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The Effects of Focus of Attention on Heart Rate During a Static Balance Task

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THE EFFECTS OF FOCUS OF ATTENTION ON HEART RATE DURING A STATIC BALANCE TASK

by

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A Research Paper
Submitted in Partial Fulfillment of the Requirements for the
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Introduction

Focus of attention literature dates back to as early as the late 1800's – one of the first cited individuals in this area was James Cattell. He was quoted as saying, "In the practiced automatic movements of daily life attention is directed to the sense impression and not to the movement…In fact, as soon as attention is directed to the movement, this becomes less automatic and less dependable" (Cattell, 1893, p. 253). In this quote, Cattell began the basis for all of the focus of attention literature that would follow. Between Cattell's first mention of focus of attention to the mid 1890's there were very few research investigations into the phenomena. Since the mid 1990's, there has been an ever growing amount of research evidence strongly supporting the conclusion that it is far more effective to adopt an external focus of attention, rather than an internal focus of attention.

To better understand the options practitioners have for focusing a learner's attention, we must define what it means to focus conscious attention internally or externally. An internal focus of attention is when a mover directs their attention to the movements of their body, conversely, a mover adopting an external focus of attention directs their attention to the effect the movement has on the environment (Wulf, Höb, & Prinz, 1998). For example, in a basic bench press task, to elicit an internal focus of attention a practitioner might say, "I want you to focus on the movement of your arms while you perform the task." To elicit an external focus of attention, the practitioner might state, "I want you to focus on the movement of the bar while you perform the task." In both cases the practitioner is instructing the individual to accomplish the same skill, but the different verbal cues elicit the exerciser to attend to different aspects of the practiced task.

An external focus of attention is superior for increased learning (McNevin, Shea, & Wulf, 2003; Wulf, Höb, & Prinz, 1998). Adopting an external focus of attention also aids in improved balance with a stabilometer (McNevin, Shea, & Wulf, 2003; Wulf & McNevin, 2003; Wulf, McNevin, & Shea, 2001; Wulf et al., 1998, Exp. 2), ski simulator (Wulf et al., 1998, Exp.1), other unstable surfaces (Wulf, Mercer, McNevin, & Guadagnoli, 2004; Wulf, Tollner, & Shea, 2007), and in a clinical population (e.g., Parkinson's Disease) (Landers, Wulf, Wallmann, & Guadagnoli, 2005; Wulf, Landers, Lewthwaite, & Tollner, 2009). Benefits of using an external focus of attention have also been revealed while performing a suprapostural tasks (McNevin & Wulf, 2002; Wulf et al., 2004; Wulf, Weigelt, Poulter, & McNevin, 2003).

It is becoming more apparent that in regards to multiple areas of human movement adopting an external focus of attention will elicit an enhancement in motor skill performance. Even with all of this evidence, there is still a need to research the underlying mechanisms responsible for the outward behavior changes. Specifically, additional research is needed to better understand the physiological responses that result by changing a person's focus of attention. By investigating how physiological responses interact with the focus of attention effect, researchers may uncover the underlying mechanisms that are responsible for the frequently reported phenomena. Previous empirical findings have shown a decrease in electromyography (EMG) activity by simply adopting an external focus of attention (Vance, Wulf, Tollner, McNevin, & Mercer, 2004; Zachry, Wulf, Mercer, & Bezodis, 2005). Marchant, Greig, and Scott

(2009), found a decrease in EMG activity while simultaneously increasing muscular force production while performing an isokinetic elbow flexion. This research seems counterintuitive physiologically, in that one would expect to require a greater neural activation (i.e., EMG activity) to increase force production. For example, early in a resistance training program the main adaptation, prior to any muscular hypertrophy, is that of the central nervous system increasing EMG activity leading to an increase in force production (Gabriel, Kamen, & Frost, 2006). Therefore, based on the findings of Marchant et al. (2009) the only way to explain the result of lower EMG activity while simultaneously increasing muscular force would be that the nervous system became more efficient as a result of the mover directing their attention externally. As practitioners we often search for any competitive edge that will allow our clientele to compete at a higher level. Typically to elicit a training result, a practitioner must utilize weeks or even months of training with their clientele. However, in the Marchant et al (2009) study, improvements in force production were established immediately by changing the participant's focus of attention. The results of the Marchant et al. (2009) study provide preliminary evidence that changes to the cognitive system can influence physiological measures. With this evidence, a question that arises is would there be an effect on the cardiovascular system by changing a person's focus of attention?

To date, there has been only one published study that has looked at the heart rate response when utilizing various foci of attention. Mullen, Jones, Faull, and Kingston (2012) measured heart rate variability during a simulated driving task under various foci of attention. They found that the internal focus group had larger increases in heart rate from baseline compared to the external condition; the authors interpreted this result to mean the internal group had to put forth more mental effort in processing task relevant information than did the external focus group (Mullen, Jones, Faull, & Kingston 2012). This finding is interesting because it adds to the wealth of knowledge for a possible connection between the cognitive system and physiological system. However a major limitation to that study was the authors only measured heart rate during the middle portion of the total time it took to perform the practiced task; which did not allow for a concurrent assessment of the rate or direction of change in heart rate through the course of the entire trial.

Recent findings using EMG (Vance, Wulf, Tollner, McNevin, & Mercer, 2004; Zachry, et al., 2005) and heart rate (Mullen, et al., 2012) point to a physiological response to an external focus of attention. One explanation provided in the literature to interpret this frequently observed phenomenon is that of the constrained action hypothesis (McNevin, Shea, & Wulf, 2003; Wulf et al., 2001; Wulf, Shea, & Park, 2001). The constrained action hypothesis suggests that an internal focus of attention constrains the motor system, while an external focus of attention promotes the motor system to self-organize unconsciously during the execution of a motor skill (Zachry, et al., 2005). Of particular interest to the present study are the findings of McNevin and Wulf (2002) and Mullen, et al. (2012). McNevin and Wulf (2002) found that adopting an external focus, relative to an internal focus, while performing a supra-postural task did not result in differences in center of pressure displacement, but did elicited a faster response to the displacement of center of pressure compared to the utilization of an internal focus and baseline condition. Mullen, et al. (2012) found that an internal focus of attention elicited a larger mental effort, which resulted in an increased heart rate. The current study was designed to test the predictions of the constrained action hypothesis; specifically, to see if the self-organization of the motor system will also result in a change to the cardiovascular system.

Thus, the purpose of this research was to further investigate the connection between the physiological and cognitive systems via heart rate measures under various foci of attention. Based on previous literature utilizing EMG and heart rate (both physiological measures), it was hypothesized that the utilization of an external focus of attention would decrease a participant's heart rate compared to trials completed while utilizing an internal and control conditions. Similar to Wulf and McNevin (2002), it was also expected that there would be no differences in center of pressure displacement between the three experimental conditions while performing a static balance task.

Method

Participants

Twenty-three college-aged participants (n = 15 males; n = 8 females, *M*age = 23.3 years, *SD* = 5.63 years) from Southern Illinois University Carbondale volunteered to participate in this study. The Human Subjects Committee at Southern Illinois University Carbondale approved the methodology and materials used in the present study. Prior to data collection, all participants were required to sign an informed consent. None of the participants were told the purpose of this research prior to data collection.

Apparatus and Task

An AccuSway^{PLUS} Balance Platform from Advanced Mechanical Technology Incorporated (AMTI) was utilized to acquire center of pressure data, with a sampling rate of 200Hz for each 30-second trial (version 2.01.00, June 2006). The platform was linked to a Windows computer loaded with the accompanying software through AMTI's PJB-101 interface, which converted force into volts.

A Polar RS800CX heart rate monitor, with a capture rate of 30 heart rates per trial (i.e., one every second), was utilized. This allowed the heart rate variability to be measured concurrently throughout the trial.

A lightweight white sheet was draped loosely (not touching the floor) over a coat rack. Not allowing the sheet to touch the floor was intentional, and was designed to ensure the weight of the sheet could not be used as a base of support and affect the subject's balance (Riley, Stoffregen, Grocki, & Turvey, 1999).

Procedures

Forty-eight hours prior to arriving at the laboratory, all participants were contacted via electronic mail by the researcher reminding them of their appointment and to not ingest caffeine 24-hours, or a large meal 3 hours in advance of their testing. Upon arrival to the laboratory, the participant was given a brief overview of the various apparatus' and the task to be performed. This procedure was used in an attempt to allow the participant to feel more comfortable with the measures that were to be performed, as stress will cause variations in heart rate. The participant was then instructed to sit down for 5 minutes prior to beginning the data collection to allow their heart rate to return to resting levels.

Prior to data collection, the participant put on a heart rate monitor, and then the researcher verified the monitor was working properly. The participant was then instructed to stand on the force platform barefooted, with their feet spaced evenly anterioposteriorly and mediolaterally. They were then instructed, from an anatomical position, to flex 90 degrees at the elbow of their dominant side, and pronate their forearm to a neutral position. The apparatus was then moved so the sheet would be touching the tip of their fingers. The apparatus was positioned in a manner that allowed the participant to see past it. Participants were then instructed to focus their vision on a 6.35 centimeters wide by 3.048 meters long streamer hanging three meters away, the streamer stretched from the ceiling of the laboratory to the floor. Instructing each participant to visually focus on the streamer was done in an attempt to ensure everyone was visually focused on the same fixation point throughout the testing session.

This experiment utilized a within-participant design. All participants began with a baseline (Control) condition. This methodology was utilized to establish a baseline measure with the Control condition first, prior to participants being exposed to other conditions – a similar method was used in a recent article by Porter, Nolan, Ostrowski, and Wulf (2010). In that study Porter and colleagues reported that their pilot testing indicated that participants often utilized the previous days focus of attention while in the control condition. For example, if they were instructed on day one to focus externally and day two was the control condition, the participants would frequently use the previous days external focus of attention during the control condition. Because of this finding, it was decided to have all participants complete trials in the Control condition prior to performing trials in the Internal and External conditions. When participants were in the Control condition they were instructed to "balance to the best of your ability." The Internal and External conditions were counterbalanced via random assignment. When trials were completed in the Internal condition participants were instructed to "focus on minimizing movement of your hand, while maintaining balance to the best of your ability." When completing attempts in the External condition participants were instructed, to "focus on minimizing movement of the sheet, while maintaining balance to the best of your ability." Participants completed a total of three trials in each of the three conditions, for a total of nine trials for the entire testing session.

Dependent Measures and Statistical Analysis

Postural sway was measured via center of pressure changes throughout each trial. A single measure of standard deviation would not suffice for the entire data set (Riley et al., 1999) as center of pressure is a constantly changing dynamic measure, the standard deviation of each 1-second window was averaged to obtain a mean moving window standard deviation of the center of pressure (McNevin & Wulf, 2002). This conversion allowed for a better representation of what was occurring throughout the trial. Center of pressure data were submitted for analysis to obtain the mean power frequency. The mean power frequency's each participant completed within each condition were averaged to create a composite score for each participant within each condition. These values were then analyzed using a univariate repeated measures analysis of variance (ANOVA) to assess differences in the measured postural sway. Heart rate was measured concurrently throughout each 30-second trial at a frequency of one measure each second. This allowed the researcher to see when the changes of heart rate occurred (i.e., early or late in the trial). The three 30-second heart rate measures for each participant within each condition were averaged. These data were then analyzed using a 3 (condition) X 30 (heart rate measures) ANOVA with repeated measures on both factors.

Results

Center of Pressure

The results of the ANOVA analyzing the center of pressure data indicated there were no significant differences between the three conditions, $F(2, 44) = .689$, $p > .05$. The average center of pressure for each condition is displayed in Figure 1.

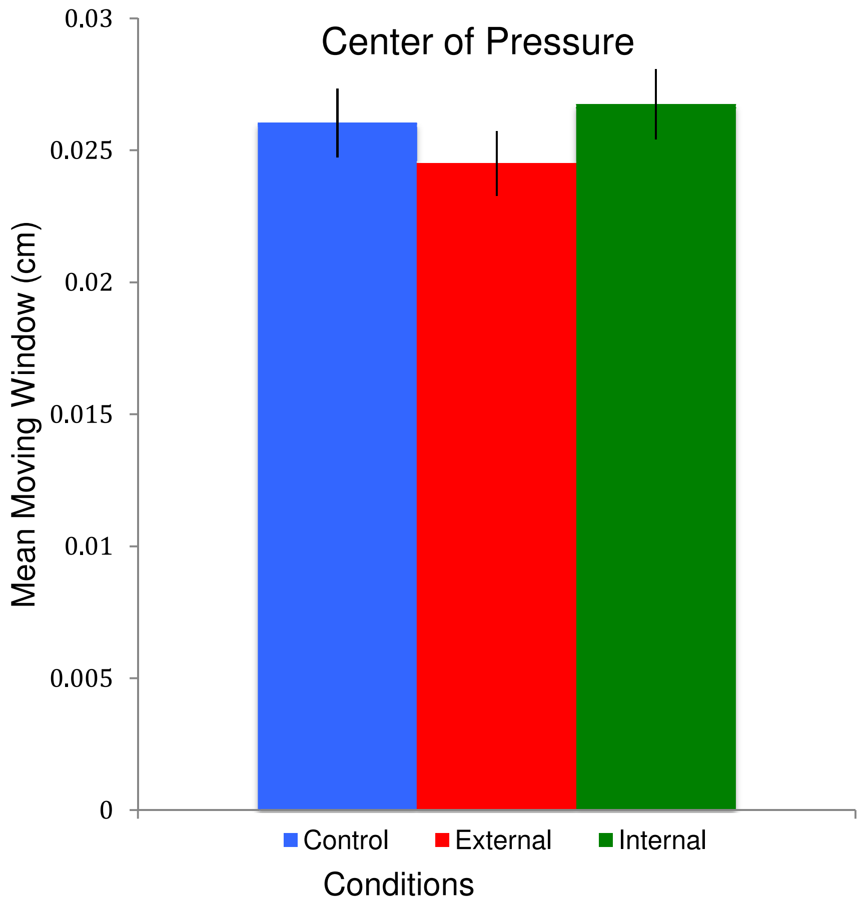

Figure 1. Average moving window for Control, External, and Internal focus of attention conditions, with the error bars representing standard deviation.

Heart Rate

The ANOVA that analyzed heart rate revealed there was a significant main effect for Condition, $F(2, 44) = 23.73$, $p < .001$. Also, the ANOVA indicated that there was a main effect for Second, *F*(2, 29) = 34.149, $p < .001$. Additionally, the analysis showed that there was an interaction between the two factors (i.e., Condition and Second), *F*(2, 58) = 2.613, $p < .001$. The concurrent heart rates for each condition are displayed in Figure 2.

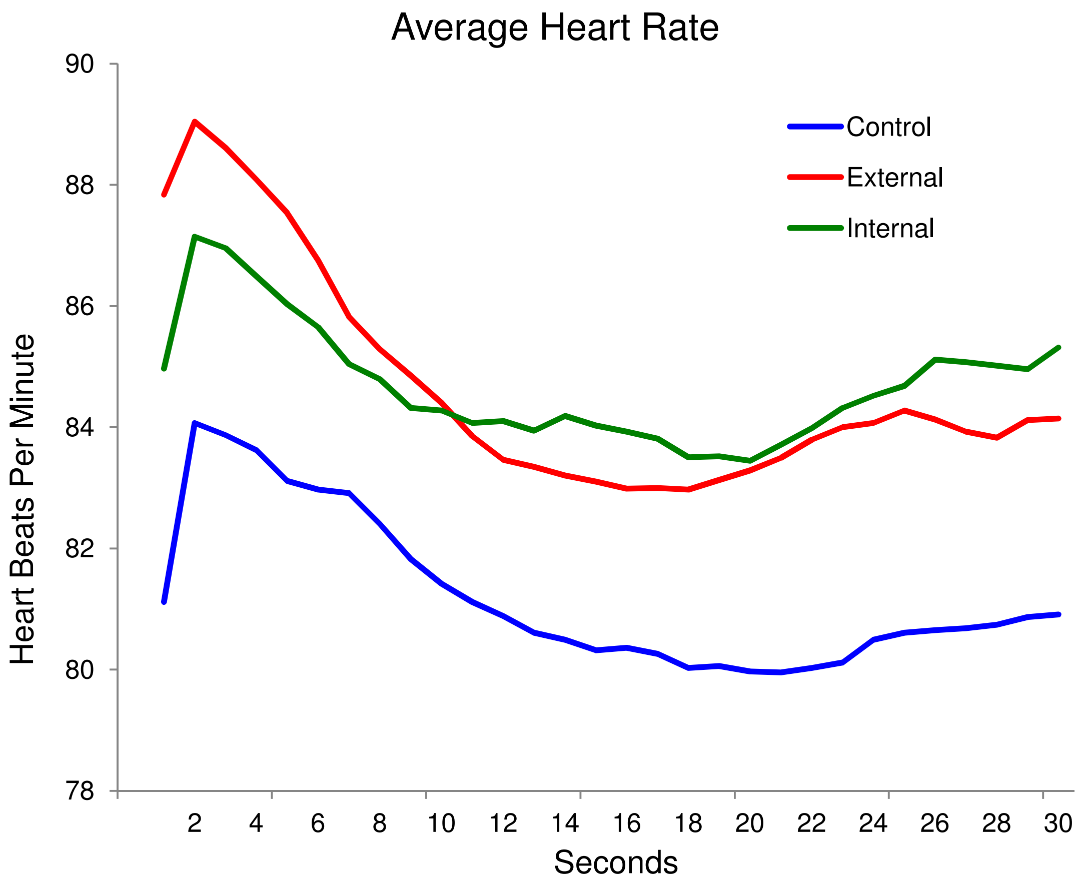

Figure 2. Heart rate data for the Control, External, and Internal conditions, revealing the changes in heart rate over time.

A least significant difference (LSD) *post-hoc* analysis of the Condition main effect indicated that participants had a significantly lower average heart rate while in the Control (81.2 beats per minute) condition compared to trials completed in the External

(84.7 beats per minute) and Internal (84.7 beats per minute) conditions. The analysis also indicated that the External and Internal conditions were not significantly different. *Post-hoc* testing of the Second main effect indicated that heart rate changed through the course of the trial in all three conditions (see Figure 2). Lastly, *post-hoc* testing showed that the significant interaction was the result of the External condition having a more rapid drop in heart rate compared to trials completed in the Internal condition (see Figure 2).

Discussion

The purpose of the current study was to investigate how altering focus of attention influenced heart rate and center of pressure while performing a static balance task. Based on previous research, it was hypothesized that heart rate would be lower when participants completed trials in the External focus of attention condition compared to trials completed in the Internal and Control conditions. It was also hypothesized that the center of pressure data would be similar to findings reported by McNevin and Wulf (2002).

As predicted, the analysis of the center of pressure data indicated that there were no significant differences in postural sway between trials completed within the three different focus of attention conditions. This result was similar to that of McNevin and Wulf (2002), which gave reliability to the task being performed. This indicates that the performance of the prescribed task in the current study was properly replicated.

The results of the analysis of heart rate were not consistent with the experimental predictions. It was hypothesized that the external focus of attention group would have the lowest heart rate among all conditions. One unexpected finding was that the heart rates of participants while in the Internal and External focus of attention conditions were not significantly different from one another. However, a noteworthy observation was the interaction in the change in heart rate between the External and Internal conditions. Specifically, the analysis indicated that the heart rate of the participants in the External condition dropped at a more rapid rate compared to trials completed in the Internal condition, however on average the heart rates were not significantly different. Contrary to what was expected, the Control condition's heart rate was significantly lower compared to trials completed in the Internal and External conditions. Another interesting result that was observed was all conditions had an initial relatively rapid increase in heart rate, followed by a decrease and leveling out of the heart rate across the 30-second trial.

One possible explanation for why participants in the Control condition had a lower heart rate compared to trials completed in the Internal and External conditions was because they received a relatively reduced amount of verbal instructions while in the Control condition. Specifically, while in the Control condition participants were instructed to "maintain your balance to the best of your ability." However when participants were in the Internal condition they were instructed to "focus on minimizing movement of your hand, while maintaining your balance to the best of your ability," which is a relatively more complicated form of instruction since participants were asked to do two things at once (i.e., maintain balance and minimize hand movement) rather than only one thing (i.e., maintain balance) as was the case in the Control condition. Similarly, when participants were in the external focus of attention condition they were asked to "focus on minimizing movement of the sheet, while maintaining your balance to the best of your ability." Consequently, this form of instruction also asked participants to focus on two things at once (i.e., maintain balance while not moving the sheet). Memory research by Peterson and Peterson (1959) suggest that our short-term memory has a capacity of 7 ± 2 items. Perhaps due to the constraints on the short-term memory system and increased attentional demands placed on participants in the Internal and External conditions, a stress response was elicited in those respective conditions causing an elevated heart rate compared to trials completed in the less cognitively demanding (i.e., stressful) Control condition. The physiological responses to stress are numerous, but the specific response of most interest to the present study is that of increased heart rate. Since acute stress causes activation of the sympathetic nervous system, which causes an increase in heart rate (Rozanski, Blumenthal, & Kaplan, 1999); it is plausible that the observed elevated heart rates of participants while in the Internal and External conditions was caused by potential cognitive stress induced by the more complex provided instructions. Currently, this possibility is purely speculative, further research is needed to validate this connection between the increased demands on the cognitive system and consequential changes in heart rate.

Another possible causation of a lower heart rate in the control group was that each participant rested prior to data collection and the control condition was always performed first. Thus, the participant's lowest heart rate would likely be during the earlier trials. However, this possibility is not likely because participants were performing a static balance task that was not physically demanding. Additionally, participants were provided 30 seconds of rest between trials, so any possible increase in heart rate caused by the practiced task (i.e., static balance) should have been negated. Moreover, if the practiced task was the cause of the elevated heart rate then one would have expected heart rate to gradually increase throughout the trial, which was not the case. In fact, the heart rate gradually decreased throughout the trial suggesting factors other than the practice task caused the observed results.

The interaction between the Internal and External focus of attention conditions can be explained by the constrained action hypothesis (McNevin, et al., 2003; Wulf et al., 2001; Wulf, Shea et al., 2001). The hypothesis states that an internal focus of attention constrains the motor system while an external focus of attention allows the system to self-organize and function more efficiently using a more autonomous form of motor control. In the case of the current research, perhaps the external condition had a greater rate of change (i.e. their heart rate dropped more quickly) because there was less stress put on the motor system. The concept of changing someone's heart rate via a slight change in instruction is consistent with the predictions of the constrained action hypothesis (McNevin, et al., 2003; Wulf et al., 2001; Wulf, Shea et al., 2001). Specifically, the heart rate of participants while in the External focus of attention condition dropped at a more rapid rate than did the same participant's heart rate when they were in the Internal focus of attention condition. The subtle change in instructions likely promoted a reduced stress response which consequently elicited a rapid reduction in heart rate when participants were in the External condition relative to the Internal condition. The increased efficiency of the nervous system resulted in measurable changes in the cardiovascular system as a more rapid decrease in heart rate during the course of the trial.

The last finding of the current research was that of the initial increase in heart rate in all groups prior to the decrease throughout the trial. To explain this phenomenon, we must refer back to nervous systems stress response. According to Allen (1983), there are three pathways in which stress occurs: 1) an immediate effect lasting two – three seconds where epinephrine and norepinephrine are released from the sympathetic nervous system, 2) an intermediate effect lasting 20 – 30 seconds where epinephrine and norepinephrine are released from the adrenal medulla, and 3) a prolonged effect lasting from minutes – days where adrenocorticotropic hormone is released from the adrenal gland. The initial release of epinephrine and norepinephrine within the sympathetic nervous system is possibly the reasoning for the initial increase in heart rate as it typically only lasts for two - three seconds. It seems that the initiation of each trial caused an immediate stress response in each of the conditions lasting approximately three seconds. The quick increase in heart rate was followed by a gradual lowering of heart rate, possibly indicating that participants where “coping” with the initial stress of performing the standing balance task.

Limitations and Future Directions

There are limitations to the current experiment, all of which establish the need for additional research to better understand the findings reported in the present study. One limitation was that the Control condition was not counterbalanced with the other conditions, meaning the Control condition was always performed first in the current study. As discussed in the Method section, this was done purposefully in an attempt to control for possible carryover effects. However it is presently unclear if this methodology had a meaningful influence on heart rate. In future studies counterbalancing all of the groups could lead to a more clearly defined answer of which condition is truly the best at reducing heart rate via verbal instruction.

A second limitation in the current study is there was no way of knowing what each participant was focused on. Meaning, there was no qualitative questioning post trial to know for certain if the individual was truly following the prescribed instructions. Retrieving qualitative data via post trial survey as to what each participant was focusing on could lead to more rich and meaningful results. The participants could very easily have changed their focus of attention without the researcher's knowledge during the task. However, this is always a limitation in research, and there is nothing the researcher can do to completely ensure participants are following prescribed instructions.

A third limitation was the presumable stress placed on the cognitive system by the complexity of the utilized instructions. A simple reduction in the complexity of the prescribed instruction could produce more profound results by not stressing the cognitive system. In the present study, during the Internal and External focus of attention conditions, participants were instructed to focus on two concurrent items (i.e., balance performance and movement of the sheet or their hand); conversely, when participants were in the Control condition they were only asked to focus on the balance task. Future studies should use more simplified instructions such as "focus on minimizing movement of the sheet" and "focus on minimizing movement of your hand" for the external and internal conditions, respectively.

Trial duration is another limitation of the current study. The trials in the present study lasted 30 seconds, but in looking at the results the heart rates of all three conditions' were gradually trending upward toward the end of each trial. In the future, a longer trial duration could give researchers more information as to how long the effects of focus of attention last from a physiological standpoint. Additionally, assessing heart rate over several minutes could provide valuable insight into the mechanisms of heart rate change as the adrenocorticotropic hormone is released from the adrenal gland into the circulatory system.

The final limitation of the current study was the ages of the volunteers. Participants were college aged males and females, which limits the generalizability of the results. A future direction that could be investigated is that of a clinical population, specifically individuals prescribed heart rate control medications (e.g., beta-adrenergic blocking agents). These medications are prescribed specifically to reduce the sympathetic nervous systems effect on heart rate, thus attenuating the heart rate response to stressors (Ehrman, 2010). Thus, to see any changes in heart rate under various focus of attention conditions could be thought-provoking. Specifically, a change in heart rate within this population would be counterintuitive due to the nature of the medications being prescribed. If a practitioner could elicit a result out of this population by simply giving instructions in a different manner, this could feasibly lead to changes in how outpatient cardiac rehabilitation programs are instructed. Practitioners could utilize their verbal instruction to elicit a change in heart rate, rather than the utilization of medications.

General Conclusions

Based on the results of the current study, the best method for eliciting a lower heart when performing a skill requiring static balance would be to instruct individuals to maintain their balance with no specific focus of attention. However, based on the limitations described above, it is too soon to conclude that providing neutral instructions ultimately promotes optimal motor behavior and cardiovascular performance. Consequently, this study has also proposed many avenues for future research to better understand the present study's findings. The findings presented above provide partial support for the constrained action hypothesis in that when participants were in the External focus of attention condition their heart rate decreased at a faster rate than it did during trials when they were using an Internal focus of attention. Looking at the results of the current study, there appears to be a need for additional research to further delineate the connection between heart rate and focus of attention.

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