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Efficacy of a Brief Biofeedback Intervention on Mood, Arousal, Mental Workload, Movement Time, and Biofeedback Device Preference

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Abstract

Biofeedback (BF) training has been utilized with performers for years. Previous literature highlights the effectiveness of multi-week intervention protocols, but there is a lack of evidence for abbreviated interventions using portable devices and the performer's preference of these devices. Therefore, we investigated the effects of a brief BF intervention on mental workload, mood, arousal, and movement time and BF device preference. Participants (N = 40) were randomly assigned to one of two heart rate variability (HRV) BF interventions or a control group. Although the brief intervention did not have a significant effect on mood, movement time, or mental workload, it did significantly and positively impact perceived arousal. Overall, 12 participants (48%) preferred the EmWave™ desktop device, eight (32%) preferred the Inner Balance™ device, and five (20%) preferred the EmWave2™ portable device. Results support limited effectiveness of a brief HRV BF protocol, although the dose–response effectiveness should continue to be explored.

Keywords Biofeedback · Technology · Sport psychology · Mental performance · Heart rate variability

Introduction

The performance demands in today's sport culture illustrate the need for higher echelons of mental focus and emotional regulation in addition to the physical, technical, and tactical aspects of human performance. As such, there are various arousal regulation strategies to assist athletes performing under stress-induced environments, including breath control, meditation, progressive muscle relaxation, and biofeedback training. Biofeedback and neurofeedback have increasingly gained popularity and have been documented to restore autonomic homeostasis and improve disorders such as asthma, functional gastrointestinal issues, cardiovascular disorders, fibromyalgia, and others (Gervirtz 2013; Lehrer et al. 2003; Lehrer et al. 2004; Moore 2000; Nestouric et al. 2008; Prinsloo et al. 2013) Broadly, therapeutic benefits have been reported for various acute and chronic clinical conditions related to health and stress (Lehrer and Gervirtz 2014).

Heart rate variability (HRV) is the measure of beat to beat changes in heart rate and is one of the most commonly used biofeedback (BF) modalities in psychophysiological research (Laborde et al. 2017). Various theoretical models explain the mechanism by which HRV is associated with mood, arousal, and performance (Grossman and Taylor 2007; McCraty 2011; Thayer and Lane 2000); HRV BF has gained popularity in the sport and performance realm and is widely used by sport and performance psychology practitioners to assess a performer's physiological signals and has shown to have numerous psychological and physiological benefits (Dessy et al. 2018; Gross et al. 2018; Laborde et al. 2017, 2014; Shaffer et al. 2014).

HRV is regulated by neural input from both the parasympathetic and sympathetic divisions of the autonomic nervous system. Low HRV is associated with decreased levels of vagal activity (decreased parasympathetic activation) and is more prevalent with chronic psychological stress and linked to mood and anxiety disorders (Hjortskov et al.

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2004; Kemp et al. 2010; Laborde et al. 2017; Moore 2000). However, increased HRV is linked with improved relaxation and cognitive performance under pressure (Hansen et al. 2003; Prinsloo et al. 2010), improved psychomotor sport performance (Paul et al. 2012), emotion recognition (Quintana et al. 2012), and improved recovery and adaptation to training (Buchheit 2014), and is an effective method for athletes and coaches to improve sport performance (Morgan and Mora 2017). Historically, expensive and complex BF devices created barriers to widespread use for coaches, performers, and practitioners (Berntson and Stowell 1998); with recent growth in peripheral and handheld devices with smartphone application utilization, this decreases the need for HRV expertise and contingencies can create "on the field" interventions for performers (Heathers 2013).

HRV BF interventions are typically delivered following Lehrer et al. (2000) resonance frequency model and methods of deep, rhythmic, abdominal breathing to achieve one's resonant frequency, or breathing pace cycle that most amplifies the response in vagal tone. Approximately six breaths per minute (4 s inhale, 6 s exhale) concentrates the frequency to about 0.1 Hz. Such a breathing pace works by using respiratory sinus arrhythmia (RSA), the mechanism by which heart rate increases during inhalation and decreases during exhalation to create maximal HRV and coincide with changes in the baroreflex (Goldstein et al. 2011).

An HRV BF breathing intervention shows significant effectiveness and increases in resting baroreflex gain across 10 sessions (Lehrer et al. 2003). However, Karavidas et al. have shown increases to start appearing after just four sessions in participants with major depressive disorders. Mood disruptions are typically shown by impaired baroreflex sensitivity, and regular HRV training can create significant change in mood even when HRV changes are small (Karavidas et al. 2007).

In addition, multiple studies show similar findings with abbreviated and shorter duration HRV BF sessions to enhance performance under pressure and to regulate emotions in elite support staff members such as coaches, nutritionists, and performance directors (Gross et al. 2016; Prinsloo et al. 2010; Wells et al. 2012).

Recent observations by sport psychology practitioners have aimed to discover effective brief contact interventions in situations with limited facetime with performers (Chow et al. 2018; Giges and Petitpas 2000; Stanley et al. 2018). Thus, finding shorter duration HRV BF interventions will benefit practitioners who have limited contact with their performers. With the increased access to smartphone and tablet devices that have HRV BF functioning, finding preferences in devices used can provide practitioners with practical applications for utilizing these devices in real world settings. The primary aim of the current study was to explore the efficacy of two brief HRV BF interventions on mood, arousal, perceived mental workload, and movement time. One intervention included the use of a desktop HRV BF plus a portable EmWave™ device, while the other intervention included the use of the same desktop HRV BF program plus an Inner Balance™ device. We hypothesized that, relative to a control group, both HRV BF interventions would increase mood, decrease arousal, decrease perceived mental workload, and improve movement time. While studies have yet to test an intervention this short, the success of previously tested abbreviated interventions led us to believe we would find positive changes. However, given that HRV BF is a learning process, one might expect minimal changes. A secondary aim was to assess performers' preference of HRV Biofeedback device between the EmWave Pro™ desktop, EmWave2™ portable unit, or the Inner Balance™ application.

Methods

Participants

Forty undergraduate students (19 females and 21 males) ages 18–29 years ($M = 22.31$, $SD = 2.77$) participated, 87.5% of whom were Kinesiology majors. Participants were randomly assigned to one of three groups: in the control (CON, $n = 15$) group, participants did not receive BF training. In the EmW2 group ($n = 13$), participants received HRV BF training on the EmWave Pro™ desktop unit as well as the EmWave2™ portable version of the desktop unit. In the IB group ($n = 12$), participants received HRV BF training on the EmWave Pro™ desktop unit as well as the Inner Balance™ portable device.

Measuring Instruments

Arousal was measured by the 1-item Felt Arousal Scale (FAS; Svebak and Murgatroyd 1985), a state measure of perceived physiological activation which elicits a response to how aroused or "worked up" an individual feels in any given moment. Participants estimated how they felt "at this moment" by circling a number ranging from 1 to 6 from 1 ("Low Arousal") to 6 ("High Arousal"). Scores from 1 to 3 represent a perceived telic (relaxed) state while scores from 4–6 represent a perceived paratelic (tense) state. The FAS was validated using construct validity with forearm EMG and thoracic respiration (Svebak and Murgatroyd 1985) and has correlated strongly with other assessments of perceived stress (Stults-Kolehmainen et al. 2016).

Mood was assessed by the Brunel Mood Scale (BRUMS; Terry et al. 2003), which was adapted for adolescents from the 65-item Profile of Mood States (McNair et al. 1971). BRUMS is a 24-item measure of five negative mood states of *anger*, *confusion*, *depression*, *fatigue*, *tension*, and one positive mood state of *vigor*. Each item contains a single mood descriptor in which the participants assesses how he or she "feels right now" on a 5-point Likert scale ranging from 0 ("not at all") to 4 ("extremely"). Subscale scores are summed across all four items, leading to possible scores between 0 and 16 per subscale. Construct validity, internal consistency, and concurrent validity has been reported to be strong for adult samples (Cronbach's alpha ranging from 0.75 to 0.86 per subscale; Terry et al. 1999).

Mental Workload was assessed by the NASA-Task Load Index (NASA-TLX; Hart and Staveland 1988), a multi-dimensional rating procedure designed to measure perceived overall workload of task effectiveness and other performances. NASA-TLX is composed of 15 pair-wise comparisons of six subscale factors: *mental demand (how much mental and perceptual activity was required), physical demand (how much physical activity was required), temporal demand (how much time pressure occurred), perceived performance (how successful do you think you were), effort (how hard did you work),* and *frustration level (how insecure, discouraged, irritated, or annoyed did you feel)*. First, participants evaluated the contribution of each factor to the workload of the task completed. The number of each factor score is tallied and weighted ranging from 0 ("not relevant") to 5 ("more important than any factor"). Second, numerical ratings for each subscale factor are marked on a 12-cm line ranging from 0 to 100 that is divided into 20 equal intervals in increments of five anchored by endpoint descriptors (e.g. Low/High, Good/Poor). Overall workload score is calculated by multiplying each rating scale by the weight given from the 15-separate pair-wise comparisons; the sums of each subscale are then divided by 15 to receive the overall workload score.

Movement time was measured using the FitLight Trainer™ system, a set of nine wireless LED lights connected to a tablet controller used to train reaction time (FitLight Sports Corp., Aurora, Ontario, Canada). Similar to the settings used by Zwierko et al. (2014), three comparable test sequences were created. Each sequence consisted of a series of 22 visual stimuli appearing as lights on nine of the FitLight™ wireless discs. Each of the three sequences used a different color light for all 22 visual stimuli, either yellow, blue or purple. Within each sequence, the delay between activation of each light varied between 0.1 and 3.0 s but added up to the same total time of delay for all three designs. The duration of the presentation of each light was standardized at five seconds across all 22 lights and each of the three sequences; doing so ensured that all lights were deactivated, and a movement time was assessed for each light stimulus. The order of the three test sequences for each participant was randomized and counterbalanced. It was from these three test sequences that average movement time and total time of task execution were assessed.

Procedures

Prior to the study, participants were randomized and counterbalanced into two groups: intervention (INT) and control (CON). For the INT group, BF devices were randomized so that participants used the EmWave Pro™ desktop device and either the EmWave2™ Portable Device or the Inner Balance™ app. All three HRV BF devices were designed and developed by HeartMath Institute (HeartMath, Canada). Desktop EmWave Pro™ software (HeartMath, Canada) was run on a laptop with an EmWave Pro USB pulse sensor, a photoplethysmograph showing high concordance with ECG (Giardino et al. 2002). Tablet HRV BF was administered on the Inner Balance™ application, ran on a sixth generation iPad (Apple Inc., California) connected to a pulse sensor. The EmWave2™ with the accompanying pulse rate sensor served as our portable device.

All procedures were approved by the University Institutional Review Board for human subjects and are summarized in Fig. 1. Participants were recruited via convenience sample through a department research website and in-class announcements. Total participation time was about one hour in a closed laboratory with four spaces for each phase of data collection. After completing informed consent and initial psychometrics [BRUMS (Terry et al. 2003) and FAS (Svebak and Murgatroyd 1985)], participants were introduced to and completed a familiarization task on the FitLights™ then completed the first of three test sequences. Similar to Zwierko et al. (2014), the FitLights™ were fixed in a semicircle pattern six centimeters apart and 40 cm from the designated starting point on a 75 cm tall table (see Fig. 2).

Prior to the initial FitLight™ test sequence, participants were instructed to take an athletic stance at table. The task was to deactivate each light as quickly as possible by moving their dominant hand within 30 cm over the light and returning it to the center marker while their non-dominant hand remained behind their back. The test began with a traffic light countdown on the center disc and ended once 22 lights were deactivated. Next, the first BF intervention was administered to participants in the INT group using a modified version of Lehrer et al.'s (2000) protocol. For those who received the Inner Balance™ app and the EmWave Pro™ intervention first, the detailed interfaces were displayed, and pacers were set to a baseline 10 s breath pace. For participants who received the EmWave2™ portable device first, participants practiced at the device's unmodifiable eight second breath pace.

During this protocol, participants were educated on respiratory sinus arrhythmia (RSA), diaphragmatic breathing techniques, and resonant frequency was determined

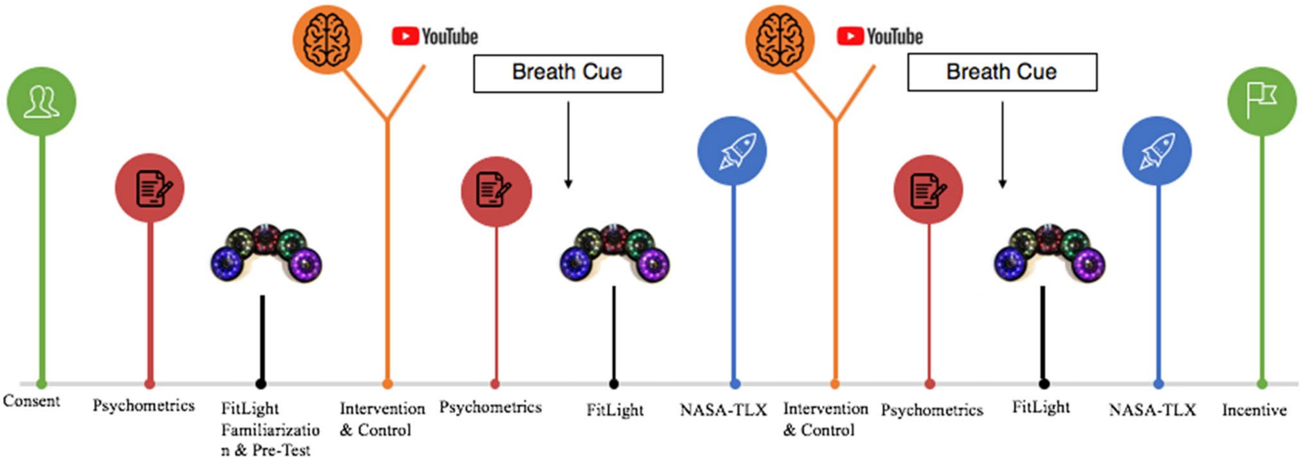

Fig. 1 Timeline of procedures during lab visit

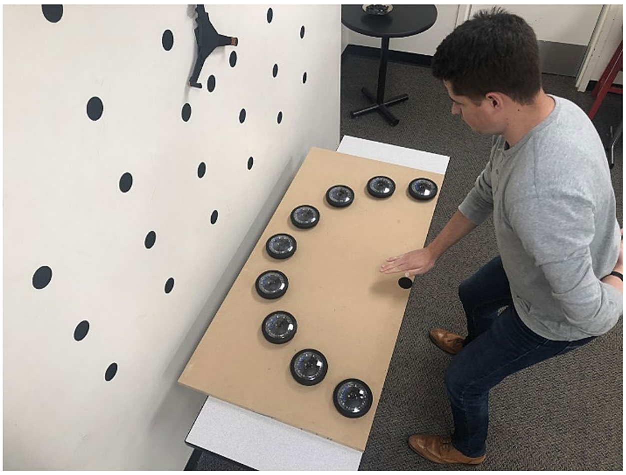

Fig. 2 Semicircle configuration of FitLight™ discs with participant in athletic stance and dominant hand in ready position

by having participants practice breathing at three different paces (9, 10, and 11 s) for two minutes each. Participants who received the EmWave2™ for their first intervention were not exposed to resonant frequency and the different paces, but instead practiced the relaxed breathing technique for a total of six minutes with check-ins every two minutes. CON participants watched a neutral non-emotional video called "Physical Education and Movement Education" (A/V Geeks 2013). Next, participants completed the next set of psychometrics, then the second FitLight™ task. They were reminded of initial instructions, and the INT group was cued to briefly utilize the diaphragmatic breathing paired with visualization of the appropriate BF device graphic. Following this task, participants completed the first NASA-TLX (Hart and Staveland 1988).

For the second BF intervention, INT participants received one of the other two HRV BF devices. For devices that allowed breath pace manipulation, RSA was set, then participants received a brief explanation of device differences, and were allowed to ask questions before practicing for three minutes. The CON group watched a three minute segment of the video "Earth" ("Earth", directed by Fothergill and Linfield 2007), a nature documentary that was previously deemed to be neutral and non-emotional (Pageaux et al. 2013; Rozand et al. 2014). Following the second intervention, participants completed the FAS and BRUMS for a third time. Prior to the third FitLight™ test sequence, the participants were reminded of the instructions, and the INT group was cued their special instruction. Following this test sequence, participants took the final NASA-TLX, and the INT group took a final questionnaire asking their HRV BF device preference.

Data Analysis

To determine intervention efficacy on perceived arousal, mood, and movement time, separate 3 × 3 (group by time) repeated measures ANOVAs were performed, with dependent variables of FAS, fatigue, tension, vigor, average movement time, and total movement time. Perceived workload differences were conducted by a 3 × 2 (group by time) ANOVA, with dependent variables of mental workload, physical workload, temporal workload, performance, effort, frustration, and total workload. Significant differences were examined using Scheffe's post-hoc tests. Device preference was analyzed using frequency of intervention group responses to either the EmWave Pro™ desktop, EmWave2™, or Inner Balance™ devices.

Results

Descriptive statistics for all dependent variables can be found in Table 1. Cronbach (1951) alpha reliability estimates for the mood state subscales fell below 0.70 for anger, confusion, and depression, so these subscales were eliminated from further analyses. Cronbach's alpha estimates for the tension, fatigue, and vigor subscales ranged from 0.82 to 0.92. FitLight™ data for the second trial of one participant was lost during data collection, leaving 39 useable data points for the FitLight™ analyses.

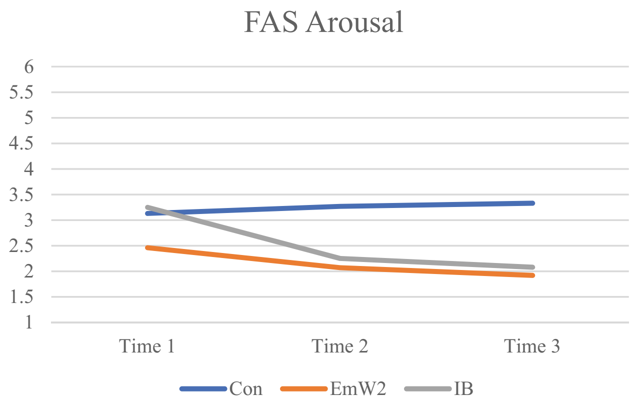

Fig. 3 Results for arousal scores

Psychometrics

Arousal

No significant group × time interaction was found for FAS scores, Wilks' $\lambda = 0.810$, $F(4, 72) = 1.99$, $p = 0.104$, partial $\eta^2 = 0.09$. However, there was a significant time main effect, Wilks' $\lambda = 0.845$, $F(2, 36) = 3.29$, $p = 0.049$, partial $\eta^2 = 0.15$, indicating that the perceived arousal scores for the control group increased over time while the perceived arousal scores for both intervention groups decreased over time. Power to detect the effect was set at 0.572. Results for arousal scores are found in Fig. 3. Follow-up group comparison for group arousal scores indicated a significant difference between the control group and desktop/EmWave2™ group (mean difference = 1.091, $p = 0.007$, 95% CIs 0.26, 1.92). Comparisons for desktop/Inner Balance group and control group were approaching significance (mean difference = 0.717, $p = 0.124$, 95% CIs − 0.13, 1.57).

Mood

No significant group × time interaction was found for fatigue, Wilks' $\lambda = 0.874$, $F(4, 72) = 1.26$, $p = 0.296$, partial $\eta^2 = 0.12$. However, there was a significant time main effect, Wilks' $\lambda = 0.733$, $F(2, 36) = 6.57$, $p = 0.004$, partial $\eta^2 = 0.27$, with power to detect the effect set at 0.885, indicating that all study participants across groups showed decreases in fatigue across the trials. No significant group × time interaction was found for tension, Wilks' $\lambda = 0.911$, $F(4, 72) = 0.85$, $p = 0.496$, partial $\eta^2 = 0.04$. However, there was a significant time main effect (Wilks' $\lambda = 0.509$, $F(2, 36) = 17.34$, $p = 0.000$, partial $\eta^2 = 0.49$, with power to detect the effect set at 1.000, indicating that all study participants across

Table 1 Mean (SD) dependent variables across trial points

	Trial 1			Trial 2			Trial 3		
	Con	EmW2	IB	Con	EmW2	IB	Con	EmW2	IB
FAS	3.13 (1.06)	2.46 (0.78)	3.25 (1.06)	3.27 (1.10)	2.07 (1.12)	2.25 (1.14)	3.33 (1.05)	1.92 (1.32)	2.08 (1.08)
Fatigue	6.60 (3.81)	4.00 (3.08)	4.50 (3.75)	4.20 (2.96)	2.77 (3.70)	3.00 (2.95)	3.07 (2.96)	2.85 (3.51)	4.17 (3.66)
Tension	3.87 (2.90)	3.00 (2.61)	2.42 (3.00)	1.33 (2.06)	0.69 (1.11)	0.33 (0.89)	1.07 (1.58)	0.62 (1.04)	1.33 (1.97)
Vigor	6.47 (2.80)	6.08 (2.66)	7.92 (4.17)	6.40 (3.60)	5.08 (2.56)	5.33 (4.70)	6.07 (3.01)	4.77 (3.52)	5.25 (6.15)
Mental				59.00 (31.46)	55.38 (29.89)	59.17 (27.62)	62.33 (31.22)	59.62 (28.02)	55.83 (29.68)
Physical				32.33 (20.34)	23.85 (21.52)	26.25 (27.89)	37.67 (27.05)	26.92 (23.76)	33.75 (28.93)
Temporal				67.00 (25.20)	61.54 (27.87)	65.83 (23.63)	63.67 (26.89)	56.92 (25.13)	64.58 (24.54)
Perf				51.00 (25.86)	42.31 (34.44)	44.58 (32.15)	45.00 (31.00)	41.54 (30.64)	46.67 (33.73)
Effort				54.33 (27.70)	49.23 (27.60)	62.92 (25.98)	53.33 (31.89)	45.38 (29.04)	57.08 (30.49)
Frustration				17.00 (17.51)	19.23 (24.48)	28.75 (27.64)	21.67 (30.45)	20.00 (24.75)	21.25 (23.27)
Total				58.33 (12.72)	52.59 (23.60)	60.64 (22.64)	58.76 (18.56)	51.15 (23.18)	58.89 (21.99)
FL Avg	0.53 (0.06)	0.54 (0.10)	0.53 (0.89)	0.54 (0.06)	0.56 (0.10)	0.56 (0.14)	0.51 (0.05)	0.53 (0.09)	0.54 (0.12)
FL Total	37.40 (1.17)	37.62 (2.31)	37.31 (1.95)	37.54 (1.38)	37.93 (2.25)	38.11 (3.17)	37.00 (1.06)	37.21 (2.03)	37.59 (2.71)

FAS Felt Arousal Scale, *Perf* Performance, *EmW2* Experimental Group (Desktop/EMW2), *IB* Experimental Group (Desktop/Inner Balance)

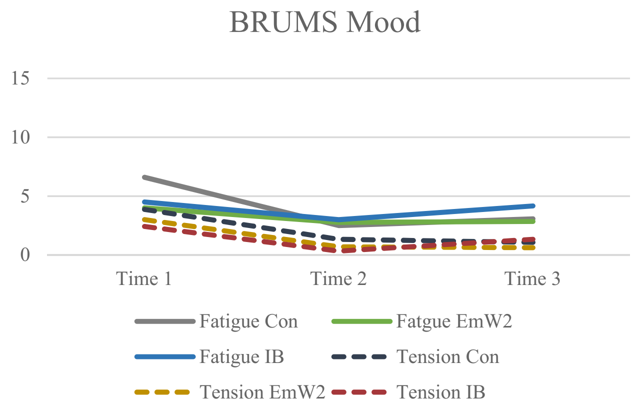

Fig. 4 Results for mood scores

groups showed decreases in tension across the trials. No significant group × time interaction was found for vigor, Wilks' λ = 0.924, F = 0.73, *p* = 0.577, nor was a significant time main effect found, Wilks' λ = 0.882, F = 2.42, *p* = 0.104. Results for mood scores are found in Fig. 4.

Perceived Workload

No significant group × time interaction was found for mental demand, Wilks' λ = 0.957, *F*(2, 37) = 0.82, *p* = 0.447, partial $\eta^2 = 0.04$, nor was a significant time main effect found, Wilks' λ = 0.992, *F*(1, 37) = 0.30, *p* = 0.585, partial $\eta^2 = 0.01$. No significant group × time interaction was found for temporal demand, Wilks' λ = 0.995, *F*(2, 37) = 0.89, *p* = 0.915, partial $\eta^2 = 0.004$, nor was a significant time main effect found, Wilks' λ = 0.976, F(1, 37) = 0.93, *p* = 0.342, partial $\eta^2 = 0.02$. No significant group × time interaction was found for physical demand, Wilks' λ = 0.981, *F*(2, 37) = 0.36, *p* = 0.702, partial $\eta^2 = 0.02$. However, there was a significant time main effect, Wilks' λ = 0.850, *F*(1, 37) = 6.53, *p* = 0.015, partial $\eta^2 = 0.15$, with power to detect the effect set at 0.701, indicating that all study participants across groups showed increases in perceived physical demand across the trials despite not having significant difference in the vigor subscale of the BRUMS. No significant group × time interaction was found for perceived effort, Wilks' λ = 0.990, *F*(2, 37) = 0.19, *p* = 0.830, nor was a significant time main effect found, Wilks' λ = 0.969, *F*(1, 37) = 1.18, *p* = 0.285. No significant group × time interaction was found for perceived performance, Wilks' λ = 0.981, *F*(2, 37) = 0.36, *p* = 0.701, nor was a significant time main effect found, Wilks' λ = 0.996, *F*(1, 37) = 0.15, *p* = 0.700. No significant group × time interaction was found for frustration, Wilks' λ = 0.956, *F*(1, 37) = 0.84, *p* = 0.438, nor was a significant time main effect found, Wilks' λ = 0.999, *F*(2, 37) = 0.03, *p* = 0.860). Finally, no significant group × time interaction was found for total perceived workload, Wilks' λ = 0.994, *F*(2, 37) = 0.12, *p* = 0.888, nor was a significant time main effect found, Wilks' λ = 0.994, *F*(1, 37) = 0.21, *p* = 0.651. Results for perceived overall workload scores can be found in Fig. 5.

Movement Time Task

No significant group × time interaction was found for FitLight™ average scores, Wilks' λ = 0.917, *F*(4, 70) = 0.778, *p* = 0.544. However, there was a significant time main effect, Wilks' λ = 0.767, *F*(2, 35) = 5.324, *p* = 0.01, partial $\eta^2 = 0.23$, with power to detect the effect set at 0.805, indicating that the average scores for all groups changed over time. No significant group x time interaction was found for FitLight™ total scores, Wilks' λ = 0.921, *F*(4, 70) = 0.733, *p* = 0.573. However, there was a significant time main effect, Wilks' λ = 0.784, *F*(2, 35) = 4.817, *p* = 0.014, partial $\eta^2 = 0.22$, with power to detect the effect set at 0.762. Results for FitLights™ scores can be found in Fig. 6.

Biofeedback Device Preference

Of the 25 participants in the two intervention groups, 12 (48%) preferred the EmWave™ desktop device over either of the portable devices. Of the 13 (52% of the total intervention sample) who preferred one of the two portable devices, 38% preferred the EmWave2™ device and 62% preferred the Inner Balance™ device. Overall, 12 participants (48%) preferred the EmWave™ desktop device, 8 (32%) preferred the Inner Balance™ device, and 5 (20%) preferred the EmWave2™ portable device.

Discussion

The present study investigated the effectiveness of a brief HRV BF intervention on mood, arousal, mental workload, and movement time on a reaction task. Our attempt was to

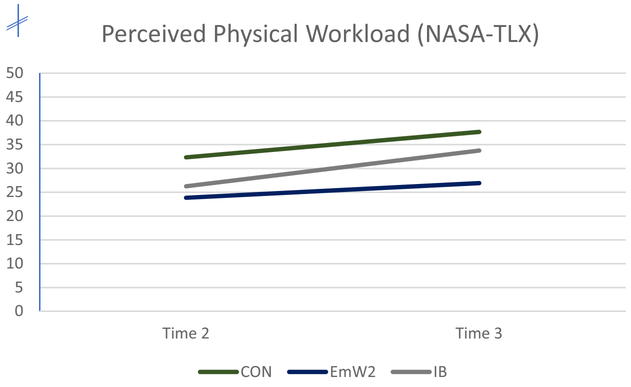

Fig. 5 Results for perceived overall workload scores

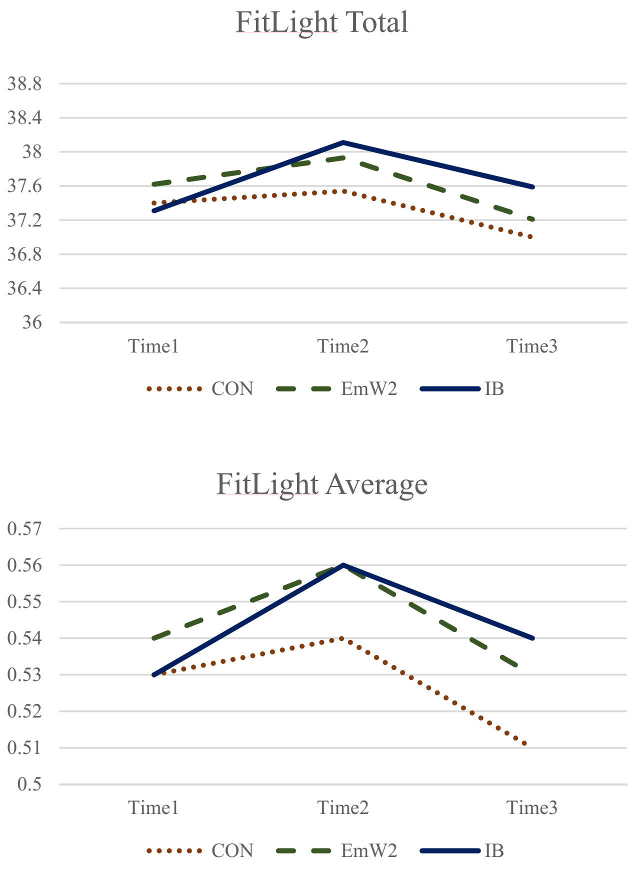

Fig. 6 Results for FitLight™ scores

determine the effectiveness of HRV BF intervention in a single lab visit. BF device preference was assessed for those in the intervention groups. While no significant interaction was found, perceived arousal scores significantly decreased across time for both HRV intervention groups and increased in the control group, providing evidence that HRV BF can be an effective self-regulation strategy. Previous research indicates that HRV BF can influence arousal, thus influencing performance (Dessey et al. 2018). However, the Felt Arousal Scale (Svebak and Murgatroyd 1985) is a one item instrument, and if we had larger variance in the response item, perhaps we could see significant changes across the trials.

With respect to mood, all three groups saw a decrease in perceptions of fatigue and tension across the trials, and no change in perceived vigor. Such a relationship has been found between low HRV and mood in clinical populations (Karavidas et al. 2007; Kemp et al. 2010). In the current study, the largest change in mood across time was between the pretest scores and the completion of the first intervention for the BF groups and the viewing of the documentary for the control groups. It is possible that participants, coming into the lab straight from classes or work, experienced a positive change in mood just by being in an isolated setting doing a task that switched their focus to something away from daily stress. Mood can change relatively rapidly in a brief intervention like HFV BF. For example, walking from a busy hallway into a calm isolated environment can change the mood one person is experiencing. Larger emotions from the BRUMS might not change as rapidly, such as depression, confusion, and anger, hence why the alpha reliabilities were too low and those were not reported in the analyses.

No significant changes in perceived mental workload were found across the intervention or control trials, indicating that a one-time HRV BF exposure may be limited in changing a performer's perception of the mental demands of a task. The NASA-TLX was originally designed to measure perceived overall workload of task effectiveness in human factor processes and systems including single-cognitive functions, manual control tasks, and even flight simulations. Recently, there has been evidence supporting the use of the NASA-TLX to measure perceived workload in sport and high-stress populations such as surgeons (Draper et al. 2017; Lowndes et al. 2018), and further research in this area is warranted in sport settings, particularly with respect to BF exposure.

Movement time using FitLights™ did not significantly improve in the intervention groups compared to the control group; in fact, average movement time decreased for all three groups across trials. The FitLight™ task is typically a novel task, so the majority of participants likely got better on the task as a result of practice. Further, with a novel task, participants would likely not have preconceived judgements or comparative concerns as they would a well-learned task. Use of a HRV BF intervention with respect to sport-specific tasks is thus warranted.

With respect to the dose–response relationship of a brief HRV BF intervention research and compared to previous research with longer interventions (Gross et al. 2016; Karavidas et al. 2007; Lehrer et al. 2003; Prinsloo et al. 2010; Wells et al. 2012), our training was designed to learn effective resonant frequency in a single visit with enough time to practice the proper breathing techniques independently. Past research has found acute changes in HRV and improvement in cognitive symptoms of clinical mood disorders after four sessions of HRV training (Karavidas et al. 2007), and multiple sessions and exposure to these techniques could potentially make a difference with regards to cognitive and movement performances. A minimum of four hours has been established to effectively learn the HRV BF techniques (Karavidas et al. 2007) while more recent studies show a minimum of five sessions to improve emotional regulation in elite support staff (Gross et al. 2018). Therefore, it is possible that perhaps a third session or second visit might have made a larger impact in the current study. Our current study and findings are novel and important given that no known study has tested a brief contact intervention this short to test the efficacy of a single BF session to show effective change in performers.

A key finding of this study was the preference of HRV BF devices between EmWave Pro™ desktop, EmWave2™ portable unit, or the Inner Balance™ application. Such information can provide insight and applicability to sport psychology professionals who are using HRV BF tools as aids in teaching psychological skills to enhance performance. The use of lab-based laptop equipment may be prohibitive in field settings, and the increased development of portable units is on the rise. Understanding the perceptions of performers with various BF modalities is important in guiding effective intervention strategies in real-world settings. A limitation of this finding is that more extensive qualitative questions were not asked to find out why participants preferred their favored device and future studies should include such questions. Another limitation is that multiple survey distributions within a small time frame could yield similar responses from participants. The researchers expected changes, albeit small, to occur regardless of time frame during data collection.

Based on the findings, there appear to be several possible directions for future research. Although there has been a great deal of research regarding protocols for HRV (Lehrer et al. 2000, 2003), little has been done to continue exploring brief interventions with athletes and performers. While past research shows the shortest protocols tested at four sessions, future studies should aim to test two and three session protocols to build on our current study of a single session. This would help to clarify the minimum amount of time that would produce significant changes. Clarifying this could help applied practitioners understand a tangible time frame they could expect to see significant changes in HRV BF training with athletes. This would also help to clarify reasonable expectations for athletes in the BF learning process and may make biofeedback more attractive to athletes and performers. For example, future research could spread the intervention across a multi-day period. Our current study had a single visit session, while next steps in could include the addition of a second session on a separate day giving participants more time in between visits. While the lack of significant results and negative findings might deter practitioners to follow this study's methodology, the meaningfulness behind these findings shows that future researchers can replicate the well-constructed intervention but lengthen the time frame of HRV BF delivery. Another possible direction could lead researchers to consider task choice (i.e. simple versus complex). Potentially in a simple task, one session of BF training might yield more significant results. Another possible direction would be to conduct the performance measures in a sport-specific environment as opposed to a laboratory setting. Although HRV device preference was established, future research should explore device preference with athletes and coaches to further aid sport psychology practitioners in their consulting.

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Compliance with Ethical Standards

Conflict of interest All authors declare that he/she has no conflict of interest with this study.

Ethical Approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed Consent Informed consent was obtained from all individual participants included in the study.

Research Involving Human and Animal Rights This article does not contain any studies with animals performed by any of the authors.

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