction that was hypothesized. Once again, further research is needed to confirm this interpretation.

5.5 Limitations & future directions

There are several limitations to consider when interpreting the results of this thesis. One limitation is that the results are only generalizable to healthy young adults. It is possible that different findings may emerge for older adults, individuals with balance deficits, or individuals with a fear of falling. Another limitation is that the results are only generalizable to the postural perturbation (anticipation) threat model. As there is evidence that the nature of the postural threat can influence behaviour, the results of the thesis may be different for other types of perceived physical threats (surface height) or social evaluative threats (Geh, Beauchamp, Crocker, & Carpenter, 2011). Another limitation is the assessment of attention focus using self-report questionnaires which may have expectancy and desirability bias; participants may not have reported directing attention to specific categories if they had not been prompted. Further, specific loci of attention focus that may have been modified through distraction may not have been assessed.

The experimental design of this thesis contains some limitations as well. First, the order of task performance has the potential to influence the results as the order of task conditions was not completely randomized. The conditions were completed in this order to determine initial threat effects without the potential confound of a distractor task. Due to the order of conditions where No Threat and Threat without a distraction are always performed first, there is a potential for adaptation of the threat-related effects with repeated exposure to the postural threat. That said, a small group of participants (n=7) who performed all the experiment trials but without any distractor tasks showed non-significant adaptations with exposure to the threat. Future research may consider the use of a between-subjects design to avoid this limitation.

Another limitation to this thesis was method of delineating frequency bins to assess COP power within a given range (Krafczyk et al., 1999; Redfern, Yardley, & Bronstein, 2001; Wuehr et al., 2016). It is possible that the examination of different bins may have yielded different results. In addition, this thesis only examined changes in quiet standing to the threat of a support surface translation. As the strategy (e.g., stepping) used to maintain stability in response to the perturbation was not captured, the effectiveness of the changes in stance control in anticipation of the perturbation can not be determined.

Another limitation of this thesis is that the distractor tasks selected may have not provided enough of a challenge to distract attention from posture to generate the expected modifications to threat-related changes in attention focus and postural control. Future research should examine whether other distractor-type tasks (e.g., more difficult, and/or more purposeful) can substantiate these modifications to threat-related changes in attention focus and, subsequently, postural control. This could include mindfulness techniques such as meditation, tai chi, yoga, or the alexander technique. All of which have the potential to purposefully distract attention by promoting steady thoughts, fluid movements (Jahnke, Larkey, Rogers, Etnier, & Lin, 2010), and inhibiting automated and anxious responses to external stimuli (Woodman & Moore, 2012).

5.6 Conclusions

This thesis provides evidence that a distractor task can influence postural control in anticipation of a support surface translation, primarily with respect to specific aspects of high frequency sway. When distracted, threat-related increases in high frequency sway (1.0-2.5 Hz) were reduced. Furthermore, understanding how a distraction can potentially reduce attention to the control of posture and/or the coping strategies used in anxious situations provides insight for clinicians and researchers attempting to minimize postural control deficits in populations with a confounding influence of emotions on balance. It is important to note that distracting attention from postural control may not always be the best strategy for certain tasks and environments, or for different populations (Woollacott & Shumway-Cook, 2002). Future research is needed to examine whether broad threat-related changes in attention focus can be modified by other types of purposeful distractions with the resultant changes in attention focus associated with postural changes.

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APPENDIX A – Brock university ethics clearance

Brock University
Research Ethics Office
Tel: 905-688-5550 ext. 3035
Email: reb@brocku.ca

Bioscience Research Ethics Board

Certificate of Ethics Clearance for Human Participant Research

DATE:	5/1/2018		
PRINCIPAL INVESTIGATOR:	ADKIN, Allan - Kinesiology		
CO-INVESTIGATOR(S):	Craig Tokuno (ctokuno@brocku.ca); Mark Carpenter (mark.carpenter@ubc.ca); Kyle Johnson (kj10yk@brocku.ca)		
FILE:	17-355 - ADKIN		
TYPE:	Faculty Research	STUDENT: SUPERVISOR:	Alexander Watson Allan Adkin

TITLE: Effects of attention on threat-related balance responses

ETHICS CLEARANCE GRANTED

Type of Clearance: NEW   Expiry Date: 5/1/2019

The Brock University Bioscience Research Ethics Board has reviewed the above named research proposal and considers the procedures, as described by the applicant, to conform to the University's ethical standards and the Tri-Council Policy Statement. Clearance granted from **5/1/2018** to **5/1/2019**.

The Tri-Council Policy Statement requires that ongoing research be monitored by, at a minimum, an annual report. Should your project extend beyond the expiry date, you are required to submit a Renewal form before 5/1/2019. Continued clearance is contingent on timely submission of reports.

To comply with the Tri-Council Policy Statement, you must also submit a final report upon completion of your project. All report forms can be found on the Research Ethics web page at http://www.brocku.ca/research/policies-and-forms/research-forms.

In addition, throughout your research, you must report promptly to the REB:

a) Changes increasing the risk to the participant(s) and/or affecting significantly the conduct of the study;
b) All adverse and/or unanticipated experiences or events that may have real or potential unfavourable implications for participants;
c) New information that may adversely affect the safety of the participants or the conduct of the study;
d) Any changes in your source of funding or new funding to a previously unfunded project.

We wish you success with your research.

Approved:

Stephen Cheung, Chair
Bioscience Research Ethics Board

Note: Brock University is accountable for the research carried out in its own jurisdiction or under its auspices and may refuse certain research even though the REB has found it ethically acceptable.

If research participants are in the care of a health facility, at a school, or other institution or community organization, it is the responsibility of the Principal Investigator to ensure that the ethical guidelines and clearance of those facilities or institutions are obtained and filed with the REB prior to the initiation of research at that site.

APPENDIX B – Demographic and health questionnaire

Participant ID Code: ___________

Age: ____________________

Height: ____________________

Weight: ____________________

Biological Sex: ____________________

Foot Length: ____________________

Heel to Ankle Length: ____________________

Have you, or are you currently diagnosed as having any of the following conditions? Please check all that apply.

☐ Hearing Impairment

☐ Diabetes

☐ Multiple sclerosis

☐ Other neurological disorders

☐ Fracture (< 8 weeks)

☐ Any other issues (e.g., sensory dysfunction) that may interfere with your balance or walking? If so, please specify.

____

APPENDIX C – Trait form of the state-trait anxiety inventory

Directions: A number of statements which people have used to describe themselves are given below. Read each statement and then place the appropriate number to the right of the statement to indicate how you *generally* feel (i.e., on a regular basis).

1 = Almost Never

2 = Sometimes

3 = Often

4 = Almost Always

1. I feel pleasant _____
2. I feel nervous and restless _____
3. I feel satisfied with myself _____
4. I wish I could be as happy as others seem to be _____
5. I feel like a failure _____
6. I feel rested _____
7. I am "calm, cool, and collected" _____
8. I feel that difficulties are piling up such that I cannot overcome them _____
9. I worry too much over something that really doesn't matter _____
10. I am happy _____
11. I have disturbing thoughts _____
12. I lack self-confidence. _____
13. I feel secure _____
14. I make decisions easily _____
15. I feel inadequate _____
16. I am content _____
17. Some unimportant thought runs through my mind and bothers me _____
18. I take disappointments so keenly that I can't put them out of my mind _____
19. I am a steady person _____
20. I get in a state of tension or turmoil as I think over my recent concerns and failures _____

APPENDIX D – Risk taking form of the domain specific risk-taking scale

Directions: For each of the following statements, please indicate the likelihood that you would engage in the described activity or behaviour if you were to find yourself in that situation. Provide a rating from *"Extremely Unlikely"* to *"Extremely Likely"* using the following scale:

1	2	3	4	5	6	7
extremely unlikely	moderately unlikely	somewhat unlikely	not sure	somewhat likely	moderately likely	extremely likely

1. Admitting that your tastes are different from those of a friend ______
2. Going camping in the wilderness ______
3. Betting a day's income at the horse races ______
4. Investing 10% of your annual income in a moderate growth mutual fund ______
5. Drinking heavily at a social event ______
6. Taking some questionable deductions on your income tax return ______
7. Disagreeing with an authority figure on a major issue ______
8. Betting a day's income at a high-stake poker game ______
9. Having an affair with a married man/woman ______
10. Passing off somebody else's work as your own ______
11. Going down a ski run that is beyond your ability ______
12. Investing 5% of your annual income in a very speculative stock ______
13. Going whitewater rafting at high water in the spring ______
14. Betting a day's income on the outcome of a sporting event ______
15. Engaging in unprotected sex ______
16. Revealing a friend's secret to someone else ______
17. Driving a car without wearing a seatbelt ______
18. Investing 10% of your annual income in a new business venture ______
19. Taking a skydiving class ______
20. Riding a motorcycle without a helmet ______
21. Choosing a career that you truly enjoy over a more secure one ______
22. Speaking your mind about an unpopular issue in a meeting at work ______
23. Sunbathing without sunscreen ______
24. Bungee jumping off a tall bridge ______
25. Piloting a small plane ______
26. Walking home alone at night in an unsafe area of town ______
27. Moving to a city far away from extended family ______
28. Starting a new career in your mid-thirties ______
29. Leaving your young children alone at home while running an errand ______
30. Not returning a wallet you found that contains $200 ______

APPENDIX E – Trait version of the movement specific reinvestment scale

Directions: Below are a number of statements about your movements. The possible answers go from 'strongly agree' to 'strongly disagree'. There are no right or wrong answers, so circle the answer that best describes how you feel for each question. Answer as honestly as possible.

1. I rarely forget the times when my movements have failed me, however slight the failure.

strongly disagree	moderately disagree	weakly disagree	weakly agree	moderately agree	strongly agree

2. I'm always trying to figure out why my actions failed.

strongly disagree	moderately disagree	weakly disagree	weakly agree	moderately agree	strongly agree

3. I reflect about my movement a lot.

strongly disagree	moderately disagree	weakly disagree	weakly agree	moderately agree	strongly agree

4. I am always trying to think about my movements when I carry them out.

strongly disagree	moderately disagree	weakly disagree	weakly agree	moderately agree	strongly agree

5. I'm self-conscious about the way I look when I am moving.

strongly disagree	moderately disagree	weakly disagree	weakly agree	moderately agree	strongly agree

6. I sometimes have the feeling that I'm watching myself alone.

strongly disagree	moderately disagree	weakly disagree	weakly agree	moderately agree	strongly agree

7. I'm aware of the way my mind and body works when I am carrying out a movement.

strongly disagree	moderately disagree	weakly disagree	weakly agree	moderately agree	strongly agree

8. I'm concerned about my style of moving.

strongly disagree	moderately disagree	weakly disagree	weakly agree	moderately agree	strongly agree

9. If I see my reflection in a shop window, I will examine my movements.

strongly disagree	moderately disagree	weakly disagree	weakly agree	moderately agree	strongly agree

10. I am concerned about what people think about me when I am moving.

strongly disagree	moderately disagree	weakly disagree	weakly agree	moderately agree	strongly agree

APPENDIX F – Self-reported anxiety questionnaire

Directions: Please respond to the following statements as honestly as possible about how you felt from the start to the end of the standing trial (or the time prior to the platform moving).

1. Using the following scale, please rate how worried you were when performing the balance task (e.g., worried about losing my balance, worried about performing the task incorrectly, etc.):

1	2	3	4	5	6	7	8	9
Not at all worried				Moderately worried				Very worried

2. Using the following scale, please rate how physically anxious (e.g., tense) you felt when performing the balance task:

1	2	3	4	5	6	7	8	9
Not at all anxious				Moderately anxious				Very anxious

APPENDIX G – State attention focus questionnaire

Directions: Please respond to the following statements as honestly as possible about where you directed your attention from the start to the end of the standing trial (or the time prior to the platform moving).

While standing, you may have directed your attention toward different information. Please indicate the extent to which you thought about or paid attention to the following:

1. Movement processes – Trying to consciously monitor or control specific parts of your movement:

1	2	3	4	5	6	7	8	9
Not at all		Slightly		Moderately		Quite a bit		Very much so

2. Task objectives – Concentrating on the specific instructions provided to you about the balance task objectives (i.e., standing quietly, visually fixated on the target):

1	2	3	4	5	6	7	8	9
Not at all		Slightly		Moderately		Quite a bit		Very much so

3. Threat-related stimuli – Feelings of anxiety or worry about the perturbation and the possibility or consequences of falling:

1	2	3	4	5	6	7	8	9
Not at all		Slightly		Moderately		Quite a bit		Very much so

4. Self-regulatory strategies – Coping strategies to help remain confident, calm, and/or focused:

1	2	3	4	5	6	7	8	9
Not at all		Slightly		Moderately		Quite a bit		Very much so

5. Task-irrelevant information – Thoughts unrelated to balance (i.e., irrelevant information):

1	2	3	4	5	6	7	8	9
Not at all		Slightly		Moderately		Quite a bit		Very much so

6. Distractor task objectives – Concentrating on the specific secondary task (i.e., numbers, words, target):

1	2	3	4	5	6	7	8	9
Not at all		Slightly		Moderately		Quite a bit		Very much so