Internal Focus Instruction Increases Psychological Stress with Conscious Motor Processing and Deteriorates Motor Performance in Dart Throwing

James C.L. LAW, BSc [1*], and Thomson W.L. Wong, Ph.D. [1, 2]

[1] School of Public Health, Li Ka Shing Faculty of Medicine, The University of Hong Kong, Hong Kong SAR, China.

[2] Department of Rehabilitation Sciences, Faculty of Health and Social Sciences, The Hong Kong Polytechnic University, Hong Kong SAR, China.

*Corresponding author:

James C.L. LAW

School of Public Health,

Li Ka Shing Faculty of Medicine,

The University of Hong Kong,

3/F, The Hong Kong Jockey Club Building for Interdisciplinary Research,

5 Sassoon Road, Pokfulam, Hong Kong SAR.

Tel: +852 96289761

E-mail: James.law@connect.hku.hk

Running head: Internal focus instruction on dart throwing

Abstract

Internal focus attention strategies have been found to diminish motor performance. This study attempted to elucidate this finding using the Constrained Action Hypothesis and the Theory of Reinvestment through exploring their underlying mechanisms. Sixty-one young participants completed a self-paced "Dart Throwing" motor task to examine the effects of internal focus instruction, compared with no focus instruction, on conscious motor processing (reinvestment), psychological stress, and motor performance. Participants threw darts with standardized internal focus and no focus instructions given before each trial block of dart throwing. Motor performance was indicated by the throw accuracy and throw time. Stress was measured using a galvanic skin response probe. An insight into real-time conscious motor processing (reinvestment) was provided by the Electroencephalography (EEG) coherence between T3 and Fz locations on the scalp. Results indicated that internal focus instruction could cause participants to have lower throw accuracy ($p = 0.008$), longer throw time ($p = 0.001$), higher stress ($p = 0.001$) and higher real-time conscious motor processing (reinvestment) ($p = 0.001$) than no focus instruction. The significant results imply that internal focus instruction should be avoided in the self-paced motor task learning due to its detrimental effects.

Keywords: Attentional focus instruction; Motor performance; Conscious motor processing; Stress; Dart throwing

Internal Focus Instruction Increases Psychological Stress with Conscious Motor Processing and Deteriorates Motor Performance in Dart Throwing

Introduction

Attentional focus strategies have been widely-accepted to affect performances of different motor tasks (Wulf 2007). The application of internal focus of attention has been recognized to deteriorate motor performances; such as reducing dart throwing automaticity and accuracy (Marchant et al. 2009). Internal focus of attention directs the performer's attention onto their bodily movements, and such focus could be induced by an internal focus instruction (Wulf 2013). The negative effects of internal focus of attention on motor performance may be explained by the Constrained Action Hypothesis (Wulf 2013). The Constrained Action Hypothesis suggested that internal focus instruction could induce greater movement awareness, such awareness constrains automatic motor processes, resulting in diminished motor performance (Wulf 2013). Motor performance can be characterized as movement effectiveness and efficiency (Wulf et al. 2007). Movement effectiveness was defined as the accuracy and consistency of movements while movement efficiency was defined as the fluency of movement executions, also seen as the physical and mental effort (Wulf et al. 2007). Although it has been well established that internal focus of attention could diminish motor performance, the underlying mechanisms have not yet been fully explained. One possible explanation by Wulf and Lewthwaite proposed that internal focus instruction promotes self-awareness and excessive concerns about the own movements. Such a phenomenon was described as "micro-choking" (Wulf and Lewthwaite 2010). A "micro-choking" event could result in performance breakdown and decreased movement automaticity, and therefore diminished motor performance (Wulf and Lewthwaite 2010). Indeed, current evidence of "micro-choking" has been derived from participants' decreased movement efficiency when using an internal focus

of attention (Lohse et al. 2010). However, other essential elements of the "micro-choking" event, such as the level of self-awareness or movement concern and psychological stress (psychological stress will be referred to stress in this paper) have not been extensively explored (Wulf 2013).

The underlying mechanisms of how induced self-awareness or excessive movement concern would cause diminished motor performance may be revealed using the Theory of Reinvestment (Masters et al. 1993; Masters and Maxwell 2008). Reinvestment has been defined as the conscious motor control with task-relevant declarative knowledge (Masters and Maxwell 2008). Task-relevant declarative knowledge includes verbal instructions that guide the movements of different body parts, where such rules are applied to consciously control motor behaviours (Maxwell et al. 2006). The behavioural patterns of conscious motor processing (reinvestment) can be described similarly to the movement awareness described by the Constrained Action Hypothesis, where the process of conscious motor processing (reinvestment) acknowledges and utilizes a set of instructions to control movement. The use of task-relevant declarative knowledge during motor task execution has been applied in previous studies to increase conscious motor control over bodily movements (Chow et al. 2019; Chu and Wong 2019; Ellmers et al. 2016; Zhu et al. 2011). Such effect is described as internal focusing. The relationship between internal focusing instruction and increased conscious motor control has been interpreted as the coherent alpha 2 (10-12 Hz) Electroencephalogram (EEG) activation between the verbal-analytical region (T3) and the motor planning region (Fz) of the scalp (Bellomo et al. 2018; Zhu et al. 2011). Coherent activation of the two electrode sites has been interpreted to reflect the level of functional communication between the two brain regions, where a stronger coherence reflects greater communication (Bellomo et al. 2018). As the T3 region is responsible for instruction comprehension while the Fz region is used for motor control, coherent activation may indicate the utilization of verbal instruction during

motor activity. Thus, the exhibited coherent neuro-activity has been proposed to index real-time movement awareness that could provide objective evidence of it, demonstrating the effects of internal focus instructions on self-awareness and movement concern.

From a psychological perspective, "micro-choking" events due to an internal focus of attention may also be related to stress. Radlo and colleagues found that the use of an internal focus strategy during dart throwing would accelerate an individual's heart rate immediately before the release of a dart throw (Radlo et al. 2002). Heart rate variability is a physiological indicator of stress; hence, internal focus instructions may be a cause of stress (Taelman et al. 2009; Salai et al. 2016). Still, heart rate variability may also be affected by other factors such as exercise intensity. Thus, other means to measure stress such as Galvanic Skin Response (GSR) may be utilized (Kuan et al. 2018). GSR reflects arousal states through detecting skin conductivity. The sympathetic nervous system is activated when our body encounters a stressful situation, the skin conductivity is then increased and detected by GSR (Kuan et al. 2018). Previous dart throwing studies displayed participants' change in arousal state using the GSR tool when placed under different stressful situations (Kuan et al. 2018). Excessive stress has a detrimental effect on low arousal motor skills, such as dart throwing (Zhang et al. 2016). One mechanism for this phenomenon can be explained by the Theory of Reinvestment. The reinvestment theory states that stress could induce the conscious utilization of task-relevant declarative knowledge, as a result causing the "de-chunking" of a movement into sequential parts (Masters and Maxwell 2008). Conscious motor processing (reinvestment) "de-chunks" a movement, where each chunk is activated and completed separately; such process decreases motor efficiency while increasing the chance of error, causing diminished accuracy and efficiency (Masters and Maxwell 2008). As stress may be a potential cause of excessive movement awareness and conscious motor processing (reinvestment) that constraints automatic motor processes and diminishes motor performance, triggers of stress should be

prevented. Understanding the relationship between different attentional focus instructions with stress may benefit the implementation of such instructions to reduce stress that aims for limiting excessive movement awareness and conscious motor processing (reinvestment).

Previous studies demonstrated that internal focus instructions could diminish performance, yet, the underlying causes have not been fully assessed. Through examining one's movement concern and stress in relation to internal focus instruction and motor performance, insights regarding the underlying mechanisms of internal focus instruction on motor performance may be explored. This study aimed to examine the effect of internal focus and no focus instructions on motor performance, stress, and real-time conscious motor processing in healthy young adults during dart throwing. It was hypothesized that internal focus instruction could diminish motor accuracy and efficiency while increasing stress and real-time conscious motor processing (reinvestment).

Method

Participants

Sixty-one healthy young adults (mean age = 22.85 ± 4.66 years) participated in a "dart throwing" motor task at the Brunel University, London and the University of Hong Kong, Hong Kong SAR. Similar number of participants were recruited from the two institutions. All participants were students of the two Universities, recruited through convenience sampling. Participants were excluded if they had more than five episodes of dart throwing experience or practiced dart throwing within three months before the experiment, such criteria were adopted from a previous study (Marchant et al. 2007). Potential participants were excluded if they had any neurological or orthopedic injuries in the past six months that might affect their ability to throw darts. The sample size was estimated based on a power analysis utilizing the effect size calculated from a similar dart throwing experiment comparing the dart throwing performance

scores under two conditions (McKay and Wulf 2012). The Cohen's *d* effect size was calculated to be 0.42; utilizing the G-power statistics software (G*Power Version 3.1.9.3) with the alpha error set as 0.05 and power as 0.80, a total sample size of 49 participants was required. To be conservative, an additional 25% sample size was recruited. As a result, 61 participants were recruited for the study. Experimental procedures were approved by the Institutional Review Board of the University of Hong Kong /Hospital Authority Hong Kong West Cluster (HKU/HA HKW IRB; IRB no.: UW 17-223), and written consents were obtained before any experimental procedure. The trial was also registered in the HKU Clinical Trial Registry (HKUCTR-2465).

Outcome Variables

Outcome variables were measured through motor performance indicators, stress, and real-time conscious motor processing (reinvestment). Motor performance indicators included the 8-point system of throw accuracy score (accuracy) and throw time (in seconds). The dart board consisted of 8 concentric circles: the center circle was 5 centimeters in diameter, and each successive circle was 5 centimeters larger in diameter. A number between 1 to 8 was marked on the circles with respective scores based on their displacement form bull's eye (**Figure 1**). A higher score was given if the dart landed in a section closer to the bull's eye, as it would indicate a smaller radial displacement from the center of the target. The accuracy score ranged from 0 to 8, where 8 was given if a dart lands directly on the bull's eye. There were no negative scores. Throw time was defined as the time (in seconds) after the experimenter announced "you may start now" until the moment when the fifth dart lands on the dart board in each block. A shorter throw time was found to correlate with lower muscle electromyography activity and lower demands on cognitive resources, demonstrating better motor efficiency (Lam et al. 2010; Lohse et al. 2010). Dart throws were recorded during the experiment using a video recorder (VIXIA HF R80 HD Camcorder, Canon Inc., Tokyo, Japan).

The video recorder was placed perpendicular to the dart board, at the height of bulls' eye to reduce perception error. Accuracy of throws was tallied with the support of the dart throwing videos. Throw time was calculated using the Final Cut Pro (Final Cut Pro, Apple Inc., California, United States) computer software which measures time to an accuracy of 0.01 second (Lohse et al. 2010). The software also provided sound amplitude relative to time, which allowed accurate indication of the start and end time for each trial.

Figure 1 near here

Stress was measured using a GSR probe (MP 100, BIOPAC Systems Inc., London, UK), analyzed with a biophysical data acquisition software (Acknowledge, BIOPAC Systems Inc., London, UK; Landers 1985). The unit of stress was in microSiemens (μS). As all participants were right-handed, the two GSR probes were wrapped around the participant's left index and middle fingers.

Real-time conscious motor processing (reinvestment) was interpreted by a wireless EEG device (PET 4.0, Brainquiry, NL). Data were processed by a real-time biophysical data acquisition software (BioExplorer 1.6, CyberEvolution, US) at a sample rate of 200 Hz activation (Chow et al. 2019; Chu and Wong 2019; Ellmers et al 2016; Zhu et al. 2011). Disposable electrodes (ARBO H124SG Ø 24 mm, Kendall, US) were placed overlaying the T3 (verbal-analytical region), T4 (visual-spatial region), and Fz (motor-planning region) according to the 10-20 system reference sites of the brain scalp (Herwig et al. 2003). T3 and T4 locations are also referred as T7 and T8 in the modified 10-20 nomenclature (Seeck et al. 2017). The EEG was referenced to the right mastoid while the ground electrode was attached to the left mastoid. An electrode was placed on the left zygotic bone (Fp1) to record eye blink (Zhu et al. 2011). EEG signals were processed by the low-pass filter (42Hz) and the high-pass

filter (2Hz) to remove potential biologic artefacts. Alpha 2 T3-Fz and T4-Fz EEG coherences signals (10-12 Hz) were calculated in 1Hz frequency bins throughout each trial, using algorithms previously described (Zhu et al. 2011). The T3 (verbal-analytical region) and Fz (motor-planning region) EEG coherence has been interpreted to indicate real-time conscious motor processing (reinvestment). The T4 (visuo-spatial region) and Fz (motor-planning region) EEG coherences were also measured. As only verbal instructions were provided to guide the dart throw where visuo-spatial cues were not prompted, coherent activation between the T4 and the Fz regions of the brain was not expected. Thus, the T4-Fz EEG coherence was measured to validate that the changes in the T3-Fz EEG coherence were not due to global activation (Chow et al. 2019; Chu and Wong 2019; Ellmers et al. 2016; Zhu et al. 2011). The levels of T3-Fz EEG coherence and the T4-Fz coherence range from 0 to 1. Higher level in T3-Fz EEG coherence has been interpreted to reflect higher real-time conscious motor processing (reinvestment) (Chow et al. 2019; Chu and Wong 2019; Ellmers et al. 2016; Zhu et al. 2011). The mean GSR and EEG recording were calculated from the commencement of the trial until the moment when the fifth dart landed on the dart board.

Experimental procedures

After written consent was obtained, participants were asked to complete dart throwing blocks under practice, internal focus, and no focus conditions. Following practice condition (5 blocks of 5 dart throws), participants completed the internal focus condition (5 blocks of 5 dart throws) and no focus condition (5 blocks of 5 dart throws). The order of the two experimental conditions (i.e., internal focus and no focus conditions) was randomized using an online program (www.random.org) to counterbalance the potential biases due to the learning effect. A commercially available dartboard (45 centimeters in diameter) with eight score bands (**Figure 1**) was placed at a regulation height (1.73 m from the point of bullseye and the ground) and distance (2.37 m from the throwing line). Participants were encouraged to throw as

accurately as possible while also focusing on the standardized instruction given before each block of dart throw. The instructions were modified from a previous dart-throwing study (Lohse et al. 2010). The internal focus instruction was: *"Think about drawing the dart back to the ear and feel the bend in the elbow as you release the dart"* while the no focus instruction was: *"Throw as accurately as possible when you release the dart"*. Throw accuracy, throw time, T3-Fz EEG coherence, T4-Fz EEG coherence, and stress were measured during the internal focus and no focus conditions of dart throws. The experimental procedures and equipment used in the two experimental laboratories were kept the same.

Data analysis

All statistical analyses were performed using the SPSS 22 (IBM Corp., Armonk, NY, USA). Descriptive statistics (mean and standard deviation) of all outcome measures were computed for the internal focus and no focus conditions. The assumptions for homogeneity of the variances and normality were met for all outcome variables. Hence, a series of One-way Analysis of Variance (ANOVA) with repeated measures were performed to examine the main effect of condition (internal focus condition and no focus condition) on throw accuracy, throw time, T3-Fz EEG coherence, T4-Fz EEG coherence, and stress.

Results

The mean and standard deviation of throw accuracy (performance score), throw time, T3-Fz EEG coherence, T4-Fz EEG coherence, and stress (GSR - µS) of the trial blocks in the internal focus and no focus conditions were calculated. T3-Fz EEG coherence, T4-Fz EEG coherence, and stress of each block were measured as the average level between the start and end time of the throw block.

Significant main effects of condition were found in throw accuracy ($F(1, 60) = 7.55$, $\eta_p^2 = 0.112$, $p = 0.008$) (**Figure 2**), throw time ($F(1, 60) = 23.70$, $\eta_p^2 = 0.283$, $p = 0.001$) (**Figure**

3), T3-Fz EEG coherence (F(1, 60) = 12.74, η_p^2 = 0.175, p = 0.001) (**Figure 4**), and stress (F(1, 60) = 13.37, η_p^2 = 0.182, p = 0.001) (**Figure 6**). No significant main effect of condition was found in T4-Fz EEG Coherence (F(1, 60) = 0.934, η_p^2 = 0.015, p = 0.338) (**Figure 5**). The results indicate that internal focus condition (internal focus instruction) induced poorer throw accuracy with longer throw time than no focus condition (no focus instruction), while demonstrating higher T3-Fz EEG Coherence (interpreted as higher real-time conscious motor processing (reinvestment)) together with higher stress.

Figure 2 near here

Figure 3 near here

Figure 4 near here

Figure 5 near here

Figure 6 near here

Discussion

The current study aimed to examine the influence of internal focus instruction on motor performance and stress in young adults (novice) during a self-paced dart throwing task. The results suggest that internal focus instruction caused poorer motor effectiveness (as depicted as lower accuracy in the motor skill of dart throwing) and efficiency (as depicted in longer throw time) than no focus instruction during the dart throwing task. Therefore, it supports our hypothesis that a diminished performance would be observed in the internal focus condition when compared with the no focus condition. This finding shows consistent results with majority of the past literature that compared internal focus of attention with external focus of attention and control conditions, where internal focus instruction also induced a deteriorated

motor effectiveness and efficiency, when compared to the no focus condition (Lohse et al. 2010; Masters and Maxwell 2013).

The Constrained Action Hypothesis suggested that internal focus instruction would induce movement awareness, causing decreased movement automaticity and diminished motor performance, yet, supporting evidence regarding the underlying mechanism was lacking. Our current neuro-activity data provides insights on the process of conscious motor processing (reinvestment) by illustrating participants' use of verbal instructions during motor planning (i.e., the EEG coherence between the verbal analytical region (T3) and motor planning region (Fz) of the brain). This process has been regarded to reflect real-time conscious motor processing (reinvestment) (Chow et al 2019; Chu and Wong 2019; Ellmers et al. 2016; Masters and Maxwell 2008; Zhu et al. 2011). As no significant difference in the T4-Fz coherence activity was found between the internal and no focus condition, the current result strengthens our interpretation that the increase in T3-Fz coherence (interpreted as real-time conscious motor processing (reinvestment)) was not due to the global activation of the brain. Such finding provides objective evidence for increased movement self-awareness during movement execution. Furthermore, as participants demonstrated an increase in stress during the internal focus condition, it is depicted that internal focus instruction could be an external factor that causes stress. According to the reinvestment theory, stress is a factor that induces conscious motor processing (reinvestment) (Masters and Maxwell 2008). It may be hypothesized that the internal focus instruction was a trigger to stress, and such accumulated stress would then further promote self-awareness and conscious motor processing (reinvestment) (Masters and Maxwell 2008). The incorporation of the Constrained Action Hypothesis and the reinvestment theory could suggest that the increased conscious motor processing (reinvestment) was induced both directly by the internal focus instruction and the stress inflicted by the instruction. The increase in conscious motor processing (reinvestment) by both the instruction and the stress

may have contributed to the motor disruption and reduced automaticity, illustrated by the significant diminished motor accuracy and efficiency. However, the potential limitation of our current study is the lack of evidence for causality.

The relatively longer throw time demonstrated by participants who were given the internal focus of attention offer further support to the Constrained Action Hypothesis, suggesting that greater mental effort was utilized during an internal focus of attention, thus, diminishing motor automaticity (Lam et al. 2010; Wulf 2007). Since the internal focus instruction consists of more motor elements (movements) than the no focus instruction, greater attention capacity was occupied (Peh et al. 2011). A high level of attention is required to perform an accuracy-related motor task such as dart throwing (Peh et al. 2011). During the dart throwing task, attention capacity is divided among the motor task and the comprehension of the instruction. As the internal focus instruction consisted of more motor elements than the no focus instruction, participants were required to activate a larger proportion of their total attention capacity in instruction comprehension during the internal focus condition, ultimately sparing less attention for the dart throwing task (Peh et al. 2011). The effects on attention capacity may be reflected by the significant difference in throw time. As less attention was available for the actual motor task, a longer processing time was required, shown by the longer throw time during the internal focus condition. Participants were not told that their throw time would be analyzed, this was so that they would not deliberately throw the darts as quickly as possible in the hope to achieve a better score for this outcome variable. Presumably, the higher level of mental effort required for processing the internal focus instruction resulted in less attention available for the motor task; limited attention placed on the motor task likely was the reason for the diminished performance accuracy. Besides, a lack of full attention may also cause a delay in motor initiation (Peh et al. 2011). The current study suggests that the use of internal focus instruction required extra mental resources which did not benefit motor

performance. However, it is also possible that conscious motor processing on the dart-throwing task simply took a longer time to run the motor skill than unconscious motor processing that could increase the throw time (Masters and Maxwell 2008).

Furthermore, the nature of the task may also affect the results. The closed, self-paced genre of the dart throwing task may have provoked a higher level of conscious motor processing (reinvestment), resulting in worsened performance than motor tasks that are more environmentally influenced. The dart throwing task was chosen in this study, as it was believed that sufficient comprehension time is available for novice participants. However, this extra thinking time before skill execution might have led to slower initiation and higher conscious motor processing (reinvestment) (Wulf 2007). Slower initiation disrupted movement efficiency, while higher conscious motor processing (reinvestment) caused the de-chunking of movement and diminished performance (Masters and Maxwell 2008). Owing to this, internal focus instruction could be argued to demonstrate amplified adverse effects when applied on a closed self-paced motor task that allowed extra time for conscious motor processing (reinvestment).

Although the current study only examined the effects of internal focus instruction on young healthy adults, the negative effects of internal focus strategies have been regarded to be generalizable across the population (Wulf 2013). Diminished motor effectiveness and efficiency due to internal focus strategies have been found in children (Chiviacowsky et al. 2013), older adults (Chiviacowsky et al. 2010), adults with motor impairments (Fasoli et al. 2002; Landers et al. 2005; Wulf et al. 2009), and children with intellectual disabilities (Chiviacowsky et al., 2013). Wong et al. demonstrated older adults with fall history to have a higher propensity to adopt conscious motor processing (reinvestment) than non-fallers; suggesting that individuals' psychological attributes (i.e., conscious motor processing (reinvestment) propensity) to have a role in the perception and tendency to reinvest (Wong et

al. 2008). Even though the negative effects of internal focus instruction may be generalizable, the level of impact may vary among populations (i.e., individuals with different conscious motor conscious processing (reinvestment) propensity) due to their psychological attributes. It may be worth understanding how the effects of the current study may affect populations who have higher and lower preferences for internal focus strategies. Furthermore, as expert performers have automatized their skill, the utilization of an internal focus strategy, which is unfamiliar to them, should demonstrate greater detrimental results (Gray 2004). Future studies may examine the effects of internal focus instructions on expert performances for additional insights in relation to stress, conscious motor processing (reinvestment), and motor performance.

The potential limitation of the current study is that only the no focus and the internal focus instructions were investigated, whereas the external focus instruction was not included. There are two reasons for not including external focus instruction: 1) to avoid causing excessive fatigue in the later dart throws, 2) to look for effective advice that can be more easily implemented for the public. The comprehension and exercising of an instruction is influenced by one's level of practice and fatigue (Freudenheim et al. 2010). Overexerting was suggested to increase physical and attentional demand, which might likely result in decreased motivation and poorer performance in the later trials (Kibler et al. 1992; MacKinnon 2000). Thus, the current study followed previous dart throwing protocols of around 70 dart throws per experimental session (Marchant et al. 2007; McKay and Wulf 2012). Moreover, the use of external focus instruction is not as common as no focus or internal focus instructions (Wulf et al. 2001). The unfamiliarity of external focus instruction may have caused difficulty in public promotion in the past (Wulf et al. 2001). Hence, it is worthier and more manageable to investigate two conditions (internal and no focus conditions) only.

Another concern with the current study may regard the EEG and GSR data collection methodology. Due to limitations of our equipment, the EEG and GSR data were measured across 5 dart throws. Although the measurement may have been influenced by other factors such as mind wandering between each individual throw, the risk was relatively low as each trial block only took around 15 second to complete. Yet, more accurate recording of conscious motor processing (reinvestment) and stress could be conducted through event-locked measurements to individual trials. Furthermore, recent research has placed doubt on the accuracy of T3-Fz coherence as an interpretation of real-time conscious motor processing (reinvestment) (Bellomo et al. 2020; Parr et al. 2019). Thus, future studies may also consider collecting multiple measures such as cardiac and muscle activity for a more convincing interpretation of this variable (Bellomo et al. 2020).

Conclusion

The current study has found that internal focus instruction could diminish motor accuracy and efficiency while increasing real-time conscious motor processing (reinvestment) and stress. Thus, it is advised that internal focus instructions should be avoided in the execution of a self-paced motor skill, such as dart throwing.

Acknowledgments

Authors' contribution

JL conducted data collection. All authors contributed to the design of the studies and preparation of the manuscript.

Compliance with ethical standards

Conflict of interest

JL and TW declared no conflict of interest.

Ethical approval

The research protocol was approved by the Institutional Review Board of the University of Hong Kong /Hospital Authority Hong Kong West Cluster (HKU/HA HKW IRB; IRB no.: UW 17-223), and written consents were obtained for all participants before any experimental procedure. The trial was also registered in the HKU Clinical Trial Registry (HKUCTR-2465).

References

Bellomo E, Cooke A, Hardy J (2018). Chunking, conscious processing, and EEG during sequence acquisition and performance pressure: A comprehensive test of reinvestment theory. Journal of Sport and Exercise Psychology, 40(3), 135-145. https://doi.org/10.1123/jsep.2017-0308

Bellomo E, Cooke A, Gallicchio G, Ring C, Hardy J (2020). Mind and body: Psychophysiological profiles of instructional and motivational self-talk. Psychophysiology, e13586. https://doi.org/10.1111/psyp.13586

Chiviacowsky S, Wulf G, Avila LTG (2013) An external focus of attention enhances motor learning in children with intellectual disabilities. Journal of Intellectual Disability Research 57:627-634. https://doi.org/10.1111/j.1365-2788.2012.01569.x

Chiviacowsky S, Wulf G, Wally R (2010). An external focus of attention enhances balance learning in older adults. Gait & Posture 32:572-575. https://doi.org/10.1016/j.gaitpost.2010.08.004

Chow VWK, Ellmers TJ, Mak TC, Young W, Wong TWL (2019) Revisiting the relationship between internal focus and balance control in young and older adults. Frontiers in neurology 9:1131. https://doi.org/10.3389/fneur.2018.01131

Chu CKH, Wong TWL (2019) Conscious postural control during standing on compliant surface by older adults. Journal of Motor Behavior 51:342-350. https://doi.org/10.1080/00222895.2018.1481820

Ellmers TJ, Machado G, Wong TWL, Zhu F, Williams AM, Young WR (2016) A validation of neural co-activation as a measure of attentional focus in a postural task. Gait & posture 50:229-231. https://doi.org/10.1016/j.gaitpost.2016.09.001

Fasoli SE, Trombly CA, Tickle-Degnen L, Verfaellie MH (2002) Effect of instructions on functional reach in persons with and without cerebrovascular accident. American

Journal of Occupational Therapy 56:380-390. https://doi.org/10.5014/ajot.56.4.380

Freudenheim AM, Wulf G, Madureira F, Pasetto SC, Corrĕa UC (2010) An external focus of attention results in greater swimming speed. International Journal of Sports Science & Coaching 5:533-542. https://doi.org/10.1260%2F1747-9541.5.4.533

Gray R (2004) Attending to the execution of a complex sensorimotor skill: Expertise differences, choking, and slumps. Journal of Experimental Psychology: Applied 10:42. https://doi.org/10.1037/1076-898X.10.1.42

Herwig U, Satrapi P, Schönfeldt-Lecuona C (2003) Using the international 10-20 EEG system for positioning of transcranial magnetic stimulation. Brain topography 16:95-99. https://doi.org/10.1023/B:BRAT.0000006333.93597.9d

Kibler WB, Chandler TJ, Stracener ES (1992) Musculoskeletal adaptations and injuries due to overtraining. Exercise and sport sciences reviews 20:99-126. https://doi.org/10.1249/00003677-199200200-00004

Kuan G, Morris T, Kueh YC, Terry PC (2018) Effects of relaxing and arousing music during imagery training on dart-throwing performance, physiological arousal indices, and competitive state anxiety. Frontiers in psychology 9:14. https://doi.org/10.3389/fpsyg.2018.00014

Lam WK, Masters RS, Maxwell JP (2010) Cognitive demands of error processing associated with preparation and execution of a motor skill. Consciousness and cognition 19:1058-1061. https://doi.org/10.1016/j.concog.2008.11.005

Landers DM (1985) Psychophysiological assessment and biofeedback. In Biofeedback and sports science. Springer, US, pp 63-105. https://doi.org/10.1007/978-1-4757-9465-6_3

Landers M, Wulf G, Wallmann H, Guadagnoli M (2005) An external focus of attention attenuates balance impairment in patients with Parkinson's disease who have a fall

history. Physiotherapy 91:152-158. https://doi.org/10.1016/j.physio.2004.11.010

Lohse KR, Sherwood DE, Healy AF (2010) How changing the focus of attention affects performance, kinematics, and electromyography in dart throwing. Human Movement Science 29:542-555. https://doi.org/10.1016/j.humov.2010.05.001

MacKinnon LT (2000) Overtrainng effects on immunity and performance in athletes. Immunology & Cell Biology 78:502-509. https://doi.org/10.1111/j.1440-1711.2000.t01-7-.x

Marchant DC, Clough PJ, Crawshaw M (2007). The effects of attentional focusing strategies on novice dart throwing performance and their task experiences. International Journal of Sport and Exercise Psychology 5:291-303. https://doi.org/10.1080/1612197X.2007.9671837

Marchant DC, Clough PJ, Crawshaw M, Levy A (2009). Novice motor skill performance and task experience is influenced by attentional focusing instructions and instruction preferences. International Journal of Sport and Exercise Psychology 7:488-502. https://doi.org/10.1080/1612197X.2009.9671921

Masters R, Maxwell J (2008) The theory of reinvestment. International Review of Sport and Exercise Psychology 1:160-183. https://doi.org/10.1080/17509840802287218

Masters RSW, Polman RC, Hammond NV (1993) 'Reinvestment': A dimension of personality implicated in skill breakdown under pressure. Personality and individual differences 14:655-666. https://doi.org/10.1016/0191-8869(93)90113-H

Maxwell JP, Masters RSW, Poolton JM (2006) Performance breakdown in sport: the roles of reinvestment and verbal knowledge. Research Quarterly for Exercise and Sport 77: 271-276. https://doi.org/10.1080/02701367.2006.10599360

McKay B, Wulf G (2012). A distal external focus enhances novice dart throwing performance. International Journal of Sport and Exercise Psychology 10:149-156. https://doi.org/10.1080/1612197X.2012.682356

Parr JVV, Gallicchio G, Harrison N, Johnen AK, Wood G (2019). All talk? Left temporal alpha oscillations are not specific to verbal-analytical processing during conscious motor control. bioRxiv, 851956. https://doi.org/10.1101/851956

Peh SYC, Chow JY, Davids K (2011) Focus of attention and its impact on movement behaviour. Journal of science and medicine in sport 14:70-78. https://doi.org/10.1016/j.jsams.2010.07.002

Radlo SJ, Steinberg GM, Singer RN, Barba DA, Melnikov A (2002) The influence of an attentional focus strategy on alpha brain wave activity, heart rate and dart-throwing performance. International journal of sport psychology 33:205-217.

Salai M, Vassányi I, Kósa I (2016) Stress detection using low cost heart rate sensors. Journal of healthcare engineering. https://doi.org/10.1155/2016/5136705

Seeck M, Koessler L, Bast T, Leijten F, Michel C, Baumgartner C, Beniczky S (2017) The standardized EEG electrode array of the IFCN. Clinical Neurophysiology, 128(10), 2070-2077. https://doi.org/10.1016/j.clinph.2017.06.254

Taelman J, Vandeput S, Spaepen A, Van Huffel S (2009) Influence of mental stress on heart rate and heart rate variability. In 4th European conference of the international federation for medical and biological engineering, Springer, Berlin, Heidelberg, pp 1366-1369. https://doi.org/10.1007/978-3-540-89208-3_324

Wong WL, Masters RSW, Maxwell JP, Abernethy AB (2008) Reinvestment and falls in community-dwelling older adults. Neurorehabilitation and Neural Repair *22*:410-414. https://doi.org/10.1177%2F1545968307313510

Wulf G (2007) Attentional focus and motor learning: A review of 10 years of research. E-journal Bewegung und Training 1:1-11.

Wulf G (2013) Attentional focus and motor learning: a review of 15 years. International Review of Sport and Exercise Psychology 6, 77-104. https://doi.org/10.1080/1750984X.2012.723728

Wulf G, Landers M, Lewthwaite R, Töllner T (2009) External focus instructions reduce postural instability in individuals with Parkinson disease. Physical Therapy 89:162-168. https://doi.org/10.2522/ptj.20080045

Wulf G, Lewthwaite R (2010) Effortless motor learning? An external focus of attention enhances movement effectiveness and efficiency. In Effortless attention: A new perspective in attention and action. MIT press, Cambridge, pp 75-101. https://doi.org/10.7551/mitpress/9780262013840.003.0004

Wulf G, McNevin N, Shea CH (2001) The automaticity of complex motor skill learning as a function of attentional focus. The Quarterly Journal of Experimental Psychology: Section A 54:1143-1154. https://doi.org/10.1080%2F713756012

Wulf G, Töllner T, Shea CH (2007). Attentional focus effects as a function of task difficulty. Research Quarterly for Exercise and Sport, 78(3), 257-264. https://doi.org/10.1080/02701367.2007.10599423

Zhang CQ, Si G, Duan Y, Lyu Y, Keatley DA, Chan DK (2016). The effects of mindfulness training on beginners' skill acquisition in dart throwing: A randomized controlled trial. Psychology of Sport and Exercise, 22, 279-285. https://doi.org/10.1016/j.psychsport.2015.09.005

Zhu FF, Poolton JM, Wilson MR, Maxwell JP, Masters RSW (2011) Neural co-activation as a yardstick of implicit motor learning and the propensity for conscious control of movement. Biological Psychology 87:66-73.

https://doi.org/10.1016/j.biopsycho.2011.02.004

https://doi.org/10.1016/j.biopsycho.2011.02.004

Figure Legend

Figure 1. Dartboard with the radial error performance score indicated (The commercially available dartboard was 45 centimetres in diameter with 8 score bands, each band 2.5 centimetres wide).

Figure 2. Performance Score during Internal focus and No focus condition trials.

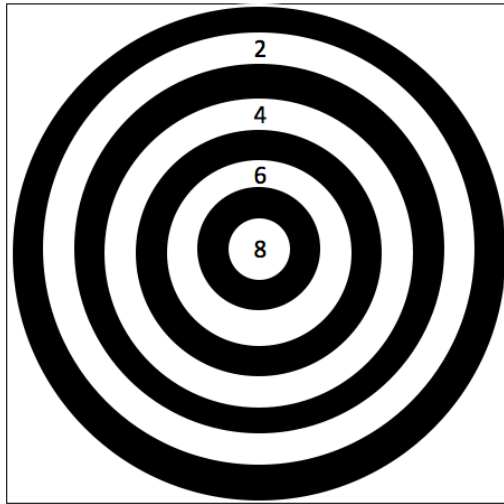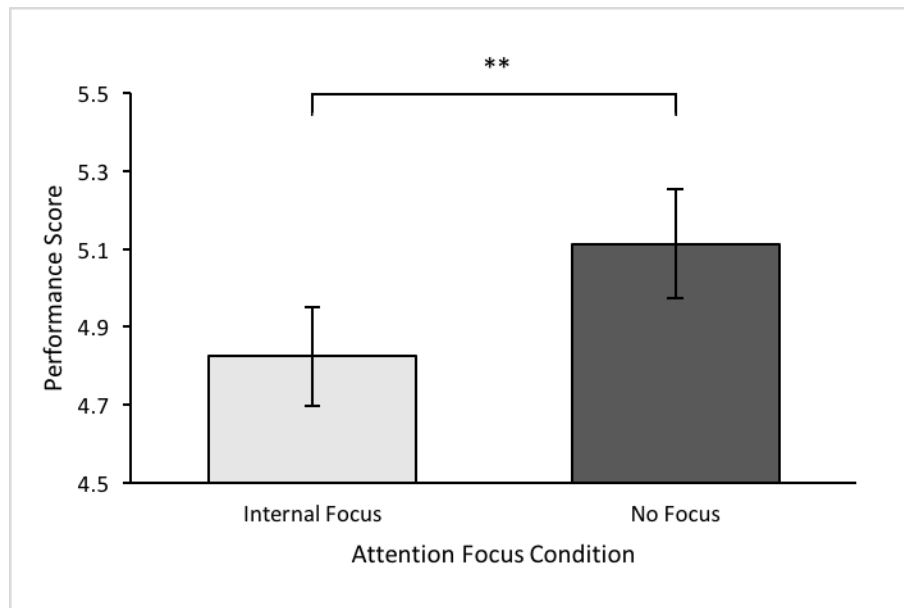**Figure 3.** Throw Time during Internal focus and No focus condition trials.

Figure 4. T3-Fz EEG Coherence during Internal focus and No focus condition trials.

Figure 5. T4-Fz EEG Coherence during Internal focus and No focus condition trials.

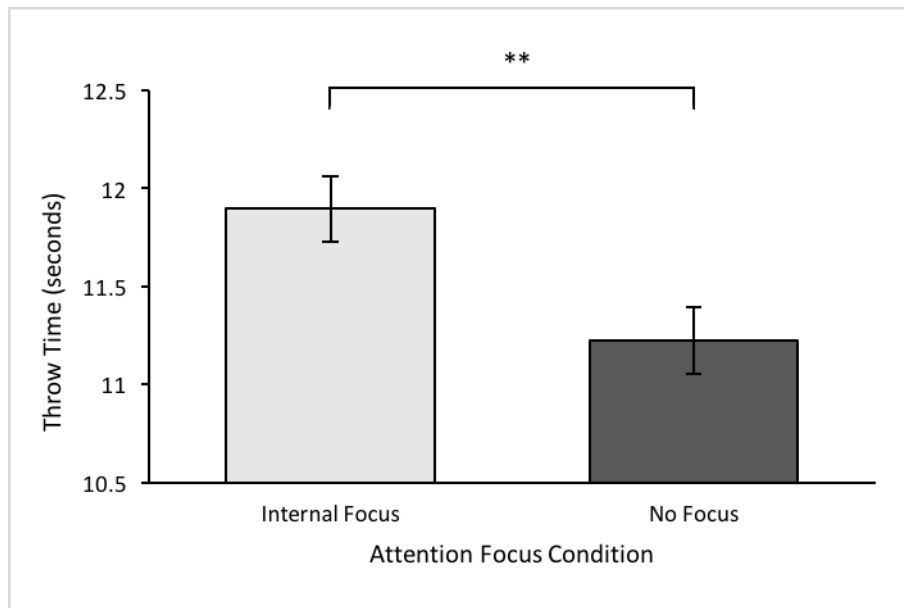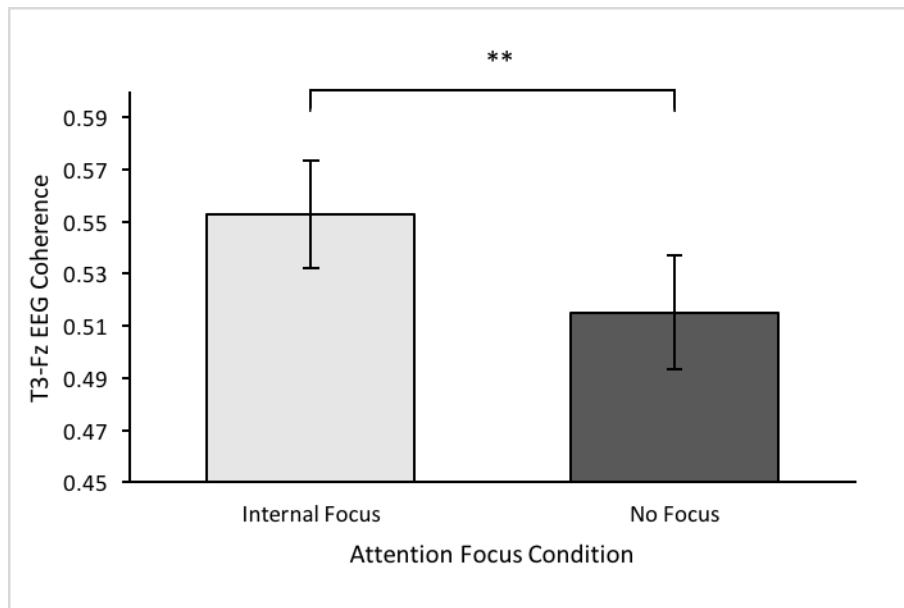**Figure 6.** Stress during Internal focus and No focus condition trials.

Figure 1.

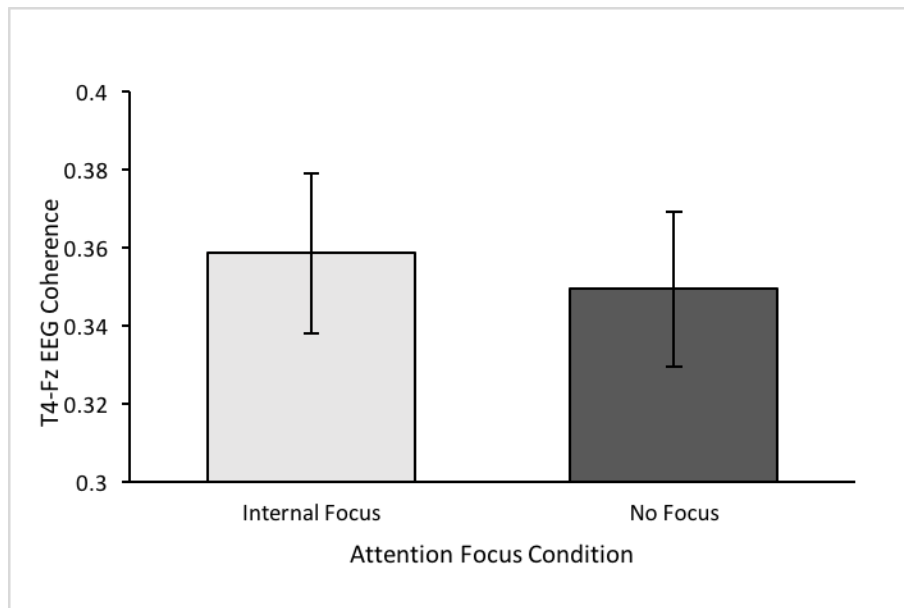*Note.* SEM values are shown as error bars; ** $p < 0.01$

Figure 2.

Note. SEM values are shown as error bars; ** $p < 0.01$
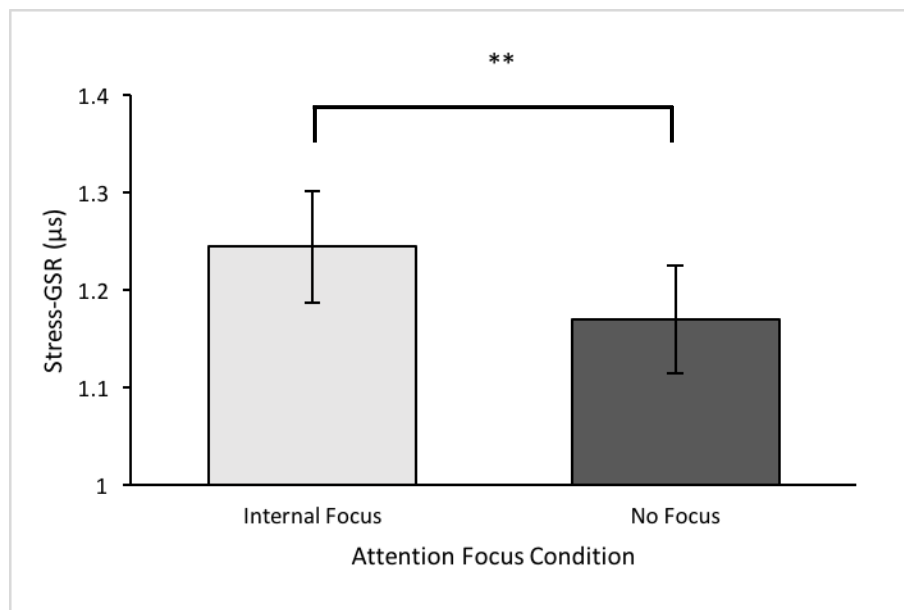
Figure 3.

Note. EEG = Electroencephalography; SEM values are shown as error bars; ** $p < 0.01$

Figure 4.

Note. EEG = Electroencephalography; SEM values are shown as error bars

Figure 5.

Note. GSR = Galvanic Skin Response; SEM values are shown as error bars

** $p < 0.01$

Figure 6.