Prestart Psychophysiological Profile of a 200-m Canoe Athlete: A Comparison of Best and Worst Reaction Times

Sommer Christie, PhD (CAD), and Penny Werthner, PhD
University of Calgary, Calgary, Alberta

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The difference between success and failure in 200-m canoe and kayak events is measured in milliseconds. The gold medal for the 200-m kayak in the Summer 2012 Olympic Games in London was won by a margin of 294 milliseconds, and the difference between winning a bronze medal and not reaching the podium was merely 31 milliseconds. In addition to physical fitness, strength, and technique, the ability to focus effectively and manage arousal is crucial to the ability to react quickly off the start. Conversely, the inability to manage arousal and focus has been shown to reduce reaction time (RT) and, in extreme cases, lead to “choking.” Research in sport psychology and psychophysiology has identified multiple psychological, physiological, and neurological characteristics that underlie peak performance. Although many of the skills and characteristics identified in the research are common to most peak performers, it is also well known that each athlete’s optimal performance zone for competition is unique. For athletes, identifying these individual zones of optimal physical, psychological, physiological, and neurological functioning can be elusive and difficult to quantify. Existing technology in bio- and neurofeedback presents a unique opportunity for athletes and researchers to explore what individual peak performance looks like both psychologically and neurologically. Thus, the purpose of this case analysis was to explore the psychophysiological differences of a 200-m canoe athlete between his best and worst reaction times.

Introduction

With the addition of the 200-m event in sprint canoe and kayak at the Olympic level, the ability to react quickly off the start, focus effectively, and manage arousal has never been more crucial. The difference between success and failure in the men’s canoe and kayak 200-m events is measured in milliseconds. The gold medal for the 200-m kayak in the Summer 2012 Olympic Games in London was won by a margin of 294 milliseconds, and the difference between winning a bronze medal and not reaching the podium was merely 31 milliseconds (Olympic.org, n.d.). Given such small margins for victory, any advantage that a paddler can gain by having a quick and efficient start, a more effective focus, and an improved ability to manage arousal will be significant for performance (e.g., Crews, Lochbaum, & Karoly, 2001; Hatfield & Kerick, 2007; Zaichkowsky, & Baltzell, 2001). Biofeedback and neurofeedback training techniques have been used to teach athletes to self-manage both psychologically and neurologically in order to enhance performance (e.g., Bar-Eli, Dreschman, Blumenstein, & Weinstein, 2002; Dupee & Werthner, 2011; Edmonds, Tenenbaum, Mann, Johnson, & Kamata, 2008; Galloway, 2011; Harvey, Beauchamp, Saab, & Beauchamp, 2011; Hatfield, Landers, & Ray, 1987). Specifically, biofeedback training enables athletes to learn to self-manage arousal levels, and neurofeedback enables athletes to learn how to focus more effectively.

Reaction Time in Sport

Reaction time (RT) is the “interval between the presentation of a stimulus and the beginning of the response” (Schmidt & Lee, 2011, p. 58). The total RT includes (a) the time it takes for a sense organ (auditory, visual, somatosensory) to detect a stimulus, (b) the time it takes to carry impulses to the brain, (c) the time it takes the brain to process the stimulus, and (d) the time for the impulses to be carried to the muscle in order for them to contract and move (Woodworth & Schlosberg, 1954). Although there are three basic types of RT experiments (simple, go/no-go, and choice), for the purpose of this study, only simple-RT will be discussed because of the nature of sprint canoe racing. Given that flatwater sprint canoe is a closed-skill sport in which skills take place in a predictable performance setting, athletes must respond to only one unanticipated stimulus with one possible
response (simple-RT). Simple-RTs have been said to range from 140 milliseconds to 180 milliseconds (Brebner & Welford, 1980) and are thought to be rarely less than 100 milliseconds (Mero & Komi, 1990). In fact, the International Canoe Federation (ICF; 2015) and the International Association of Athletics Foundation (2015) use 100 milliseconds as the current false-start criterion in competition. One of the limitations of RT research in sport is that it is primarily studied in highly unrealistic situations (Schmidt & Lee, 2012, p. 92). In psychophysiological terms, measurements are regularly obtained from pressing keys with fingers in response to stimuli (Pain & Hibbs, 2007, p. 80). More recent research (Pain & Hibbs, 2007) has challenged this by measuring the RT of nine elite (county- to international-level) sprinters during an actual sprint start. With this group of highly trained athletes, Pain and Hibbs (2007) found that the neuromuscular-physiological component of simple-RTs could be less than 100 milliseconds, and possibly less than 85 milliseconds. For this reason, RT trials in this study were conducted in a lab on a paddle ergometer to simulate as much as possible real-life race starts without being on the water.

Several factors will influence an athlete’s speed of information processing in a simple-RT task. Research has shown that individuals elicit quicker RTs to auditory stimulus compared with visual (e.g., Brebner & Welford, 1980; Woodworth & Schlosberg, 1954), particularly when the auditory stimulus is loud enough (≥124 dB) to elicit a startle response (i.e., Carlsen, Maslovat, Lam, Chua, & Franks, 2011). Other relevant factors affecting RT include, but are not limited to, the complexity of the movement, length and location of the stimulus, gender, age, mental fatigue, amount of practice, presentation of a warning stimulus, level of arousal, and attention (e.g., Ando, Kida, & Oda, 2004; Arent & Landers, 2003; Dane & Erzurumluoglu, 2003; Hultsch, MacDonald, & Dixon, 2002; Welford, 1980). For the purpose of this study with its focus on psychophysiological factors, the present study will focus on both attention and level of arousal as it relates to RT.

### Arousal

Research on psychophysiological arousal and sport performance involves “highly variable terminology, such as arousal, alertness, vigilance, and attention” (Bertollo et al., 2012, p. 92). In psychophysiological terms, arousal refers to the level of physiological activity and the intensity of behavior (Andreassi, 2007). A basic understanding of the relationship between arousal and performance was derived from research conducted by Yerkes and Dodson (1908). The inverted-U hypothesis posits that increased arousal enhances performance up to a certain level of “optimal arousal.” Beyond this optimal level, arousal becomes excessive (i.e., anxiety), performance may decrease and, in extreme cases, lead to choking (Baumeister, 1984). Further research has expanded this singular approach to encompass the idiosyncratic differences (e.g., Bortoli, Bertollo, Hanin, & Robazza, 2012; Hanin, 2000; 2007) that each individual may experience as arousal relates to performance. The psychophysiological effects of arousal include increased respiration rate, increased heart rate (HR), increased muscle tension, increased skin conductance (sweating response), decreased peripheral body temperature (cold hands), and perceptual narrowing (Filaire, Alix, Ferrand, & Verger, 2009). Dependent on the athlete and the type of activity, higher levels of arousal can be seen to facilitate performance (M. V. Jones, 2003). For example, heightened arousal can lead to increased anaerobic power (Hardy, Jones, & Gould, 1996) and to increased perceptuomotor speed (J. G. Jones & Cale, 1989), and it may help athletes narrow attention and block out irrelevant distractions. In contrast, excessive arousal can impair motor performance (Eysenck, Derakshan, Santos, & Calvo, 2007), reduce dexterity and affect grip (Davis, Sime, & Robertson, 2007; Parfitt, Jones, & Hardy, 1990), disrupt rhythm and timing (Libkuman, Otani, & Steger, 2002; Oxendine, 1970), disrupt attention (e.g., Davis & Sime, 2005; Janelle, Singer, & Williams, 1999), and reduce RT (Williams & Andersen, 1997). Specifically, the effect of perceptual narrowing leads to a shift of attention from central to peripheral locations, more erratic eye movements, and slower RT (Janelle et al., 1999). In sum, excessive arousal has been shown to result in deterioration in performance (Davis et al., 2007).

### Attention

Athletes have the ability to attend to multiple tasks simultaneously (e.g., listening to the starter, strategizing a race plan, looking at the other competitors), but that capacity is limited. The determining factor for effective attention is the ability to selectively attend to the essential information and appropriate cues while ignoring irrelevant and distracting internal (i.e., negative thoughts) and external (i.e., weather conditions) stimuli (Abernethy, Maxwell, Masters, van der Kamp, & Jackson, 2007; Bouthier, 2008; Williams, Nideffer, Wilson, Sagal, & Peper, 2010). Abernethy and colleagues (2007) have identified three fundamental roles (selective attention, alertness, and information-processing resources) that attention plays in skill development and expert performance. Selective attention is the ability to attend to the desired stimuli and block out irrelevant information (Abernethy et al., 2007). Further, the ability to switch attention from one source of information to another is crucial to the learning of sport skills and to performance...
(Boutcher, 2008). Alertness—the capacity to “maintain optimal sensitivity and readiness to respond” (Abernethy et al., 2007, p. 245) to stimuli—also plays an essential role in attention and the ability for athletes to react quickly to external relevant stimuli. Factors such as fatigue, anxiety, and motivation have been found to influence an athlete’s ability to remain alert for long periods of time (sustained attention; Abernethy et al., 2007). The third key role is the athlete’s ability to manage and allocate limited information-processing resources (Abernethy et al., 2007). Motor acquisition theory suggests that individuals, as they master skills, progress from control (step-by-step information processing while learning new skills) to automatic (little conscious thought to perform skills) information processing (Fitts & Posner, 1967). As skills become automatic, expert performers do not need to think about the execution of the skill and therefore are more efficient at allocating their limited resources to what is important and can therefore react more quickly to essential external stimuli (i.e., the start gun).

In fact, quicker RTs have been used as a measure of greater availability of attentional resources (Abernethy, 1988).

**Bio- and Neurofeedback Training in Sport**

Bio- and neurofeedback training involves the development of self-awareness and self-regulation of both physiological (arousal) and neurological (attention) activity in the body and mind. Biofeedback includes several forms of feedback including electromyography (EMG), electrodermal activity (EDA), peripheral body temperature, HR, and respiration rate and depth. Specifically, feedback provides the athlete with visual information about his or her physiological responses and therefore enables the athlete to learn to self-regulate arousal. Neurofeedback, or electroencephalography (EEG) biofeedback, provides information on the athlete’s cortical activity (Tenenbaum, Corbett, & Kitsantas, 2002; Vernon, 2005). Cortical activity is measured in various frequencies ranging from delta (associated with deep sleep) to high-beta (associated with mental work, worry, and rumination; Thompson & Thompson, 2007). In the form of quantitative EEG (QEEG), athletes receive visual and/or auditory feedback and are encouraged to enhance beta1 for focused attention and limit both theta (daydreaming) and high beta (rumination, anxiety; e.g., Gomez, Vazquez, Vaquero, Lopez-Mendoza, & Cardoso, 1998; Schwartz & Schwartz, 2003). Overall, attention training via neurofeedback provides the athlete with self-regulation skills enabling him or her to effectively focus on the task at hand. Further, arousal training via biofeedback enables the athlete to self-manage arousal levels physiologically to a level that is facilitative for his or her individual performance.

**Bio- and Neurofeedback Training in Combination with RT Training**

There are several physical (i.e., plyometrics, resistance training, and stability exercises) and cognitive (i.e., visualization) techniques used to improve RT in sport. However, these techniques often lack ecological validity and rarely account for the extreme pressure of high-performance sport. Biofeedback training (particularly EMG) has been shown to improve RT performance (Harvey et al., 2011; Schultz, Etnyre, McArthur, & Brelsford, 1987). An early study examined the effects of EMG-biofeedback and EMG information only (no instruction) on RT and motor time (MT) compared with a control in a simple-RT task (Schultz et al., 1987). The EMG-biofeedback group was able to observe EMG feedback and was provided with written instruction on EMG-biofeedback that encouraged the individual to increase the EMG wave signal amplitude prior to the stimulus in order to reduce RT and MT. The other EMG experimental group (EMG-only) was able to observe EMG feedback but was not provided any instruction on the use of the signal. All three groups completed four blocks of 25 trials with a 2-minute rest period in between blocks. A randomly selected foreperiod (time the warning stimulus occurs before the start) of 1, 2, 3, or 4 seconds preceded an auditory stimulus. The only significant main effect was over the block trials for all three groups, which was likely due to learning, and contrary to the hypothesis, no significant differences between groups was observed (Schultz et al., 1987). Schultz and colleagues proposed that anxiety due to additional environmental stimuli could have affected the results for the two experimental groups.

Given the above findings and limitations, the rationale for incorporating RT training with bio- and neurofeedback training is to provide real-time feedback to the athlete about his or her psychophysiological responses simultaneously with RT results. This has the potential to allow for the athlete to make small changes (i.e., what they are paying attention to, how tight his or her muscles might feel) to improve RT. Overall, the combination of RT training and bio- and neurofeedback training allows for the athlete to practice psychophysiological self-regulation concurrently during simulated sport-specific RT scenarios.

**Methodology**

**Purpose**

The purpose of this single-case study was to investigate the idiosyncratic psychophysiological patterns associated with best and worst RTs in one male national team 200-m canoe athlete. The participant selected for this case analysis was 26
years of age and was currently competing as part of the Canoe/Kayak Canada national team.

**Procedure**
The athlete-participant completed one bio- and neurofeedback baseline assessment, 10 hours of bio- and neurofeedback training, and 10 sets of 30 RT trials over the span of 6 weeks. EEG data were recorded at Cz according to the International 10-20 system (Jasper, 1958). Each training session included 1 hour of bio- and neurofeedback training followed by three sets of 10 RT trials on a paddle ergometer to simulate as much as possible real-life race starts. Bio- and neurofeedback training was focused on helping the athlete learn to manage arousal (recover and quiet the autonomic nervous system), focus effectively, and recover both physiologically and neurologically. Please see Werthner, Christie, and Dupee (2013) for more detailed information on training procedures.

RT trials were conducted using an adapted version of the start gate protocol in Thought Technology’s Reaction Time Suite™ for use with Biograph Infiniti™ (Thought Technology Ltd., Montreal, Canada). The protocol begins with the first-person view (Figure 1) of a race course lane on a computer screen positioned in front of the athlete (Figure 2). The athlete also hears crowd noise. A verbal warning to “check your boats” is then given by the researcher at the same time as an illustrated start gate appears at the base of the screen. “Check your boats” is a typical warning canoe athletes hear as they approach the start line and position the nose of their canoe into the start gate. Exactly 3 seconds after the start gate appears a verbal warning “ready – set” given by the researcher at the same time as the word *ready* appears on the screen. Two seconds after the warning stimulus “ready – set,” the athlete hears a high-pitched tone delivered through headphones and sees the start gate disappear to indicate the start (“go”). At this point, the athlete then reacts and moves forward on the paddle ergometer in the same fashion as he would on the water (forceful forward push from their top hand and pull with the bottom hand on the paddle). The foot pedal sensor positioned on the handle of the paddle is depressed as the athlete reacts, therefore calculating the athlete’s RT to the start/go signal. After the athlete reacts, he has 15 seconds of rest before the next “check your boats” command is heard and the protocol is repeated.

**Analysis**
Psychophysiological data (EMG, respiration rate, EDA, peripheral body temperature, and QEEG) were recorded simultaneously with RT using a synchronizing device (Thought Technology Ltd.). From the RT trial results, the five best (i.e., quickest) and the five worst (i.e., slowest) RTs were selected for analysis. RTs of less than 100 milliseconds were excluded from data because of the false start criterion set by the ICF (2015). Data were analyzed by extracting the time-locked psychophysiological data (5×1-second epochs) during the prestart phase, prior to the “go” stimulus, of the RT time trial. Analysis of prestart psychophysiological variable means were examined using paired-samples t test.

**Results**

**RT**
Results indicated that there was a significant difference in the mean RT between the athlete’s five best RT trials and five worst RT trials ($p < .05$; Table 1; Figure 3). Best starts occurred later in the training (RT Trials 6 and 10), and the worst starts occurred early in the training (RT Trials 1 and 2).

**Respiration Rate**
The mean respiration rate was significantly higher ($p < .005$) in the 5 seconds prior to best starts compared with the worst starts (Table 2). Analysis of 1-second-epoch trends
leading up to the start demonstrates that respiration rate was relatively stable (zero correlation, $r = .02$) in the best and was increasing (moderate positive correlation, $r = .53$) in the worst starts (Figure 4).

**Electrodermal Activity**

Mean EDA was significantly lower ($p < .001$) in the 5 seconds prior to best starts compared with the worst starts (Table 2). Analysis of 1-second-epoch trends leading up to the start does not demonstrate any change in the EDA prior to best (strong positive correlation, $r = .84$) or worst (moderate positive correlation, $r = .43$) starts (Figure 5).

**EMG Activity**

Mean EMG activity was significantly higher ($p < .05$) in the 5 seconds prior to best starts compared with the worst starts (Table 2). Analysis of 1-second-epoch trends leading up to the start demonstrates that EMG activity was decreasing in best starts (moderate negative correlation, $r = -.39$) and was increasing (strong positive correlation, $r = .81$) in worst starts (Figure 6).

**Peripheral Body Temperature**

The mean peripheral body temperature was significantly higher ($p < .001$) in the 5 seconds prior to best starts compared with the worst starts (Table 2). Analysis of 1-second-epoch trends leading up to the start demonstrates that peripheral body temperature was decreasing in best starts (strong negative correlation, $r = -.99$) and was

### Table 1. Reaction times for five best and five worst starts

<table>
<thead>
<tr>
<th>Reaction Time (ms)</th>
<th>Worst</th>
<th>Best</th>
</tr>
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<tbody>
<tr>
<td>292.97</td>
<td>164.06</td>
<td></td>
</tr>
<tr>
<td>308.59</td>
<td>167.97</td>
<td></td>
</tr>
<tr>
<td>437.50</td>
<td>164.06</td>
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<td>285.16</td>
<td>167.97</td>
<td></td>
</tr>
<tr>
<td>289.06</td>
<td>152.34</td>
<td></td>
</tr>
</tbody>
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| Mean       | 322.66 | 163.28 |
| SD (±)     | 64.81  | 6.42   |

**Figure 3.** Comparison of five best and five worst react time means.

| Table 2. Psychophysiological variable means for best and worst reaction times |
|-------------------|-------------------|-------------------|-------------------|
|                    | Worst             | Best              | Significance (Two-Tailed) |
| Respiratory rate   | Mean 20.21        | Mean 21.79        | .002               |
|                    | SD (±) 0.27       | SD (±) 0.51       |                   |
| Electrodermal activity | 5.61        | 2.94              | .000               |
|                    | SD (±) 0.06       | SD (±) 0.02       |                   |
| Electromyography   | 31.53            | 54.93             | .017               |
|                    | SD (±) 8.67       | SD (±) 8.06       |                   |
| Temperature        | 25.94            | 26.02             | .000               |
|                    | SD (±) 0.00       | SD (±) 0.01       |                   |
| Theta              | 11.13            | 11.05             | .010               |
|                    | SD (±) 0.02       | SD (±) 0.04       |                   |
| Low alpha          | 5.43             | 5.40              | .002               |
|                    | SD (±) 0.01       | SD (±) 0.00       |                   |
| High alpha         | 2.78             | 2.97              | .000               |
|                    | SD (±) 0.01       | SD (±) 0.00       |                   |
| Sensorimotor rhythm| 3.99             | 4.42              | .000               |
|                    | SD (±) 0.03       | SD (±) 0.00       |                   |
| Beta1              | 4.95             | 5.23              | .000               |
|                    | SD (±) 0.01       | SD (±) 0.01       |                   |
| Low beta           | 5.40             | 5.65              | .000               |
|                    | SD (±) 0.00       | SD (±) 0.01       |                   |
| High beta          | 4.23             | 4.45              | .000               |
|                    | SD (±) 0.00       | SD (±) 0.01       |                   |
| Busy brain         | 6.45             | 7.41              | .000               |
|                    | SD (±) 0.02       | SD (±) 0.01       |                   |
relatively stable (zero correlation, $r = .09$) for worst starts (Figure 7).

QEEG
All QEEG frequencies measured were significantly different across best and worst starts (Table 2). Theta ($p < .05$) and low alpha ($p < .005$) were significantly lower in best starts compared with worst starts. Conversely, high alpha, sensorimotor rhythm (SMR), beta1, low beta, high beta, and busy brain were all significantly higher ($p < .001$) in best starts compared with worst starts (Figure 8). One-second-epoch analysis of EEG frequencies is beyond the scope of the current analysis.

Discussion
The purpose of this single-case study was to investigate the idiosyncratic psychophysiological patterns associated with best and worst RTs in one male national team 200-m canoe athlete. The data suggest that, for this athlete, best starts were associated with higher EMG, respiration rate, peripheral body temperature, high alpha, SMR, beta1, and high beta, in addition to lower EDA, theta, and low alpha.
In this case study, analysis of prestart psychophysiological values was unbiased by the assumption that a best psychophysiological state exists across all athletes and all sports. Previous research has suggested optimal physiological and neurological performance states in archers, golfers, racecar drivers, and marksmen (i.e., Filho et al., 2014; Landers & Arent, 2006). The current limitations with EEG recording require that the individual or athlete be relatively still while recording, making an ecologically valid study very difficult to conduct. For this reason, the present study used the measurement of 5-second epochs prior to the movement in a simulated environment to approximate real-life race starts and capture valid psychophysiological data (i.e., limit interference due to excessive muscle tension during movement).
Analysis of the athlete’s data, in the present study, suggests that higher EMG and higher respiration rates were more effective for quicker starts. These data should be interpreted with caution, however, because it cannot be assumed that because EMG and respiration rates were

Figure 4. Comparison of 1-second-epoch respiration rate means prior to best and worst starts.

Figure 5. Comparison of 1-second-epoch electrodermal activity activity means prior to best and worst starts.

Figure 6. Comparison of 1-second-epoch electromyography activity means prior to best and worst starts.

Figure 7. Comparison of 1-second-epoch peripheral body temperature activity means prior to best and worst starts.
higher than it is optimal. We only know that it was better for this athlete, in this sport, at this point in time, and under these conditions. In this case study, a trend toward decreasing muscle activity was also observed in best starts, and a trend toward increasing muscle activity was observed in worst starts. This observation supports the literature in other sports, in which higher muscle tension was found to be associated with increased RTs and reduced performance (e.g., Fontani, Maffei, Cameli, & Polidori, 1999).

The findings also suggest that, for this athlete, temperature was higher and EDA was lower in his best starts. This finding supports the literature on nervous system arousal/relaxation states, which has suggested that lower EDA and higher peripheral body temperature are indicative of a more relaxed sympathetic nervous system (e.g., Filaire et al., 2009; Janelle, 2002). As well, it supports the findings in shooting sports where preshot EDA levels for expert shooters was found to be lower prior to best shots compared with worst shots (Bertollo et al., 2012; Guillot et al., 2003; Tremayne & Barry, 2001). Thus, the interpretation can be made that this athlete’s sympathetic nervous system was less activated in his best starts. Currently, little is known about the optimal cortical state for athletic performance in sports other than archery, golf, and marksmanship. The neural efficiency hypothesis in sport suggests that expert athletes show less activation (increased alpha) in the left hemisphere prior to self-paced psychomotor performance (e.g., Babiloni et al., 2010; Hatfield et al., 1984; Pullum, 1977). Supporting this hypothesis, the QEEG data suggest that the athlete in the present study produced more high alpha (11–12 Hz) prior to his best starts compared with his worst starts. QEEG data also suggest that the athlete exhibited lower theta (4–8 Hz), indicative of less drowsiness or dreamlike states (e.g., Schwartz & Schwartz, 2003; Vernon, 2005), and lower low alpha (8–10 Hz), associated with internally oriented states of physical calmness and lack of visual activity (Petruzzello, Landers, & Salazar, 1991; Thompson & Thompson, 2003), in his best starts compared with his worst starts. Further, the athlete produced higher SMR (12–15Hz), correlated with an alert but calm mental state (Hammond, 2011; Thompson & Thompson, 2003; 2007), and beta 1, associated with states of high alertness, concentration, and focused attention (e.g., Gomez et al., 1998; Schwartz & Schwartz, 2003) in his best starts. The athlete also produced more high beta (23–35 Hz) or “busy brain,” which can be related to work or may represent worry and rumination (Thompson & Thompson, 2007). Further research is necessary to explore and better understand the EEG profiles of various athletes in various sports related to optimal performance.

It is essential to note that the majority of the research on biofeedback and neurofeedback training in sport that links psychophysiological variables to performance is based on association. Rarely does biofeedback research explore idiosyncratic psychophysiological profiles of athletes and collect data on the psychophysiological variables as they relate to performance (during performance). For example, biofeedback interventions in sport are largely based on the assumption that reducing the sympathetic nervous system stress response will enhance performance (e.g., Bar-Eli & Blumenstein, 2004; DeWitt, 1980; Dupee & Werthner, 2011; Galloway, 2011; Harvey et al., 2011). This may be correct, but currently we have little evidence to support this notion in terms of sport performance. Intervention research often proceeds to implement the intervention (reduction of stress) with the goal of enhancing performance, but it is rarely demonstrated how or if the psychophysiological variables have changed during performance. Therefore, we suggest that more research is necessary, across a variety of sports and with a greater number of athletes, that measures psychophysiological responses during (or just prior to) actual performance.

Nevertheless, the results of this idiosyncratic case expand the research on optimal psychophysiological states in athletes. The psychophysiological demands that athletes experience in training and in competition vary by sport (i.e., archery or hockey), position (i.e., quarterback or linebacker), discipline (200-m or 1,000-m distances), level of danger (i.e., golf or aerial skiing), and by individual (i.e., some athletes perform better with higher levels of arousal and narrowed attention, whereas others require a calm, relaxed, broad focus to perform). Because of the nature of sport, it is still very difficult to identify the perfect profile to achieve optimal performance in sport. Psychophysiological responses as they relate to performance vary greatly.
between athletes, and therefore an idiosyncratic approach is necessary to delve deeper into the individual athlete’s performance and explore what enables him or her to perform at his or her best. This study has also been able to advance ecological validity by having the athlete in a simulated environment and furthered the research in RT for sport because the majority of empirical RT studies are not sport specific, and RT measurements are regularly obtained from pressing keys with fingers (Pain & Hibbs, 2007).

In summary, this case study was able to demonstrate significant differences across psychophysiological variables (respiration rate, EMG, EDA, peripheral body temperature, and QEEG) for a 200-m canoe athlete’s best and worst starts. It provides insight into the potential optimal state for a high-performance athlete and expands the research by enhancing ecological validity by collecting data during simulated performance. Although larger sample sizes are preferred in experimental research in order to make generalizations about populations, perhaps single-case studies are required when exploring the psychophysiological idiosyncrasies of elite athletes.

Limitations and Future Directions

One key limitation of the present study is that it provided a picture of performance for only one athlete, in one sport, in one environment. Thus, future research should seek to explore patterns across athletes by increasing the number of athletes and sports in the sample. A second limitation is that EEG was measured from a single site (Cz), and the addition of multiple-site EEG recordings would provide specificity and the ability to detect interhemispheric differences. A third limitation is that the start protocol was preset. In real-life race events, it is often a human being giving the warning (ready, set) and the “go” signal (sounding the horn). Because this is not timed and is dictated by the individual starter, it can vary quite a bit. The present study had a set protocol in which every cycle lasted 20 seconds and the prestimulus warning (“check your boats”) occurred consistently at 5 seconds prior to the “go” signal and the prestimulus warning (ready, set) occurred exactly 2 seconds prior to the “go” signal. Thus, to approximate real-life race starts, future research protocols should vary the foreperiod before every cycle. Multiple psychophysiological measurements during movement can be problematic to capture effectively. In this case study, the placement for recording HR (electrocardiogram [EKG] with wrist straps) was not effective in capturing data prior to movement.

A fourth limitation is that missing data in certain trials led to the exclusion of the data for analysis. A fifth limitation to the current study is that we cannot say definitively that quicker RTs are causally linked to overall performance. However, research in track and field has shown that the sprint start is highly correlated to start velocity and overall performance (Mero, 1988). Thus, future research should endeavor to explore whether improved RT affects overall performance (i.e., reduction of total time) in a variety of sports.

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