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Author

Neumann, David L, Heng, Sandor

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Running head: ATTENTIONAL FOCUS AND MUSCLE ACTIVITY

The effect of associative and dissociative attentional focus strategies on muscle activity and
heart rate during a weight training exercise

David L. Neumann & Sandor Heng

School of Psychology

Griffith University, Australia

Please direct correspondence to: David Neumann, School of Psychology, Griffith University
(Gold Coast Campus), Mail: GRIFFITH UNIVERSITY QLD, Queensland, 4222, Australia, E-
mail D.Neumann@griffith.edu.au, Facsimile +61(0)7 5552 8291, Telephone +61(0)7 5552 8052.

Abstract

Performance outcomes, such as distance rowed or kilometres run, can be influenced by the attentional focus an individual adopts. The present study tested how attentional focus during a weight training exercise influenced a direct measure of performance production (muscle activity) and heart rate. Participants executed bicep curls while adopting an associative, dissociative, or no specific attentional focus. Muscle activity, as measured by electromyographic recordings, and heart rate were lower in the associative condition than in the dissociative and control conditions. The participant's level of experience in weight training and the amount of weight lifted had little influence on this pattern of results. The results highlight that attentional focus is an important variable that can influence muscle activity, and ultimately training outcomes, during exercise.

Key words: attention; electromyographic; heart rate; performance

Introduction

Weight training plays an important role in sport. It can be a vital component of training programs and the performance in some sports, such as weight lifting and wrestling, are heavily influenced by the athletes' strength. The biomechanical nature of weight training has led to an emphasis on physical factors and technique during training. Researchers have examined the optimal number of sets (Carpinelli & Otto, 1998) and repetitions (Rhea, Alvar, Burkett, & Ball, 2003), and training intensity and frequency (Fleck, 1999) in influencing gains in strength, hypertrophy, and motor performance. Cognitive factors, like concentration and focus, can be an additional factor that influences training outcomes and psychophysiological methodology provides an excellent means to study such factors. Indeed, research has highlighted the important role of attention while exercising in directly influencing muscle activity during weight training (Marchant, Greig, & Scott, 2008; Vance, Wulf, Tollner, McNevin, & Mercer, 2004).

The effects of attentional focus on muscle activity were investigated by Vance et al. (2004) during a biceps curl exercise. The participants were asked to make 10 repetitions of a biceps curl when either concentrating on the movements of the bar (external attentional focus) or on the biceps muscles (internal attentional focus). An internal attentional focus was associated with higher muscle activity than an external attentional focus, as measured by electromyographic (EMG) recordings from the biceps and triceps muscles. The internal attentional focus was also associated with a greater range of movement and a slower velocity than the external attentional focus. Due to the possibility that the differences between conditions in movement speed influenced EMG activity, Vance et al. calculated an integrated EMG (iEMG) measure that corrected for these differences. The iEMG measure confirmed the higher muscle activity during an internal attentional focus. Moreover, a second experiment that controlled movement speed across conditions also replicated the higher muscle activity in

the internal attentional focus condition.

In interpreting the results of Vance et al. (2004) it is relevant to consider whether an internal attentional focus produces a relative increase in muscle activity or whether an external attentional focus produces a decrease in muscle activity. To answer this question, Marchant et al. (2008) investigated bicep EMG activity while athletes performed 10 isokinetic concentric elbow flexions in an external and internal attentional focus condition and in a control condition. In this new control condition, participants were given no additional instructions other than what the goal of the task was. The results showed that muscle activity in the internal focus and control conditions did not differ, but they were both higher than in the external focus conditions. An external focus of attention thus seems to produce a relative reduction in muscle activity.

The results reported by Vance et al. (2004) and Marchant et al. (2008) appear consistent with the theoretical perspective of Wulf (2007). Wulf (2007) has argued that an internal attentional focus creates “noise” (i.e., disturbances within the attentional system) that hampers fine motor control and automaticity of movements. Such disturbances can be manifested at the neuromuscular level and at the level of performance outcomes. For example, Zachary et al. (2005) examined basketball free throwing and found better performance with an external than an internal focus of attention. Moreover, although the internal instructions required participants to focus on wrist flexion, greater muscle activity was detected in the surrounding muscle groups (i.e., the flexor carpi radialis, biceps, and triceps brachii).

The internal versus external attentional focus distinction is, however, not the only way in which an individual may attend during an exercise. Association and dissociation are two broad attentional strategies that have been identified (Masters & Olges, 1998; Morgan & Pollock, 1977; see also Stevinson and Biddle 1999). Associative strategies involve the individual focusing on bodily sensations, movements, and performance cues. Dissociative

strategies aim to block out sensory feedback by performance distraction. The studies of Vance et al. (2004) and Marchant et al. (2008) were thus specific to an associative cognitive strategy. In terms of performance measures, an associative strategy has been associated with better outcomes of swimming times (Couture, Jerome, & Tihanyi, 1999), distance rowed (Scott, Scott, Bedic, & Dowd, 1999), and pace in walking (Tammen, 1996). On the other hand, performance on a quadriceps repetition task (Gill & Strom, 1985) and endurance when running on a treadmill (Morgan, 1981) has been better with a dissociative strategy. The contradictory findings may reflect differences in the task or participants (e.g., experience) used. To our knowledge, associative and dissociative strategies have not yet to be compared during a weight training exercise.

The present experiment examined the effects of an associative and dissociative cognitive strategy while individuals performed bicep curls. A third condition involving no specific attentional focus instructions was used as a control. Two additional variables were also examined: skill level and the amount of weight lifted. Skill level was examined because experienced athletes may be more accustomed to an associative strategy, whereas novice athletes may be more accustomed to a dissociative strategy (Morgan & Pollock, 1977). The amount of weight lifted was varied because of the suggestion that under conditions of high exercise intensity, athletes are more likely to adopt an associative strategy (see Masters & Ogles, 1998). The primary measure was EMG activity of the biceps and triceps muscles. Additional measures of heart rate, movements, and subjective ratings of perceived exertion and exercise satisfaction level were also taken. Due to the finding of lower EMG activity in an external attentional focus than an internal and control condition (Marchant et al., 2008; Vance et al., 2004), it was hypothesized that the associative condition would be associated with less EMG activity than the dissociative and control conditions.

Method

Participants

Participants were 16 novice and 14 experienced weight lifters recruited from Griffith University. The novice participants had not done any prior weight training and the experienced participants had done weight training for at least 4 hours per week on average over the previous 12 months. The novice group consisted of 2 females (21 to 37 years; $M = 29$, $SD = 11.31$) and 14 males (18 to 32 years; $M = 23.14$, $SD = 4.28$) and the experienced group consisted of 1 female (22 years) and 13 males (20 to 31 years; $M = 24.31$, $SD = 3.30$). All participants were screened for health-related concerns (e.g., cardiovascular disease) using the Sports Medicine Australia Pre-exercise Screening System. Participants received partial course credit or \$15 for participation. All participants provided informed consent to a protocol approved by the Institutional Ethics Review board.

Apparatus

Testing was completed in a room with a mean temperature and humidity of 23.1°C and 63.4%, respectively. A PowerLab 16s (ADInstruments, Sydney) data acquisition system was used for physiological recordings using a 1000 Hz sampling rate. The system comprised of a ML408 Dual BIO Amp, ML132 BIO Amp, and MLTS700 electrogoniometer for the EMG, electrocardiogram (ECG), and movement recordings, respectively. Pairs of surface-mounted Ambu Blue Sensor T Ag/AgCl disposable electrodes were placed on the skin above the belly of the *biceps brachia* and the long head of the *triceps brachia* muscles of the preferred arm to measure EMG. The electrodes were also attached on the chest-region (one over the *manubrium* and the second over the *xiphoid process*) to measure ECG. The electrogoniometer was attached to span across the elbow of the preferred arm to measure the angle of the elbow. The biceps curls were completed using a York Fitness cast iron dumbbell set with disc weights allowing a varying weight to be set. Auditory stimuli were presented via

Harman/Kardon HK206 desktop computer speakers.

A questionnaire obtained subjective ratings and for manipulation check purposes. Participants were asked to rate *Your level of exertion on the task* and *Your level of satisfaction with your effort* to measure the rating of perceived exertion and exercise satisfaction level, respectively. Ratings were given on a 7-point scale, ranging from 1 = *very low*, 4 = *moderate*, and 7 = *very high*. Two further questions asked *Did you execute the task as you normally would?* and *Did you try your best to follow the instructions provided* to measure whether execution was typical of their normal way of exercising and adherence to the instructions, respectively. The two items were rated on a 7-point scale, ranging from 1 = *strongly disagree*, 4 = *neutral*, and 7 = *strongly agree*.

Procedure

A set of instructions were given to participants on how to perform the biceps curl in order to standardize the task across participants and to isolate the biceps muscle during the exercise. Looking forward at all times, participants were required to lift the weight with their preferred arm standing up with their feet, back, shoulders, and elbow against a wall. The posture immobilized the *brachii* so that the curl was performed at the elbow and not the shoulder. Prior to the task, a strength assessment was done. The dumbbell was loaded with a weight and the participant attempted a single repetition. Further adjustments (via 0.5 kg increments) were made until the participant reached a maximum weight for completion of one repetition. The heavy and light weight amounts for the subsequent sets were 30% (light weight condition) and 70% (heavy weight condition) of this maximum weight.

After the strength assessment, the physiological recording instruments were attached. To allow individual calibration of EMG activity, participants performed an unweighted, maximal-effort isometric contraction of the elbow flexors at maximal elbow flexion, followed by the elbow extensors at full elbow extension. Peak EMG magnitude during these

contractions was used to normalize EMG magnitudes. Preliminary baseline measurements under no specific attentional focus instructions were made next. All participants completed this condition first to compare the novice and experienced groups in a way that could not be influenced by any subsequent attentional focus instructions. In counterbalanced order, participants completed a set of six repetitions of the biceps curl for the light and heavy weight. No specific instructions were made regarding what to attend to. For this and all subsequent sets, a 1-minute and 3-minute rest period followed the sets using the light and heavy weights, respectively. During the rest interval, participants completed the self-report questionnaire and reported what they had focused their attention on during the set.

Following the baseline condition, the participants completed sets of six bicep curls under associative, dissociative, and control conditions. In the control condition, participants were reminded of how they had lifted the weight during the baseline condition and were asked to similarly complete another set. In the dissociative condition, participants were instructed to attend to the lyrics of a song that was played (“Rhythm of the Night”, Corona, Italy, December 1993, Dance World Attack record label). The participants were asked to report the number of times in which the word “rhythm” was heard during the set. In order to control for the use of an auditory stimulus in the dissociative condition, the associative condition made use of auditory feedback. Participants were instructed to concentrate to a tone that varied in intensity according to the magnitude of the EMG signal recorded from their biceps. The signal was produced from the auditory output of the ADInstruments ML408 Dual BIO Amp. To ensure that the participants attended, they were asked to report which repetition was associated with the loudest sound output. In total, participants completed four sets for each of the associative, dissociative, and control conditions. Two of the sets used the light weight and two used the heavy weight. The trials were organised into two blocks, such that each block contained one set of each condition for the light and heavy weights. Trial order in

each block was counterbalanced across participants.

Data Scoring

Heart rate (HR) was measured using the Chart (ADInstruments, Sydney) software. The ECG signal was screened for artefacts and the R-peaks in the signal were identified. The HR was calculated between the onset of the first repetition until the end of the last repetition. For the movement and EMG measures, the first and last repetitions in each set were excluded because they were mechanically different from the other repetitions (Vance et al., 2004). A repetition began with the onset of the movement up and terminated when the bar was returned to the starting position as determined from the electrogoniometer recordings. The electrogoniometer recordings were used to calculate degrees of movement and angular velocity for each repetition. The EMG recordings were processed using custom laboratory software (LabView, National Instruments). The signal was filtered using a Butterworth low-pass filter ($F_c = 100$ Hz) and full-waved rectified. The raw biceps EMG and triceps EMG was calculated as the mean activity across each repetition. The iEMG measure was also used because it normalized muscle activity and accounted for the time taken to complete each repetition. The iEMG measure was calculated by first finding the percentage change in mean raw EMG activity for each repetition from the peak in EMG activity recorded during the unweighted maximal isometric contraction. A negative percentage change indicates less muscle activity during the curl task than the peak EMG. The resulting value was multiplied by the number of seconds to complete the repetition to derive the final value for iEMG.

Results

The weights used for novice participants (light weight, $M = 3.12$ kg, $SD = .78$; heavy weight, $M = 7.03$ kg, $SD = 1.87$) and experienced participants (light weight, $M = 4.83$ kg, $SD = .96$; heavy weight, $M = 11.13$ kg; $SD = 2.61$) were compared. As expected, the overall weight was heavier for experienced participants than for novice participants, $t(28) = 4.19$, $p <$

.001.

Baseline condition

Preliminary analyses were conducted for the baseline trials to test for differences between the novice and experienced groups independent of the later attentional focus instructions. The variables examined were perceived exertion, exercise satisfaction, degrees of movement, angular velocity, HR, and biceps and triceps raw EMG and iEMG. A difference between groups emerged in a 2 x 2 x 4 (Group x Weight x Repetition) ANOVA for angular velocity with a main effect for Group, $F(1, 28) = 6.24$, $p = .019$, $\eta_p^2 = .18$. Novice participants ($M = 79.76$ °/s, $SD = 18.78$) executed the curls with greater velocity than the experienced participants ($M = 64.43$ °/s, $SD = 14.92$). A 2 x 2 (Group x Weight) ANOVA for HR yielded a Group x Weight interaction, $F(1, 28) = 6.92$, $p = .014$, $\eta_p^2 = .20$. Post hoc analyses to examine this and all other subsequent effects were conducted with *t*-tests calculated using an adjusted α -value based on Sidak's multiplicative inequality to avoid inflated Type I error. Heart rate was higher for the heavy weight than for the light weight in novice (light weight: $M = 88.77$ bpm, $SD = 15.14$; heavy weight: $M = 94.68$ bpm, $SD = 14.02$), $t(28) = 4.44$, $p < .0005$, and experienced participants (light weight: $M = 84.76$ bpm, $SD = 9.81$; heavy weight: $M = 95.80$ bpm, $SD = 12.81$), $t(28) = 7.75$, $p < .0005$, although the magnitude of the difference was greater for the experienced participants. Finally, the expected differences between groups emerged in raw bicep EMG activity. A 2 x 2 x 4 (Group x Weight x Repetition) ANOVA yielded a significant Group x Weight interaction, $F(1, 84) = 5.28$, $p = .03$, $\eta_p^2 = .16$. Raw EMG was higher in experienced participants than in novice participants for the heavy, $t(28) = 2.88$, $p = .008$, but not for the light weight, $t(28) = 1.23$, $p = .23$.

Ratings to the question of whether the task was executed as it normally would were examined for the experienced participants. Ratings for the light weight ($M = 6.00$, $SD = 1.24$) and the heavy weight ($M = 5.93$, $SD = 1.27$) were high on the 7-point scale and did not differ

significantly, $t(13) = 1.00$, $p = .34$, indicating a high level of comparability to normal training conditions. Self-reports indicated that the main difference was the requirement during testing to have their feet, back, and shoulders against the wall.

Attentional focus strategy conditions

The mean values for the subjective ratings, HR, and EMG measures in the cognitive strategy conditions are shown in Table 1 for each group. The statistical analyses primarily focussed on the differences in the dependent measures as a function of the attentional focus conditions.

 Insert Table 1 about here

Subjective ratings. The ratings of perceived exertion and satisfaction level were examined with separate $2 \times 3 \times 2 \times 2$ (Group x Condition x Weight x Block) ANOVAs. The ratings of perceived exertion showed a main effect for Weight, $F(1, 28) = 97.84$, $p < .001$, $\eta_p^2 = .78$, a main effect for Block, $F(1, 28) = 11.57$, $p = .002$, $\eta_p^2 = .29$, a Condition x Block interaction, $F(2, 56) = 3.25$, $p = .046$, $\eta_p^2 = .10$, a Weight x Block interaction, $F(1, 28) = 4.26$, $p = .048$, $\eta_p^2 = .13$, and a near significant Group x Condition interaction, $F(2, 56) = 3.46$, $p = .053$, $\eta_p^2 = .11$, $\epsilon = .75$. The Condition x Block interaction was due to higher perceived exertion in Block 2 than in Block 1 for the control condition, $t(56) = 4.89$, $p < .001$, whereas there was no difference across blocks for the other conditions, all other $ts < 1.70$, $p > .05$. The ratings of satisfaction level showed a main effect for Weight, $F(1, 28) = 10.85$, $p = .003$, $\eta_p^2 = .28$, indicating higher satisfaction with a heavy weight than a light weight, whereas all other effects were not significant, all $Fs > 4.06$, $p > .05$.

Movements. The degrees of movement and movement velocity were analysed with separate $2 \times 3 \times 2 \times 4 \times 2$ (Group x Condition x Weight x Repetition x Block) ANOVAs. The

degrees of movement showed a main effect for Block, $F(1, 28) = 6.17, p = .019, \eta_p^2 = .18$, a main effect for Weight, $F(1, 28) = 36.19, p < .001, \eta_p^2 = .56$, a significant Group x Condition interaction, $F(2, 56) = 4.15, p = .033, \eta_p^2 = .13, \varepsilon = .74$, and a Weight x Block interaction, $F(1, 28) = 6.86, p = .014, \eta_p^2 = .20$, all other $F_s < 3.23, p > .05$. The Group x Condition interaction reflected that there was more degrees of movement in the control condition than in both the associative, $t(56) = 3.13, p = .003$, and dissociative, $t(56) = 2.85, p = .006$, conditions for the novice group. However, there were no differences between conditions for the experienced group, all $t_s < 1.68, p > .10$.

Movement velocity showed a main effect for Group, $F(1, 28) = 7.00, p = .013, \eta_p^2 = .20$, a main effect for Condition, $F(2, 56) = 5.70, p = .006, \eta_p^2 = .17, \varepsilon = .96$, a main effect for Weight, $F(1, 28) = 68.46, p < .001, \eta_p^2 = .71$, a main effect for Block, $F(1, 28) = 10.17, p = .003, \eta_p^2 = .27$, a Group x Weight interaction, $F(1, 28) = 5.97, p = .021, \eta_p^2 = .18$, a Weight x Block interaction, $F(1, 28) = 9.94, p = .004, \eta_p^2 = .26$, and a Weight x Repetition interaction, $F(3, 84) = 4.99, p = .008, \eta_p^2 = .15, \varepsilon = .72$. No other effects were significant all $F_s < 2.31, p > .05$. The main effect for condition indicated that velocity was lower in the associative condition than in the control, $t(56) = 2.95, p = .005$, and dissociative conditions, $t(56) = 2.91, p = .005$, whereas the two latter conditions did not differ, $t = .03, p > .05$.

Heart rate (HR). A 2 x 3 x 2 x 2 (Group x Condition x Weight x Block) ANOVA for HR yielded a main effect of Condition, $F(2, 56) = 15.17, p < .001, \eta_p^2 = .35, \varepsilon = .95$, a main effect for Weight, $F(1, 28) = 109.03, p < .001, \eta_p^2 = .80$, a main effect for Block, $F(1, 28) = 6.85, p = .014, \eta_p^2 = .20$, a Group x Weight interaction, $F(1, 28) = 11.51, p = .002, \eta_p^2 = .29$, and a Weight x Block interaction, $F(1, 28) = 6.39, p = .017, \eta_p^2 = .19$, all other $F_s < 2.85, p > .05$. The main effect for Condition was due to a lower mean HR in the associative condition, than in both the control, $t(56) = 3.42, p = .001$, and dissociative condition, $t(56) = 5.45, p < .001$, whereas the two latter conditions did not differ, $t(56) = 2.03, p > .05$.

Electromyographic activity. The EMG activity measures were examined with separate $2 \times 3 \times 2 \times 4 \times 2$ (Group x Condition x Weight x Repetition x Block) ANOVAs. The effect of the instructions influenced raw biceps EMG, as shown by a main effect of Condition, $F(2, 56) = 6.82, p = .003, \eta_p^2 = .19, \epsilon = .89$. Pairwise comparisons showed that EMG activity was lower in the associative condition than in both the control, $t(56) = 3.40, p = .001$, and dissociative, $t(56) = 2.85, p = .006$, conditions. The control and dissociative conditions did not differ, $t(56) = 0.54, p = .59$. Biceps EMG activity was also higher in the experienced group than in the novice group, main effect for Group, $F(1, 28) = 6.29, p = .018, \eta_p^2 = .18$, and increased across blocks, main effect for Block, $F(1, 28) = 7.12, p = .013, \eta_p^2 = .20$. Finally, a main effect for Weight, $F(1, 28) = 61.45, p < .001, \eta_p^2 = .69$, a main effect for Repetition, $F(3, 84) = 50.53, p < .001, \eta_p^2 = .64, \epsilon = .50$, Weight x Repetition interaction, $F(3, 168) = 23.24, p < .001, \eta_p^2 = .45, \epsilon = .64$, were also found.

Triceps EMG yielded a near significant main effect for Condition, $F(1, 56) = 3.49, p = .05, \eta_p^2 = .11, \epsilon = .80$. However, there were significant results for the main effect for Block, $F(1, 28) = 7.84, p = .009, \eta_p^2 = .22$, and main effect for Weight, $F(1, 28) = 34.82, p < .001, \eta_p^2 = .56$. These effects indicated that triceps EMG increased across blocks and was higher for the heavy weight than the light weight. No other main effects or interactions were significant, all $F_s < 2.72, p > .05$.

The analyses for the biceps iEMG confirmed the results of the raw EMG by yielding a main effect for Condition, $F(2, 56) = 6.14, p = .004, \eta_p^2 = .18$. The iEMG activity was lower in the associative condition than in the control, $t(56) = 2.77, p = .008$, and dissociative conditions, $t(56) = 3.25, p = .002$, which themselves did not differ, $t(56) = 0.48, p = .64$. The analyses also yielded a main effect for Weight, $F(1, 28) = 7.59, p = .01, \eta_p^2 = .21$, a main effect for Repetition, $F(3, 84) = 6.99, p = .004, \eta_p^2 = .20, \epsilon = .53$, a main effect for Block, $F(1, 28) = 15.32, p = .001, \eta_p^2 = .35$, and a Condition x Weight x Block interaction, $F(2, 56) =$

4.47, $p = .02$, $\eta_p^2 = .14$. Post hoc analyses showed lower iEMG for the light weight than the heavy weight in the control condition in Block 1 only, $t(56) = 3.21$, $p = .002$, and for the associative condition for both Block 1, $t(56) = 3.12$, $p = .003$, and Block 2, $t(56) = 4.56$, $p < .001$, and for the dissociative condition for Block 1 only, $t(56) = 4.77$, $p < .001$. No other comparisons were significant, all $ts < 1.79$, $p > .08$.

Similar to the iEMG for biceps, the analyses for the triceps muscle yielded a main effect for Condition, $F(2, 56) = 3.20$, $p = .048$, $\eta_p^2 = .10$. The difference across conditions was due to greater change in iEMG activity in the associative condition than in the dissociative condition, $t(56) = 2.51$, $p = .015$. A similar difference was found when the associative and control conditions were compared, although the comparison was not significant using α -corrected values, $t(56) = 2.17$, $p = .034$. The analyses also yielded a main effect for Block, $F(1, 28) = 17.07$, $p < .001$, $\eta_p^2 = .38$, and a Condition \times Weight \times Block, $F(2, 56) = 4.25$, $p = .019$, $\eta_p^2 = .13$. The interaction due to lower iEMG activity for the light weight than the heavy weight for the dissociative condition in Block 2, $t(56) = 2.91$, $p = .005$, whereas all other comparisons were not significant, all $ts > 1.36$, $p > .05$.

Discussion

The present results showed that the nature of the attentional focus adopted during a bicep curls task influenced a number of measures. The dissociative strategy required participants to attend to music. To control for the requirement to attend to an auditory stimulus, the associative condition required participants to attend to the sound output from the EMG recordings taken from the biceps muscle. The results showed that the associative strategy produced a lower HR, lower raw EMG, and lower iEMG when compared to the dissociative strategy and the control condition. In most cases, differences in the non-associative conditions (dissociative and control) on these measures were negligible. The associative and dissociative strategies did not influence subjective ratings of perceived

exertion or exercise satisfaction level. Furthermore, although there were differences across the measures as a function of experience level and weight lifted, these variables showed minimal interactions with the attentional focus conditions.

An associative focus promoted less physical effort to complete a biceps curl exercise as reflected in the physiological measures of HR and EMG activity when compared to a dissociative focus and a control condition. The results are consistent with those reported by Vance et al. (2004) and Marchant et al. (2008). In particular, Marchant et al. (2008) found that attending to the movements of the crank handle of the isokinetic dynamometer (a form of associative focus) produced less biceps EMG activity than a no instruction condition. The present study extends these results to the measurement of HR, which is another physiological index of physical effort, and to a comparison with a dissociative strategy. According to the notion of Wulf (2007), fine motor control and automaticity of movements is facilitated by an associative focus, particularly when the focus is external on the effects of the movement. The associative condition in the present experiment may be expected to have components of both an internal and external associative focus. While the sound corresponded to the activity of the muscles (internal associative), the participant was also attending to the effects of the exercise on a stimulus in the environment (external associative).

The converse interpretation of the present results is that a dissociative strategy elicits the greatest muscular and cardiovascular effort during a biceps curl exercise. While this effort was not greater than when no specific strategy was adopted, it was greater than when adopting an associative strategy. Distracting participants away from the physiological and sensory feedback of movements during weight training appears to be counterproductive in terms of the economy of the muscular system. While this strategy would not normally be recommended during competition, it may have a role to play during training (e.g., to fatigue the muscles as a way to building strength and muscle mass). The increased muscle activity

and HR when dissociating, relative to associating, also appears to occur in the absence of any subjective effects on perceived exertion or exercise satisfaction level. A dissociative strategy may thus be expected to allow individuals to continue the exercise for longer (e.g., complete another repetition) in the presence of aversive physiological feedback caused by muscle fatigue.

The attentional focus conditions also differed as a function of the degrees of movement and movement velocity. In both novice and experienced participants, movement velocity was slower in the associative condition than in the dissociative and control condition. The pattern in movement velocity and EMG activity contrasts somewhat to that observed by Vance et al. (2004). In their study, an external attentional focus was associated with less EMG activity, but faster movements than an internal attentional focus. In the present study, the associative condition was associated with less EMG activity, but slower movements than the dissociative condition. Thus, faster movements are not always associated with reduced EMG activity. Even though the conditions differed in some aspects of movements, this is unlikely to have influenced the pattern in EMG. The iEMG measure reflects both the amount of EMG activity and the time taken to produce the movement. To produce this measure, the larger numerical change from peak EMG during the maximal isometric contraction was multiplied by the smaller numerical value for the time taken to complete the repetitions in the associative condition and the converse was true for the dissociative and control conditions. The iEMG measure still showed that muscle activity was smaller in the associative condition than in the dissociative and control conditions.

Experience level and the amount of weight lifted showed limited interactions with the attentional focus instructions. The results obtained during the baseline condition at the start of the experiment confirmed that there were differences in subjective ratings, movements, HR, and muscle activity measures across the different experience levels and weights. For the

attentional focus conditions, the control condition was associated with a greater degree of movement than the associative and dissociative conditions in the novices, but not in the experienced participants. However, the lack of consistent effects of experience level and weight on heart rate and EMG activity suggests that the effects of attentional focus are general effects across a range of individuals and exercise intensities. The present study did use predominantly male participants, however, and so it remains to be determined whether gender differences exist in the effects of attentional focus on performance.

The present results, and those reported by Vance et al. (2004) and Marchant et al. (2008), suggest a number of tentative implications for sport and exercise and physical rehabilitation following physical or brain injury. For instance, it would be recommended that weight training done for the purpose of building strength and muscle tone be done while adopting a dissociative focus because it elicits greater muscle maximization for the same weight lifted and greater distraction from the negative physiological feedback from muscle fatigue. In contrast, if weights are to be lifted during a competition, the athlete should adopt an associative focus, particularly one that focuses on movement effects. An associative focus will produce more efficient movements and better performance outcomes. Further research could examine differences in muscle activity as a function of both type of attentional focus and the direction of attention (e.g., dissociative-internal, dissociative-external, associative internal, and associative-external) according to Stevinson and Biddle's (1998) two-dimensional model.

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Table 1.

Mean values for the subjective ratings, movements, heart rate, and electromyographic activity in the novice and experienced groups for the control, associative, and dissociative instruction conditions (standard deviations are in parentheses).

Measure	Novice Group			Experienced Group		
	Control	Associative	Dissociative	Control	Associative	Dissociative
Ratings of perceived exertion	3.59 (0.64)	3.89 (0.85)	3.89 (0.65)	3.48 (0.81)	3.39 (0.99)	3.30 (0.96)
Ratings of exercise satisfaction level	4.87 (1.13)	4.84 (1.11)	5.02 (1.02)	4.93 (1.69)	4.75 (1.73)	4.69 (1.75)
Ratings of executing task as normally would	6.27 (0.88)	5.70 (1.33)	5.58 (1.40)	6.27 (1.08)	6.07 (1.28)	5.98 (1.15)
Degrees of movement (°)	210.78 (25.15)	204.34 (30.98)	204.90 (25.89)	201.65 (19.21)	203.61 (19.92)	200.15 (17.82)
Velocity of movement (°/s)	94.52 (22.24)	88.04 (23.97)	93.20 (23.69)	71.56 (19.53)	70.50 (17.21)	72.80 (19.63)
Heart rate (bpm)	90.35 (14.59)	88.66 (14.34)	91.35 (14.53)	90.22 (11.16)	88.33 (11.22)	91.36 (9.92)
Biceps raw EMG (µV)	0.319 (0.09)	0.306 (0.09)	0.322 (0.08)	0.452 (0.16)	0.414 (0.17)	0.439 (0.17)
Triceps raw EMG (µV)	0.117 (0.05)	0.116 (0.05)	0.115 (0.05)	0.132 (0.04)	0.129 (0.04)	0.129 (0.04)
Biceps iEMG change (%Δ from peak MIC × s)	-186.52 (55.53)	-201.81 (71.93)	-187.50 (68.54)	-220.12 (63.41)	-230.73 (57.62)	-214.69 (59.41)
Triceps iEMG change (%Δ from peak MIC × s)	-190.31 (50.49)	-202.90 (68.07)	-192.72 (63.94)	-217.32 (68.71)	-220.19 (73.08)	-212.48 (74.00)

Note: EMG refers to electromyographic activity, iEMG refers to integrated electromyographic activity, and MIC refers to the maximal isometric contraction.