

New technology holds promise for the future application of psychophysiological methods  
for the enhancement of performance during sport and exercise

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## COMMENTARY

Psychophysiology is the study of psychological processes through the measurement and interpretation of physiological responses (Cacioppo, Tassinary, Berntson, 2007). The realisation of the relationship between the so-called “mind” and “body” has encouraged the application of psychophysiology in various areas of psychology, including sport psychology (see Hatfield & Hillman, 2000). Unfortunately, methodological problems have limited the application of psychophysiological techniques to the study of sport. The gross body movements in most sports cause considerable degradation in the quality of the physiological recordings. The obtrusiveness of the electrode attachments and the wiring of the electrodes to a data acquisition system can also severely impede the athlete’s mobility and performance. It is perhaps not surprising that most psychophysiological research has been concerned with sports that involve minimal movements, such as pistol shooting (e.g., Mets, Kontinen, & Lyytinen, 2007). However, a range of new technological advances are giving encouragement for future applications of psychophysiological methodology in sport.

New data filtering and processing techniques have been developed to greatly improve signal quality. A case in point is the recording of heart rate, which has shown to be sensitive to both physical and psychological states in exercising individuals (e.g., Szabo, Peronnet, Gauvin, & Furedy, 1994). Commercially available equipment can record heart rate averaged across several seconds or more using non-invasive and robust devices that can be worn on the wrist like a watch or as a strap around the chest. Such techniques are useful, but can be limited when more precise measurement of heart rate is required. In many cases, heart rate needs to be time locked to certain behaviours (e.g., the

onset of a baseball pitch) or indices derived from the biosignal that underlies heart rate (e.g., T-wave amplitude) are required. In such cases, the electrocardiogram (ECG) itself must be acquired.

Although the ECG is a relatively large biosignal, it can still be difficult to obtain clear recordings in active athletes due to the noise created by muscle activity and artefacts created by movement. Improvements in the quality of the recording electrodes to allow for a firmer attachment and improved conductive gels can reduce artefacts caused by moderate movements at the source. New data processing techniques are providing additional solutions. Noise may be removed in many cases using digital signal processing techniques such as wavelets (Celka & Gysels, 2006), nonlinear methods (Schreiber & Kaplan, 1996), adaptive filtering (Thakor & Zhu, 1991), and principal components analysis (Moody & Mark, 1989). Motion artefacts that persist in the signal may also be removed with some success using these modern digital signal processing techniques (e.g., Renevey, Vetter, Krauss, Celka, & Depeursinge, 2001). Significant challenges still remain for smaller biosignals, such as the electroencephalogram, although future technologies hold promise for improvements in the quality of even these biosignals.

The use of an electromyographic signal to cancel out muscle and motion artefacts from the ECG was recently demonstrated during a rowing task (Celka & Kilner, 2006). Rowing is a continuous and energetic task that greatly impacts on the recording of ECGs from the chest. For such recordings, the biosignals generated by the pectoral and surrounding muscles and movement artefacts are a problem. To recover the ECG during rowing, the electromyogram recording of the distal pectoral muscle was used to provide a reference signal for motion and muscle activity cancellation. This additional reference

information, in combination with band-pass and adaptive filters, allowed the ECG to be recovered even during highly vigorous rowing by trained rowers. I have applied the same technique during a cricket batting task. Although cricket batting represents a different task to rowing (e.g., it is a discrete task of relatively clear ECG recordings punctuated by sudden and rapid movements), the ECG during the entire task could be recovered successfully using the relatively low-complexity technique of Celka and Kilner (2006). It should also be noted that such techniques could be used the other way around, that is, by using concurrent recordings of ECG and cancellation techniques to improve the quality of electromyographic recordings.

Another technological advancement that encourages further psychophysiological study in sport is the increased simplicity of the data acquisition equipment. In addition to becoming less expensive, the recording equipment has become easier to set up. Interfacing with a computer no longer necessitates the use of input/output cards and complicated calibration settings. There are now several commercially available systems that interface with a computer by using plug-and-play universal serial bus (USB) connections. Such technology also allows the standard laptop computer to be used for data acquisition. Finally, the recording equipment is becoming smaller in size, thus increasing the portability of the system when used during on-field studies of a sport.

Perhaps one of the most significant technological advances for sport application has been the development of new wireless portable or telemetry systems. Such systems allow the athlete to be physically separated from the data acquisition equipment. As such, the athlete is afforded greater freedom of movement and can be less conscious of avoiding the wires and damaging the equipment. This can be particularly important for

psychological research because researchers want to avoid a situation in which the measurement technique changes the behaviours they were designed to observe. Also from a researchers perspective, wireless systems can allow psychophysiological measurements to be taken in many sports that have been unable to be studied in the past. Portable wireless systems can be used stand-alone in that the same unit can acquire the biosignal, do some signal processing, and store the information for later retrieval. Improved technology has increased the storage capacity of portable systems, thus allowing for recordings to be made for longer periods or at higher sampling rates. Telemetry systems can be used to acquire the biosignal and send this information via a wireless protocol to a receiving station for signal processing and storage. Such telemetry systems can allow for more sophisticated data processing techniques to be used and for on-line monitoring of the athletes psychophysiological responses.

The adoption of new technological advancements in the psychophysiological study of sport has the potential to increase our understanding of performance-related psychological factors. Psychophysiological methods can provide unique information about psychological factors in sport that can be difficult to measure using self-report or behavioural observation. Moreover, psychophysiological techniques provide an excellent interface between the psychological and physical demands of many sports. Biofeedback, the process in which an individual's biological state is played back to an athlete to help them gain control over a mental state or motor actions (Blumenstein, Bar-Eli, & Tenenbaum, 2002), is particularly well positioned to produce improvements in sports performance through the application of new technology. By using information obtained from biofeedback during the actual sport performance, rather than during simulated or

post-session periods, a greater correspondence between performance and psychological state can be achieved. Moreover, by using new technological advancements in psychophysiological recording techniques, biofeedback information can be more accurate and applied in a wider variety of sports.

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