Don’t make me angry! A psychophysiological examination of the anger-performance relationship in intermediate and elite fencers

Zur, Itzhak; Cooke, Andrew; Woodman, Tim; Neil, Richard; Udewitz, Robert

Journal of Applied Sport Psychology

DOI:
10.1080/10413200.2018.1464079

Published: 03/07/2019

Don’t make me angry! A psychophysiological examination of the anger-performance relationship in intermediate and elite fencers

Abstract

We aimed to identify the effect of state-anger on precision, speed, and power components of performance during fencing attacks. We conducted a laboratory-based, single-case research experiment to test the fine motor task performance of two experienced and two elite-level fencers under two emotional states: anger and emotion-neutral. We assessed anger via psychophysiological and self-report measures, and we induced anger via a brief imagery intervention. Through the use of an innovative design, which included multiple measures of change, we showed that anger had a consistent negative effect on precision, but an inconsistent relationship with response time and muscle activity. The current research design and protocol offer a novel and in-depth method for examining the specific relationships between affective states, emotions, and the complexities that underpin performance. The specific effects of anger on performance were multifarious, complex, and inconsistent. Nonetheless, the results tend to indicate that anger facilitates response time and debilitates performance, and these effects were clearer for the most elite performers. The effects of anger on performance are clearly complex so it would be rather premature to make any suggestions for future practice at this point. Nonetheless, the clearer findings with the elite fencers indicate that researchers will likely yield the most fruitful insights by examining the effects of emotion of performance in elite performers.

Keywords: Anger, EMG, psychophysiology, fencing, single-subject methodologies, emotion

Introduction

Anger can be evoked by stress, frustration, disrespect, threats to reputation, rule violation, and an overall sense of injustice (Potegal & Stemmler, 2010), and it is frequently experienced during competitive sports (Davis, Woodman, & Callow, 2010; Martinent, Campo, & Ferrand, 2012). Attack is often associated with angry behavioral responses. For example, Valentino Rossi, a multiple MotoGP World Champion, was penalized for kicking his rival Marc Marquez off his bike in the 2015 Malaysian Grand Prix. Equally, Zinedine Zidane, World Cup winner, and one of soccer’s greatest ever players, was infamously sent off for head butting an Italian player who had insulted him in the final of the 2006 World Cup.

Such negative attacking behaviors have been linked to an anger-induced increase in activation of sympathetic systems in order to motivate and support individuals in regaining their superiority (Stemmler, 2010). Exhorting athletes into anger could thus increase their strength, alertness and determination, and ultimately help them to hit harder, jump farther, or run faster (Harmon-Jones, Peterson, & Harmon-Jones, 2010). Anger is thought to be especially beneficial for the performance of tasks whose requirements closely mirror anger’s associated action tendency (i.e., attack; Lazarus, 2000) and are characterized by gross motor components. For instance, Woodman et al. (2009) found that participants produced greater physical force when “lashing out” under anger conditions than when acting under emotion-neutral conditions.

Conversely, anger can have damaging effects on concentration, attentional focus (Hahn, 1989), and systematic reasoning (Tiedens & Linton, 2001). These effects of anger could impair sport performance, especially on tasks that involve fine adjustments in motor activity. Evidence to support this contention is admittedly sparse. However, one qualitative study found that table tennis players reported anger as almost always detrimental to their performance (Martinent et al., 2012), presumably because anger can disrupt the relaxation and calmness that are thought to be important to achieve optimal outcomes in precision-based sports (Nicholls, Polman, & Holt, 2005; Nicholls, Polman, & Levy, 2012). However, even within these sports, there may be situations in which anger's action tendency could be constructive. This usefulness might be seen when a task demands quick response time and/or powerful reaction for a relatively short duration (Davis et al., 2010; Woodman et al., 2009). For instance, in Martinent et al.'s (2012) study, it was reported that "single-point anger" (i.e., a player experiences anger with a duration of one point on the scoreboard) was sometimes facilitative to performance. Thus, the effects of anger in performance settings warrant further scrutiny.

Fencing is an Olympic sport that involves fast and powerful bursts of energy, such as the *attack* (i.e., flèche), while also containing a crucial precision component (i.e., must hit the target with accuracy to score) (Tsolakis & Vagenas, 2010). The fencing attack is an attractive task to investigate the precise mechanisms underpinning the anger-performance relationship because several theoretically-driven predictions can be examined to shed new light on the anger-performance relationship. For instance, the greater muscular force that is said to be summoned when angry (Robazza & Bortoli, 2007; Woodman et al., 2009) could facilitate the power of a fencing attack. The increased alertness and action tendency that is associated with anger may facilitate the speed of a fencing attack. However, with increases in speed and power, it is possible that there will be a decrease in accuracy, which may be associated with over-arousal (e.g., Stemmler, 2004, 2010) and/or insufficient time afforded for accurate motor planning and online corrections (e.g., Proteau, 1992). Consequently, by measuring the effects of anger on a fencing attack, we are equipped to test the impact of anger on speed, power, and accuracy of a sporting performance for the first time. This represents an important development on previous anger and performance studies, which have focused predominately on crude performance measures such as performance outcome (e.g., win/loss), or subjective assessments of performance quality (Martinent et al., 2012; Robazza & Bortoli, 2007; Ruiz & Hanin, 2011; Woodman et al., 2009).

An additional limitation of existent anger and performance research in sport is a reliance on self-report measures of anger (Martinent et al., 2012; Robazza & Bortoli, 2007; Ruiz & Hanin, 2011). Self-report measures of negative emotions can be subject to social desirability bias. Accordingly, in the current experiment we provide the first sport-based assessment of heart rate, skin conductance, and facial temperature measures, which have been found to increase when angry (Stemmler, 2004), as corroborative physiological indices that can complement self-report measures of emotion (e.g., Cooke, Kavussanu, McIntyre, & Ring, 2013).

Finally, previous investigations in sport have failed to determine causality in the anger-performance relationship. Thus, we conducted a laboratory-based experiment to test fencers’ fine motor task performance (i.e., a fencing flèche attack) under two emotional states: anger and neutral. We induced each emotional state via an imagery script. This “non-provocative” imagery induction of anger has been found to have a consistent effect on somatovisceral responses (Stemmler, 2010). We recorded psychophysiological responses throughout the experiment to afford a first look at the mechanisms that could underlie anger’s effects on performance, and we measured anger’s effects on precise subcomponents of performance, namely precision, speed, and power. We designed the experiment, therefore, to provide the most comprehensive insight into the anger and sport performance relationship to date. Based on the literature reviewed above, we hypothesized that increased anger would facilitate the speed (i.e., quicker response time) and power (i.e., increased peak muscle activity) of fencing attacks, but would compromise their accuracy (i.e., decreased precision).

Method

Participants

Four right-handed fencers volunteered to take part in the experiment. *Fencer A* was a 22-year-old female elite fencer with 13 years of experience including the 2012 and 2016 Olympics. *Fencer B* was a 19-year-old world top-100 junior female fencer with 10 years of competitive experience at international level. *Fencer C* was a 24-year-old female fencer with six years of competitive experience at regional level. *Fencer D* was a 35-year-old male fencer with eight years of training but little competitive experience. All participants were healthy as indexed by the absence of any self-reported illnesses, injuries, and prescribed medications at the time of the experiment.

Design

In line with the call for innovative single-subject design research in sport psychology (e.g., JASP special issue, 2013), we employed a withdrawal, repeated measures, multiple-baseline single-subject design (Barker, McCarthy, Jones, & Moran, 2011) to assess the impact of state-anger on fencers' precision, response time, and peak-muscle activity. This procedure begins with an *observation phase* (A_1) that provides a stable and representative picture of the independent variables and indicates a participant's baseline state. Then follows the *intervention phase* (B) that manipulates the independent variables. Finally, there is the *reversal phase* (A_2) where the intervention is removed. No control group is required because participants act as their own control; if changes are observed when the intervention is applied, and are reversed when the intervention is removed, then the change in performance can be attributed to the intervention. This design is thereby regarded as a powerful and robust procedure for assessing the effects of an independent variable on target variables with small samples (Barker et al., 2011; Gast, Ledford, & Ledford, 2014).

Task

The task was to hit the center point of a 37-cm wide square target, using a fencing foil, as quickly and as accurately as possible, in response to a *Go* signal, which appeared on a screen. The start position for each participant was seated on a cube bench situated 44cm above the floor. Participants held the foil in their dominant hand, with the tip of the weapon resting on a point positioned 37cm above the floor, and at a distance away from the target that corresponded to the difference in length between the tip of the foil when their arm was fully extended, and the tip of the foil when their arm was flexed in their natural fencing preparatory position (Fencer A: 18cm; Fencer B: 22.7cm; Fencer C: 20cm; and, Fencer D: 22.5cm). Participants were seated on the bench throughout the task, ensuring that each attack required only the arm to be extended. The task and set-up are depicted in Figure 1.

All participants performed the task in nine *blocks*, which each contained eight *trials* (i.e., attacks on the target). To help avoid anticipation effects, catch trials (i.e., a red *NoGo* stimulus) were randomly employed within each block at a ratio of one *NoGo* to four *Go*.

Measures

State anger.

The State-Anger Inventory (Spielberger, Jacobs, Russell, & Crane, 1983) was employed as the basis for our state-anger measure. We used this inventory to help athletes measure and identify anger during performance. This inventory contains five items to measure “anger-in”, which represents how angry one feels (e.g., I feel irritated), and five items to measure “anger-out”, which represents one’s feelings about expressing anger (e.g., I feel like banging on the table). Traditionally items are rated on a Likert scale from 1 (*Not at all*) to 4 (*Very much so*). Spielberger et al. (1983) reported high internal consistency with a Cronbach alpha coefficient of .92. However, in the present experiment we trained participants to report single-integer scores (0 to 15) for each subscale. This method has been used previously (e.g., Hardy, Woodman, & Carrington, 2004) to obtain fast and accurate measures of emotions, eliminating the need for participants to repeatedly complete multi-item questionnaires. Further explanation of this training is outlined in the Procedure section below and the supplementary online material that accompanies this manuscript.

Psychophysiological indices.

To corroborate our self-reported measurements of state-anger, physiological measurements of heart rate, skin conductance, and facial temperature were recorded continuously during each block of trials. In his meta-analysis of anger, based on 15 studies which reported anger and fear contrasts in at least two somatovisceral responses, Stemmler (2004) revealed that, compared to control, anger elicited greater increases in heart rate, skin conductance, and facial skin temperature.

Skin conductance. Two skin conductance sensors (SA9309M, Thought Technology Ltd. Canada), with two UniGel electrodes, were attached to the inner palm of the non-weapon arm to monitor skin conductivity in MicroMho (0 – 30 MΩ). An increase/decrease in MicroMho indicates an increase/decrease in anger-related arousal (Stemmler, 2004).

Skin surface temperature. We used a single sensor (SA9310M, Thought Technology Ltd. Canada) to measure the skin surface temperature of the forehead. On average, the skin temperature range was 28ºC - 34ºC. To standardize the temperature of the laboratory across testing sessions, the room temperature was set to a steady 21ºC.

Heart rate. We attached a blood volume pulse (BVP) sensor (SA9308M, Thought Technology Ltd. Canada) to the thumb on the non-weapon arm to assess heart rate.

All signals were acquired using a ProComp Infinity data acquisition system (Thought Technology Ltd. Canada) and computer running BioGraph Infinity software.

Performance.

Precision. Precision was assessed as the distance between the 37-cm wide square target’s center point and the weapon's strike point (i.e., radial error). The weapon strike point was captured by two HD C525 Logitech webcams measuring error in the x and y axes, respectively. The Pythagorean equation was then applied to calculate radial error.

Response time. Response time was calculated as the duration in milliseconds between the presentation of the “*GO*” stimulus and the foil-target contact. Stimulus presentation was controlled, and its timing was captured, by a computer running a bespoke script for BioGraph infinity V6.0.4 software (Thought Technology Ltd. Canada). Foil-target contact was captured by a bespoke pressure sensor switch mounted on the rear of the target, connected to a ProComp Infinity data acquisition system (Thought Technology Ltd. Canada) and computer running BioGraph Infinity software.

Peak muscle activity. We recorded muscle activity using electromyogram (EMG) electrodes (MyoScan-Z^{TM} Sensor- T9503Z, Thought Technology Ltd. Canada) placed on the triceps brachii muscle of the weapon arm (Frère et al., 2011). Signals were sampled at 2048 Hz and acquired through a ProComp Infinity data acquisition system (Thought Technology Ltd. Canada) and computer running BioGraph Infinity software. EMG data were root-mean-squared, and the peak activity for each trial (i.e., peak activity between stimulus presentation and target contact) was extracted using BioGraph Infinity software.

Procedure

Each participant made a single laboratory visit, which consisted of four stages. First, participants were briefed about the nature of the experiment, given the opportunity to ask questions, before providing their consent to take part. The next stages were imagery susceptibility, anger-ratings training, and finally, the fencing task. The procedure for each of these stages is described below. The flowchart of the experiment is depicted in Figure 2.

Imagery susceptibility. Participants were asked to practice visualizing (external visual, internal visual, and kinesthetic) three commonplace scenes. After this brief practice, the experimenter asked the participant to complete the Vividness of Movement Imagery Questionnaire-2. This allowed us to verify that all participants possessed moderately clear to vivid imagery ability (scores <36, for more detail see Callow, Jiang, Roberts, & Edwards, 2017). Reliability analysis in the current experiment revealed the following alpha coefficients for the VMIQ-2: EVI = .88, IVI = .73, KIN = .90.

Anger learning stage. Following the imagery susceptibility stage, participants were taught how to report anger-in and anger-out on a single-integer scale from 0 to 15, which ensured the same range of scores as would be possible from the traditional State-Anger Inventory (minimum = 5, maximum = 20). Specific details of this training phase are provided in the supplementary online material that accompanies this manuscript (see also Hardy et al., 2004). Analyses reported in the supplementary material confirmed that participants were sufficiently trained to provide reliable single-item anger ratings in this experiment.

Experimental procedure. Upon completion of the training phases, the participant put on his or her fencing glove and sat on a cube bench in preparation for the fencing task. Recording sites for the psychophysiological measures were then located, abraded, and cleaned using alcohol wipes, and conductive paste was applied to the EMG recording sites, before electrodes were attached. This ensured that all electrode impedances were below 15 kOhms.

After the electrodes were attached participants were issued with a pair of noise-cancelling headphones that would be used to play the imagery scripts. Before the first script began, participants sat in silence for a two-minute *rest period.* Once the two-minute rest had elapsed an audio recording of the imagery script commenced as follows:

"You will soon hear a situation being described to you. Your task is to close your eyes and imagine yourself in the situation being described, as if it were happening right now. Allow yourself to become completely involved in the situation, by involving your mind and body in doing what is being described. Continue imagining until you are asked to stop."

In phases A_1 and A_2, the subsequent imagery script was designed to elicit a neutral emotional state, and outlined the process of brushing one's teeth (see Kavanagh & Hausfeld, 1986).

In phase B, the imagery script was designed to elicit anger by asking the participant to think about an angry situation and then walking him or her through an anger induction script, asking the participant to relive their angry experience by using all their senses (see Woodman et al., 2009). When the imagery script had finished, the experimenter asked the participant to report anger-in and anger-out levels on the single integer scales. The participants were then instructed for the experimental task, as described in the Task section above. In brief, they were told to fixate on the computer screen in front of them, and when the "*Go*" stimulus appeared, they were to launch an attack with their weapon to hit the center point of the target as accurately and quickly as possible. After each attack, participants returned the tip of their weapon to the resting point, ensuring that the tip of the weapon was the same distance from the target at the start of each trial. There were nine *blocks* of eight *trials* (i.e., eight attacks) in the experiment. The identical procedure of rest, imagery, anger ratings, and experimental task was repeated for each block. Upon completion of all nine experimental blocks, the recording electrodes were removed, while participants were asked to briefly share their thoughts and feelings about the experiment. Any insights offered were recorded by the experimenter since it was deemed that this qualitative detail may prove useful in interpreting each participant's results. Finally, participants were thanked and paid $80 to compensate for their time.

Data Analysis

Trial-by-trial performance and psychophysiological data were averaged for each of the nine blocks. We then calculated means for each experimental phase (i.e., phases A_1, B, and A_2) per the experimental procedure. Next, we calculated linear best-fit trend-line, mean-line, and slope for each phase, and plotted graphs for visual inspection. To assess the effects within single-case designs, we used five features to examine between-phase data patterns: *level*, *trend*, *immediacy* of the effect (IE), *overlap*, and *consistency* of data patterns across similar phases (Kazdin, 2011; Morgan & Morgan, 2008). *Level* refers to the mean score for the data within a phase. *Trend* refers to the slope of the best-fitting straight line for the data within a phase, a zero-celeration trend or in an opposite direction to those predicted by the effect of the intervention increases our confidence that an effect has been observed. *Immediacy* of the effect refers to the change in level between the last data point in one phase and the first data point of the next; the more immediate the effect, the more convincing the inference that change in the outcome measure was due to the intervention. *Overlap* refers to the proportion of data from one phase that overlaps with data from the previous phase. The greater the percentage of non-overlapping data points (*PND*), the more compelling the demonstration of an effect. *Consistency* of data in similar phases involves looking at data patterns from all phases within the same condition; the greater the consistency, the more likely the data represent a causal relation (Hrycaiko & Martin, 1996; Kratochwill et al., 2010).

Constructing a trend-line enables change in slope across phases to be calculated (for details of slope calculations, see Kazdin, 2011). The slope of trend-lines is expressed in a ratio with a plus sign (+) or a minus sign (-) to indicate a positive or a negative slope, respectively. Once the trend lines have been determined, a Binomial test can be used to assess the significance of change between the phases.

To determine whether changes in the physiological, performance, and muscle activity data resulted from the experimental effect, we conducted visual examination of the data (including a Binomial test). This method of analysis is standard in single-case research and allows manageable and self-explanatory analysis via pictorial illustration of the data (Bloom, Fischer, & Orme, 2006; Kinugasa, Cerin, & Hooper, 2004).

Visual analysis is used to assess whether the data demonstrate at least three features(as identified above) of an effect at different points in time (Kratochwill et al., 2010). For example, a *trend* reversion from positive to negative across the phases, no or minor *overlapping* data between the phases, and *immediate* change when the intervention was introduced/removed. If this criterion is met, the data are deemed to document a causal relation, and an inference may be made that change in the outcome variable is causally related to manipulation of the independent variable.

Results

State-anger emotional state and bodily activity

The impact of the anger manipulation on self-report and physiological indices of anger is illustrated in Figure 3.

Analyses revealed that all participants reported greater state-anger in the intervention phase than in the observation and reversal phases. Hence, our imagery-based anger intervention was effective. The intervention also prompted an increase in the skin surface temperature of Fencer A, evidenced by the positive trend in the observation phase (A_1) being accelerated in the intervention phase (B) by a ratio of +1.01, and being reversed by a ratio of -1.03 in the reversal phase (A_2). Finally, anger prompted an increase in the heart rate of Fencer B, evidenced by the negative trend in the observation phase (A_1) being reversed to a positive trend in the intervention phase (B) by a ratio of +1.10, and being decreased to a zero-celeration trend by a ratio of -1.02 in the reversal phase (A_2). The *immediacy* of this effect was also noteworthy, with a ratio change of ×1.06 phases (× denoting a step up) immediately after the introduction of the intervention and a ratio change of ÷1.07 phases (÷ indicating a step down) when the intervention was removed. These results provide some corroborative evidence to suggest that the anger intervention was more effective in Fencer A and Fencer B.

Performance

Performance data are illustrated in Figures 4, 5, and 6. For brevity, we report the level, trend, level change, trend change, immediacy of the effect (IE), and percentage of non-overlapping data (PND) within the figures.

Precision. The radial error in centimeters between the foil’s striking point and the target’s center point are presented in Figure 4. Visual inspection of the graphs suggests that the introduction of the intervention led to a decline in precision performance in relation to *level, trend*, IE, and PND for Fencer A. The change in performance following the introduction of the intervention suggests a mild debilitating impact of anger on the precision of Fencer B, Fencer C, and Fencer D. However, Fencer C’s precision scores did not return to baseline in the reversal phase, while Fencer D’s Binomial test was non-significant.

Response time. The time in milliseconds between the appearance of the *GO* stimuli and the moment the fencing foil hit the target is presented in Figure 5. Visual inspection of the graphs shows a decrease in *level* from the A_1 to the B phase for Fencers A, fencer B, and Fencer D, a change in *trend* for Fencer A, Fencer B, and Fencer C, and a significant IE with zero overlapping data for Fencer D, providing tentative evidence that the introduction of the intervention led to faster response times, except for Fencer C. Fencer B demonstrated a statistically significant change in response time between the anger phase and the pre and post emotion-neutral phases. Fencer A’s and Fencer D’s response time did not return to the base-line level when the intervention was withdrawn.

Peak muscle activity. The peak muscle activity in microvolts of the triceps of the weapon arm, are presented in Figure 6. The increase in *level*, and the change in IE, from the A_1 to the B phase for Fencer B, Fencer C and Fencer D, and the change in *trend* for Fencer B and Fencer C suggest that the introduction of the intervention led to higher peak muscle activity. However, only Fencer B returned to the base-line level when the intervention was withdrawn, so Fencer B is the only participant we can firmly identify as producing more powerful attacks in the anger condition. Fencer A demonstrated a gradual reduction in peak-muscle activity across the phases. Fencer D's Binomial test was not significant.

Discussion

We designed this experiment to provide a comprehensive test of the anger and performance relationship while addressing three principal limitations of previous research. First, we examined the relationships between anger and the performance subcomponents of precision, speed, and power (as opposed to crude outcome-based measures) within a fine motor task. Second, we adopted a multi-measure psychophysiological approach to provide a more comprehensive assessment of anger than previous studies that relied on retrospective self-report. Finally, we adopted a withdrawal repeated measures multiple-baseline single-case study design, which allowed us to investigate causality while using a small sample size.

Anger Manipulation

As expected, participants reported greater anger in the intervention phase than in the pre- and post-intervention phases. According to our 15-point anger scale, anger was low to moderate in the intervention phases, while it was completely absent or very low during the pre- and post-intervention phases. Thus, in terms of the self-report data, the emotion manipulation was successful. However, per the physiological indices of anger, the intervention seemed more effective for Fencer A and Fencer B (i.e., the more skilled fencers), who showed anger-induced increases in skin temperature and heart rate, respectively, than for

Fencer C and Fencer D (i.e., the intermediate level fencers), who showed no systematic autonomic changes. This difference across fencers raises a possibility that the effects of anger on autonomic responses are moderated by skill-level, with more skilled performers better able to summon anger’s arousal-inducing properties.

However, due to the limited agreement between self-report measures of anger (i.e., consistently increased during the intervention phase) and proposed physiological measures (i.e., inconsistent changes across A_1, B and A_2), our findings could raise concerns about the validity of either our self-report or our physiological measures. For instance, while researchers tend to agree that emotions elicit physiological responses, some researchers argue that physiological emotion specificity is questionable (Barrett, 2006; Ortony & Turner, 1990). Emotional physiological responses can overlap, like anger and fear (Ax, 1953; Funkenstein, King, & Drolette, 1954; Stemmler, 2010), and/or be moderated by other factors (e.g., effort, motivational tendencies, and energy) hence making the underlying psychology of cardiovascular responses vary substantially (Hilmert & Kvasnicka, 2010). Thus, our physiological variables could reflect other emotional and motivational processes aside from anger. Alternatively, self-report measures are susceptible to social desirability and Hawthorne effects, especially in experiments using imagery to manipulate emotion, as the goal of the imagery is obvious to participants. Hence, self-reported anger scores may have been overstated. Since the optimal measurement of emotion remains a source of debate, measuring both autonomic and self-report variables is recommended (Mauss & Robinson, 2009). We are therefore confident that the multi-measure method that we adopted here was appropriate and rigorous.

Effects of Anger on Performance, and Underlying Mechanisms

As hypothesized, Fencer A and Fencer B demonstrated a decrease in precision when they were angry, thus supporting the contention that increased state-anger is harmful to the performance of a fine motor skill. These results are consistent with findings by Martinent and colleagues (Martinent et al., 2012; Martinent & Ferrand, 2009). Fencer C and Fencer D also demonstrated a decrease in their precision during anger compared to the initial emotion-neutral condition. However, the precision of their performance did not recover to base-line levels in the second emotion-neutral phase. Given that these fencers were less skilled than Fencers A and B, they might not have had the stamina and skills required to sustain a consistent level of performance for extended periods of time. Equally, elite athletes may be better at ‘switching’ between states due to better psychological skill usage (Neil, Hanton, & Mellalieu, 2006). Support for this argument can be drawn from Fencer C’s sudden drop in heart rate and skin conductance beginning at trial-block 5 and onward. Decreases in these variables can be associated with reduced effort and arousal, so these factors may indicate a decrease in level of alertness (Ito et al., 2011; Jones, Meijen, McCarthy, & Sheffield, 2009).

We next predicted that any decrease in accuracy caused by elevated anger would be associated with faster response times. This prediction was supported for Fencer B, hence, we cannot provide unequivocal support for our response time hypothesis. In the follow-up interview, Fencer A said, “I was focusing on precision, not much on response time”. This statement may provide an explanation for why Fencer A’s response time did not change throughout the experimental phases. Furthermore, due to Fencers A’s high proficiency level it is possible that there was a floor effect in her response time; in other words, she was so proficient at baseline there was limited scope for improvement. Increasing fatigue and/or decreased engagement, as implied through her progressive decrease in heart rate, could account for the lack of anger effects on response time for Fencer C. A learning curve rather than any clear effects of anger could explain the response time profile observed in the least skilled Fencer D (i.e., initially very slow during $A_{1,}$ before improving and stabilizing in B and A_2).

Finally, we predicted that anger would be associated with increased power of attacks, as indicated by an increase in peak-muscle activity during the intervention phase. Similar to our response time data, we only found support for this prediction in Fencer B. Her peak muscle activity was 7% and 10% higher during the intervention compared to the pre- and post-intervention phases, respectively. Moreover, she revealed “In the anger scenarios, I cycled through sort of spots in my history…I definitely don’t think I was as angry as in the bouts…but it definitely worked.” Fencer B’s results extend previous findings of anger-induced increases in force on gross motor tasks (e.g., Davis et al., 2010; Woodman et al., 2009) to the fine motor task of precision fencing. They are also consistent with the notion that increased force is facilitated by anger-induced increases in sympathetic activation (e.g., Stemmler, 2010), as this was evidenced by Fencer B’s elevated heart rate in the anger phase. However, we are unable to conclude confidently that anger facilitates an increase in power among motor precision athletes, since only one out of four fencers demonstrated this effect.

The muscle activity profile observed in Fencer A (i.e., decrease over time) is perhaps not surprising, considering her comment in the follow-up interview, that she was more focused on precision than on speed or power. The profile observed in Fencer C (i.e., slightly elevated muscle activity from A_1 to B and A_2, but accompanied by largely unchanged response times and slightly impaired precision) could reflect a progressive reduction in movement efficiency that occurs during fatigue (cf., Eysenck & Calvo, 1992; Eysenck, Derakshan, Santos, & Calvo, 2007). The changes in muscle activity observed in Fencer D could be associated with the performance learning curve displayed by this performer, as speculated in our discussion of his response time results.

Taken together, anger was positively associated with powerful (i.e., increased muscle activity) and fast (i.e., decreased response times) fencing attacks in only one of our participants (i.e., Fencer B). Instead, our data are more supportive of the notion that anger can negatively impact fine motor precision, evidenced by the general tendency across participants in our experiment for anger to increase radial error, especially among highly-skilled performers (i.e., Fencers A and B).

Limitations and Future Research Directions

There are some methodological limitations that should be considered when interpreting the results. First, the self-report and psychophysiological data indicated that while imagery reliably increased anger, it was only increased to a moderate level in the case of anger-in and anger-out. Despite this limitation, we observed some clear effects of anger on precision. Second, given the often acute emotional response of anger, there is the possibility that the anger that the participants experienced might not have lasted across all eight trials of each block. Although the data within each 30-second trial block did not indicate this effect in this study, researchers would do well to consider how long they are aiming for the emotion to last and adopt their protocol accordingly. Future studies could develop more impactful anger manipulations to investigate the effects of high levels of anger-in and anger-out and to further evaluate the relationship between anger and subcomponents of performance such as speed and power.

Third, regarding the self-reported anger scores, all participants except Fencer B experienced a carry-over effect for anger-in from the intervention phase to the second emotion-neutral phase (A_2). This effect is likely an artefact of the intervention. That is, participants might struggle to return to baseline levels after being exposed to emotion-laden interventions such as the one that we used in the present experiment. An induction of anger in isolation from baseline and post intervention, on separate days, for example, will potentially prevent cross-phase contamination (Gast et al., 2014).

Fourth, we concede that the physiological measures are associates rather than pure indices of anger, since they could also be influenced by a range of other emotional and motivational processes (e.g., increased heart rate is also a characteristic of elevated anxiety and effort). Moreover, the sensitivity of physiological measures in capturing psychological processes can be obscured by physical demands of a task, which also have a positive relationship with autonomic activity (e.g., increased physical activity elevates heart rate). By focusing on manipulating anger independently of other emotions, and minimizing physical movements by seating participants throughout, we aimed to counter these potential confounds. A beneficial advancement would be to adopt a wider array of alpha-adrenergic measures.

Finally, future research could use a similar single-subject approach to probe cause and effect relationships between a wider range of emotions and performance. Such studies could also consider expertise as a potential moderating variable in the emotion-performance relationship, based on our observation that the most elite fencers displayed some important differences when angry from the less-skilled fencers. To date, sport scientists have used single-case research designs to show effectiveness of behavioral interventions (Callow, Hardy, & Hall, 2001; Neil, Hanton, & Mellalieu, 2013). The present experiment provides further support for this method as a useful means of shedding light on the mechanisms underlying performance in small samples of skilled athletes.

Implications and Conclusion

In conclusion, the results provide some evidence that anger can have a debilitative effect on the fine motor performance of highly skilled athletes. By assessing precision, speed, and power, we also revealed several nuanced aspects of the complex anger–performance relationship in skilled performers. Finally, and, critically, the study offers a new methodological path in the pursuit of better understanding the emotion-performance relationship in sports. We hope that future researchers will embrace this innovative withdrawal multiple baseline case study design to determine, more clearly, the cause and effect relationships with small numbers of elite athletes in applied sport psychology.

References

Ax, A. F. (1953). The Physiological differentiation between fear and anger in humans. *Psychosomatic Medicine, 15*, 433-442.

Barker, J., McCarthy, P., Jones, M., & Moran, A. (2011). *Single case research methods in sport and exercise psychology*. London: Routledge.

Barrett, L. F. (2006). Are emotions natural kinds? *Perspectives on Psychological Science, 1*, 28-58. doi:10.1111/j.1745-6916.2006.00003.x

Bloom, M., Fischer, J., & Orme, J. (2006). *Evaluating practice: Guidelines for the accountable professional* (Vol. 1): Allyn & Bacon.

Callow, N., Hardy, L., & Hall, C. (2001). The effects of a motivational general-mastery imagery intervention on the sport confidence of high-level badminton players. *Research Quarterly for Exercise and Sport, 72*, 389-400. doi:10.1080/02701367.2001.10608975

Callow, N., Jiang, D., Roberts, R., & Edwards, M. G. (2017). Kinesthetic imagery provides additive benefits to internal visual imagery on slalom task performance. *Journal of Sport & Exercise Psychology, 39*, 81-86. doi:10.1123/jsep.2016-0168

Cooke, A., Kavussanu, M., McIntyre, D., & Ring, C. (2013). The effects of individual and team competitions on performance, emotions, and effort. *Journal of Sport & Exercise Psychology, 35*, 132-143. doi:10.1123/jsep.35.2.132

Davis, P. A., Woodman, T., & Callow, N. (2010). Better out than in: The influence of anger regulation on physical performance. *Personality and Individual Differences*, *49*, 457-460. doi:10.1016/j.paid.2010.04.017

Eysenck, M. W., & Calvo, M. G. (1992). Anxiety and performance: The processing efficiency theory. *Cognition and Emotion, 6*, 409-434. doi:10.1080/02699939208409696

Eysenck, M. W., Derakshan, N., Santos, R., & Calvo, M. G. (2007). Anxiety and cognitive performance: Attentional control theory. *Emotion, 7*, 336-353. doi:10.1037/1528-3542.7.2.336

Frère, J., Göpfert, B., Nüesch, C., Huber, C., Fischer, M., Wirz, D., & Friederich, N. F. (2011). Kinematical and EMG-classifications of a fencing attack. *International journal of sports medicine, 32*, 28-34. doi:10.1055/s-0030-1267199

Funkenstein, D. H., King, S. H., & Drolette, M. (1954). The direction of anger during a laboratory stress-inducing situation. *Psychosomatic Medicine, 16*, 404-413.

Gast, D. L., Ledford, J. R., & Ledford, J. R. (2014). *Single case research methodology*. Florence: Taylor and Francis.

Hahn, E. (1989). Emotions in sports. In D. Hackfort & C. D. Spielberger (Eds.), *Anxiety in sports: An international perspective* (pp. 153-162). New York: Hemisphere.

Hardy, L., Woodman, T., & Carrington, S. (2004). Is self-confidence a bias factor in higher-order catastrophe models? An exploratory analysis. *Journal of Sport & Exercise Psychology, 26*, 359-368. doi:10.1123/jsep.26.3.359

Harmon-Jones, E., Peterson, C. K., & Harmon-Jones, C. (2010). Anger, motivation, and asymmetrical frontal cortical activations. In M. Potegal, G. Stemmler, & C. Spielberger (Eds.), *International handbook of anger* (pp. 61-78): Springer New York.

Hilmert, C., & Kvasnicka, L. (2010). Blood pressure and emotional responses to stress: Perspectives on cardiovascular reactivity. *Social and Personality Psychology Compass, 4*, 470-483. doi:10.1111/j.1751-9004.2010.00275.x

Hrycaiko, D., & Martin, G. L. (1996). Applied research studies with single-subject designs: Why so few? *Journal of Applied Sport Psychology, 8*, 183-199. doi:10.1080/10413209608406476

Ito, H., Yamauchi, H., Kaneko, H., Yoshikawa, T., Nomura, K., & Honjo, S. (2011). Prefrontal overactivation, autonomic arousal, and task performance under evaluative pressure: A near-infrared spectroscopy (NIRS) study. *Psychophysiology, 48*, 1563-1571. doi:10.1111/j.1469-8986.2011.01220.x

Jones, M., Meijen, C., McCarthy, P. J., & Sheffield, D. (2009). A theory of challenge and threat states in athletes. *International Review of Sport and Exercise Psychology*, *2*, 161-180. doi:10.1080/17509840902829331

Kavanagh, D., & Hausfeld, S. (1986). Physical performance and self-efficacy under happy and sad moods. *Journal of Sport Psychology, 8*, 112-123. doi:doi.org/10.1123/jsp.8.2.112

Kazdin, A. E. (2011). *Single-case research designs: Methods for clinical and applied settings (2nd ed.)*. New York, NY, US: Oxford University Press.

Kinugasa, T., Cerin, E., & Hooper, S. (2004). Single-subject research designs and data analyses for assessing elite athletes’ conditioning. *Sports Medicine, 34*, 1035-1050. doi:10.2165/00007256-200434150-00003

Kratochwill, T. R., Hitchcock, J., Horner, R., Levin, J. R., Odom, S., Rindskopf, D., & Shadish, W. (2010). Single-case designs technical documentation. *What Works Clearinghouse*.

Martinent, G., Campo, M., & Ferrand, C. (2012). A descriptive study of emotional process during competition: Nature, frequency, direction, duration and co-occurrence of discrete emotions. *Psychology of Sport and Exercise, 13*, 142-151. doi:10.1016/j.psychsport.2011.10.006

Martinent, G., & Ferrand, C. (2009). A naturalistic study of the directional interpretation process of discrete emotions during high-stakes table tennis matches. *Journal of Sport & Exercise Psychology, 31*, 318-336. doi:10.1123/jsep.31.3.318

Mauss, I. B., & Robinson, M. D. (2009). Measures of emotion: A review. *Cognition and Emotion, 23*, 209-237.

Morgan, D. L., & Morgan, R. K. (2008). *Single-case research methods for the behavioral and health sciences*: Sage publications.

Neil, R., Hanton, S., & Mellalieu, S. D. (2006). Psychological skills usage and the competitive anxiety response as a function of skill level in rugby union. *Journal of Sports Science & Medicine, 5*, 415-423.

Neil, R., Hanton, S., & Mellalieu, S. D. (2013). Seeing things in a different light: assessing the effects of a cognitive-behavioral intervention upon the further appraisals and performance of Golfers. *Journal of Applied Sport Psychology*, *25*, 106-130. doi:10.1080/10413200.2012.658901

Nicholls, A. R., Polman, R. C. J., & Holt, N. L. (2005). The effects of an individualized imagery interventions on flow states and golf performance. *Athletic Insight, 7*, 43-66.

Nicholls, A. R., Polman, R. C. J., & Levy, A. R. (2012). A path analysis of stress appraisals, emotions, coping, and performance satisfaction among athletes. *Psychology of Sport and Exercise, 13*, 263-270. doi:10.1016/j.psychsport.2011.12.003

Ortony, A., & Turner, T. J. (1990). What's basic about basic emotions? *Psychological Review, 97*, 315-331. doi:10.1037/0033-295X.97.3.315

Potegal, M., & Stemmler, G. (2010). Cross-disciplinary views of anger: Consensus and controversy. In M. Potegal, G. Stemmler, & C. D. Spielberger (Eds.), *International handbook of anger* (pp. 3-7). New York: Springer.

Proteau, L. (1992). On the specificity of learning and the role of visual information for movement control. In P. Luc & E. Digby (Eds.), *Advances in psychology* (Vol. 85, pp. 67-103): North-Holland.

Robazza, C., & Bortoli, L. (2007). Perceived impact of anger and anxiety on sporting performance in rugby players. *Psychology of Sport and Exercise, 8*, 875-896. doi:10.1016/j.psychsport.2006.07.005

Ruiz, M. C., & Hanin, Y. L. (2011). Perceived impact of anger on performance of skilled karate athletes. *Psychology of Sport and Exercise, 12*, 242-249. doi:10.1016/j.psychsport.2011.01.005

Spielberger, C. D., Jacobs, G., Russell, J. S., & Crane, R. S. (1983). Assessment of anger: The State-Trait Anger Scale. In J. N. Butcher & C. D. Spielberger (Eds.), *Advances in Personality Assessment* (pp. 161-187). London: Wiley

Stemmler, G. (2004). Physiological processes during emotion. In P. Philippot & R. S. Feldman (Eds.), *The regulation of emotion* (pp. 35-72).

Stemmler, G. (2010). Somatovisceral activation during anger. In M. Potegal, G. Stemmler, & C. D. Spielberger (Eds.), *International hanbook of anger: Constituent and concomitant biological, psychological, and social processes* (pp. 103-121). New York: Springer.

Tiedens, L. Z., & Linton, S. (2001). Judgment under emotional certainty and uncertainty: The effects of specific emotions on information processing. *Journal of Personality and Social Psychology, 81*, 973-988. doi:10.1037/0022-3514.81.6.973

Tsolakis, C., & Vagenas, G. (2010). Anthropometric, physiological and performance characteristics of elite and sub-elite fencers. *Journal of Human Kinetics 23*, 43-50. doi:10.2478/v10078-010-0011-8

Woodman, T., Davis, P. A., Hardy, L., Callow, N., Glasscock, I., & Yuill-Proctor, J. (2009). Emotions and sport performance: An exploration of happiness, hope, and anger. *Journal of Sport & Exercise Psychology, 31*, 169-188. doi:doi.org/10.1123/jsep.31.2.169

Figure Captions