Psychophysiology of Sport, Exercise, and Performance

Cooke, Andrew; Ring, Christopher

Sport, Exercise, and Performance Psychology

DOI:
10.1037/spy0000156

Published: 01/02/2019

Peer reviewed version

Psychophysiology of Sport, Exercise and Performance: Past, Present and Future

RUNNING HEAD: PSYCHOPHYSIOLOGY OF SPORT & EXERCISE

Psychophysiology of Sport and Exercise: Past and Present

Psychophysiology is the scientific study of the reciprocal relations between mind and body. It is characterised by interdisciplinary, multi-measure research studies, which shed light on the processes and mechanisms underpinning human behavior. The origins of psychophysiology can be traced to the late 19th and early 20th century, when scientists, such as Charles Darwin, William James and Walter Cannon, began to chart physiological changes during emotions and other psychological states. Psychophysiology established itself as a distinct research discipline in the 1960's, when the Society for Psychophysiological Research was formed, and dedicated psychophysiology journals first emerged. Psychophysiology is a broad church and today it encompasses a range of sub-disciplines, including cognitive and social neuroscience, neuropsychology, and cardiovascular psychophysiology. However, elucidation of the relationships between psychological states, physiological responses, and human behavior remains the discipline's core mission.

The first psychophysiological studies of sport and exercise emerged in the 1970's (e.g., Baslet, Fisher & Mumford, 1976; Sherwood & Selder, 1979). Then, in 1983, a seminal review for sport psychologists announced psychophysiology as an exciting new approach to unmask performance mechanisms, provide assessment tools to diagnose performance problems, and yield new performance-optimization interventions (Hatfield & Landers, 1983). Despite these promising avenues - which continue to be just as relevant today - psychophysiological research in sport and exercise psychology has not grown as quickly as was predicted. A search of scientific databases indicates that the absolute number of publications concerning psychophysiology in sport, exercise and performance has increased in a linear fashion since 1983, with a particular acceleration during the last 10 years (Figure 1A). However, when considered relative to the total number of sport, exercise and performance publications during that period, it is clear that psychophysiology remains a niche

area, accounting for less than 10% of the total number of publications in the wider field (Figure 1B).

INSERT FIGURE 1 NEAR HERE

Today, in an age of interdisciplinarity (Porter & Rafols, 2009) where research is increasingly scrutinised for its methodological rigor (Larson & Moser, 2017), we foresee further prospects for a new era for sport and exercise psychophysiology. The psychophysiological research tools of the present are vastly superior to the tools of 1983, and probably unrecognisable to the likes of Darwin, Cannon and James. For example, psychophysiologists can now record objective physiological measures (e.g., autonomic, cortical, somatic, eye-gaze) via lightweight wireless amplifiers during sport performance. Modern psychophysiology thereby presents new opportunities to conduct rigorous interdisciplinary research and tackle the complex and mechanistic questions at the very core of sport, exercise and performance science. To help kickstart this new era, we are delighted to showcase eight high-quality manuscripts that embody the strengths of modern sport, exercise and performance psychophysiology, in this landmark special issue of the journal.

Introduction to the Special Issue

The special issue begins with a collection of three articles utilizing electroencephalography (EEG) to better understand the cortical mechanisms underpinning motor learning and performance under pressure. Frist, van Duijn, Hoskens and Masters (2019) report the first EEG-study to examine the mechanisms underpinning analogy learning. Their results indicate that analogy instructions help foster resilient performance by reducing left-temporal activity traditionally associated with verbal-analytic processing, thereby

increasing cognitive efficiency. Second, Lo, Hatfield, Wu, Chang and Hung (2019) present a study investigating the effects of increased state anxiety on cortical activity and accuracy-based motor performance. They report that increases in anxiety increase left temporal to frontal connectivity and right occipital high-alpha power. These findings are discussed in the context of contemporary stress and performance theories. Third, Christie, Werthner and Bertollo (2019) provide one of the first studies of cortical activity during a reactive sport task. Specifically, they examined cortical activity while ice hockey players, primed to hit the puck, waited for a target to be identified. Their results show a widespread cortical activation in the moments preceding target presentation, followed by a deactivation after the target appeared. These findings deviate from some of the results generated by self-paced aiming studies, and thereby highlight the important role of task and situation-specific factors on performance-related cortical activity.

The next three articles showcase eye-gaze and cardiovascular measures to provide insight to attentional and biological theories of human performance. First, Campbell and colleagues (2019) provide a methodological contribution that highlights the utility of pupillometry in sport psychology. Campbell et al. (2019) use pupillometry to argue that the onset of the so-called "quiet-eye" – a period of eye stillness prior to and during aiming movements (Vickers, 1996) – coincides with the most cognitively demanding period of motor preparation. They conclude that the mechanisms underpinning the effects of the quiet-eye on performance – a much-debated issue (Gonzalez et al., 2015) – reside in the cognitive domain. Second, Brimmell, Moore, Parker, Wilson and Vine (2019) contribute an eye-tracking study of soccer penalty takers to investigate the biopsychosocial model of challenge and threat (Blascovich, Seery, Mugridge, Norris & Weisbuch, 2004). They report that relative increases in cardiac output and reductions in total peripheral resistance during the minutes preceding penalties were associated with longer quiet-eye durations and, importantly, better

performance. This highlights the potential of pre-performance cardiovascular measures as useful assessment tools. Third, Hase, Gorrie-Stone and Freeman (2019) evaluate challenge and threat states as candidate mechanisms to explain the effects of a nutritional supplement – tyrosine – on performance. In accord with previous supplementation research (e.g., Hase, Jung & Rot, 2015), tyrosine ingestion benefited motor performance. While tyrosine did not directly influence cardiovascular reactivity, regression analyses revealed that more threat-like cardiovascular responses were associated with better performance during the tyrosine supplementation. This raises the intriguing possibility that tyrosine supplementation could be used as an intervention for performers displaying threat-like cardiovascular responses prior to competition.

The penultimate article of the special issue employs psychophysiology to investigate the mechanisms underpinning the relationship between personality and performance. In a two-study manuscript, Roberts et al. (2019) employed continuous (i.e., during performance) measures of heart rate variability and muscular efficiency to show that people high in narcissism excel when opportunities for self-enhancement are high due to increased mobilisation of physiological resources (e.g., increased physical effort). Results also showed that people high in narcissism perform sub-optimally when the spotlight is off due to poor physiological engagement. This manuscript provides a psychophysiological study template that can be re-applied to examine the mechanisms underlying the effects of other personality traits on performance. The moderating role of personality on the stress and performance relationship is an under-researched field and presents an exciting new avenue for sport and performance psychophysiology.

Finally, Naderi and colleagues (2019) answer the call for exercise psychophysiology research by reporting an examination of the effects of brief resistance exercise on executive function. They revealed in a sample of 60-75 year olds that a single-bout of low- or

moderate-intensity resistance exercise yielded greater improvements in performance on tests of executive function than were achieved by a no-exercise control group. Physiological variables are considered as mechanisms to explain the exercise effects. The findings argue that regular resistance exercise could optimize the executive function of older adults.

Psychophysiology of Sport, Exercise and Performance: Future

The articles published in the special issue showcase an array of psychophysiological applications for sport and exercise science and highlight the exciting potential of psychophysiological research to shine new light on theory and mechanisms in sport and exercise psychology. They all embody psychological and physiological interdisciplinarity, and follow good practice guidelines to increase methodological rigor, such as replicating effects across multiple studies (e.g., Roberts et al. 2019), providing clear statements of statistical power (e.g., Hase et al., 2019), and combining self-report and multiple levels of physiological measures to yield corroborative modes of inference (e.g., Brimmell et al., 2019). We encourage future research to follow these good practice examples.

Each manuscript also provides specific directions for future avenues to further advance the sport, exercise and performance field. For example, based on the work of Christie et al. (2019), we encourage researchers to study cortical activity across new sporting tasks. This can shed further light on the task-specific nuances of performance-related cortical activation, and will provide important implications concerning the generalizability of theory and interventions. Building on the findings of Hase et al. (2019), an applied intervention study could provide a field-test of the effects of tyrosine supplementation on those who display threat-like psychophysiological responses to stress. Meanwhile, the studies by Brimmell et al. (2019) and Roberts et al. (2019) provide a model platform for future research

to investigate the mechanistic inter-relations between multiple levels of mind, body and performance variables, with targeted moderation and mediation hypotheses.

In its short history as a journal, *Sport, Exercise and Performance Psychology* has championed interdisciplinary research that adopts advanced and rigorous methods (Kavussanu, 2017). It already has a record of publishing several original psychophysiological manuscripts (e.g., Gallicchio, Cooke & Ring, 2016, 2017; Harris, Vine & Wilson, 2017; Hunt, Rietschel, Hatfield & Iso-Ahola, 2013; Miller et al., 2014). This special issue further establishes *Sport, Exercise and Performance Psychology* as a primary outlet for sport and exercise psychophysiology research. We sincerely hope that the contents of the special issue will inspire the next wave and continuous stream of high-quality sport and exercise psychophysiology. In our view, a comprehensive understanding human behavior requires interdisciplinary research including psychological and physiological measures. Psychophysiology as a discipline is well placed to meet the call for rigorous interdisciplinary research and provides much exciting potential to move performance science forwards in the 21st century. We look forward to this new era of breakthroughs and anticipate charting the rise of psychophysiology as an increasingly significant player within the sport, exercise and performance field in years and decades to come.

References

Basler, M. L., Fisher, A. C., & Mumford, N. L. (1976). Arousal and anxiety correlates of gymnastic performance. *Research Quarterly. American Alliance for Health, Physical Education and Recreation*, *47*(4), 586-589. https://doi.org/10.1080/10671315.1976.10616714

Blascovich, J., Seery, M. D., Mugridge, C. A., Norris, R. K., & Weisbuch, M. (2004). Predicting athletic performance from cardiovascular indexes of challenge and threat. *Journal of Experimental Social Psychology*, *40*(5), 683-688. https://doi.org/10.1016/j.jesp.2003.10.007

Brimmell, J., Parker, J., Wilson, M. R., Vine, S. J. & Moore, L. J. (2019). Challenge and threat states, performance and attentional control during a pressurized soccer penalty task. *Sport, Exercise and Performance Psychology*.

Campbell, M. J., Moran, A. P., Bargary, N., Surmon, S., Bressan, L., & Kenny, I. C. (2019). Pupillometry during golf putting: A new window on the cognitive mechanisms underlying quiet eye. *Sport, Exercise, and Performance Psychology.* . http://dx.doi.org/10.1037/spy0000148

Christie, S., Werthner, P., & Bertollo, M. (2019). Exploration of event-related dynamics of brain oscillations in ice hockey shooting. *Sport, Exercise, and Performance Psychology*. http://dx.doi.org/10.1037/spy0000134

Gallicchio, G., Cooke, A., & Ring, C. (2016). Lower left temporal-frontal connectivity characterizes expert and accurate performance: High-alpha T7-Fz connectivity as a marker of conscious processing during movement. *Sport, Exercise, and Performance Psychology*, *5*(1), 14-24. http://dx.doi.org/10.1037/spy0000055

Gallicchio, G., Cooke, A., & Ring, C. (2017). Practice makes efficient: Cortical alpha oscillations are associated with improved golf putting performance. *Sport, Exercise, and Performance Psychology, 6*(1), 89-102. http://dx.doi.org/10.1037/spy0000077

Gonzalez, C. C., Causer, J., Miall, R. C., Grey, M. J., Humphreys, G., & Williams, A. M. (2015). Identifying the causal mechanisms of the quiet eye. *European Journal of Sport Science*, *17*(1), 74-84. https://doi.org/10.1080/17461391.2015.1075595

Harris, D. J., Vine, S. J., & Wilson, M. R. (2017). Is flow really effortless? The complex role of effortful attention. *Sport, Exercise, and Performance Psychology, 6*(1), 103-114. http://dx.doi.org/10.1037/spy0000083

Hase, A., Gorrie-Stone, T., & Freeman, P. (2019). Tyrosine intake and cardiovascular responses in a motivated performance situation. *Sport, Exercise, and Performance Psychology*. http://dx.doi.org/10.1037/spy0000144

Hase, A., Jung, S. E., & aan het Rot, M. (2015). Behavioral and cognitive effects of tyrosine intake in healthy human adults. *Pharmacology, Biochemistry, and Behavior, 133*, 1–6. https://doi.org/10.1016/j.pbb.2015.03.008

Hatfield, B. D., & Landers, D. M. (1983). Psychophysiology–A new direction for sport psychology. *Journal of Sport Psychology*, *5*(3), 243-259. https://doi.org/10.1123/jsp.5.3.243

Hunt, C. A., Rietschel, J. C., Hatfield, B. D., & Iso-Ahola, S. E. (2013). A psychophysiological profile of winners and losers in sport competition. *Sport, Exercise, and Performance Psychology, 2*(3), 220-231. http://dx.doi.org/10.1037/a0031957

Kavussanu, M. (2017). Sport, Exercise, and Performance Psychology: Past, present, and future. *Sport, Exercise, and Performance Psychology*, *6*(1), 1-5. http://dx.doi.org/10.1037/spy0000087

Larson, M. J., & Moser, J. S. (2017). Rigor and replication: Toward improved best practices in human electrophysiology research. *International Journal of Psychophysiology*, (111), 1-4. https://doi.org/10.1016/j.ijpsycho.2016.12.001

Lo, L., Hatfield, B. D., Wu, C., Chang, C. & Hung, T. (2019). Elevated state anxiety alters cerebral cortical dynamics and degrades precision cognitive-motor performance. *Sport, Exercise and Performance Psychology*.

Miller, M. W., Presacco, A., Groman, L. J., Bur, S., Rietschel, J. C., Gentili, R. J., . . . Hatfield, B. D. (2014). The effects of team environment on cerebral cortical processes and attentional reserve. *Sport, Exercise, and Performance Psychology*, *3*(1), 61-74. http://dx.doi:10.1037/spy0000001

Naderi, A., Shaabani, F., Esmaeili, A., Salman, Z., Borella, E., & Degens, H. (2019). Effects of low and moderate acute resistance exercise on executive function in community-living older adults. *Sport, Exercise, and Performance Psychology.* . http://dx.doi.org/10.1037/spy0000135

Porter, A., & Rafols, I. (2009). Is science becoming more interdisciplinary? Measuring and mapping six research fields over time. *Scientometrics*, *81*(3), 719-745. https://doi.org/10.1007/s11192-008-2197-2

Roberts, R., Cooke, A., Woodman, T., Hupfeld, H., Barwood, C., & Manley, H. (2019). When the going gets tough, who gets going? An examination of the relationship between narcissism, effort, and performance. *Sport, Exercise, and Performance Psychology*. http://dx.doi.org/10.1037/spy0000124

Sherwood, D. E., & Selder, D. J. (1979). Cardiorespiratory health, reaction time and aging. *Medicine and Science in Sports, 11*(2), 186-189. https://www.ncbi.nlm.nih.gov/pubmed/491879

van Duijn, T., Hoskens, M. C. J., & Masters, R. S. W. (2019). Analogy instructions promote efficiency of cognitive processes during hockey push-pass performance. *Sport, Exercise, and Performance Psychology.* http://dx.doi.org/10.1037/spy0000142

Vickers, J. N. (1996). Visual control when aiming at a far target. *Journal of Experimental Psychology: Human Perception and Performance, 22(2),* 342–354. https://doi.org/10.1037/0096-1523.22.2.342

Acknowledgements

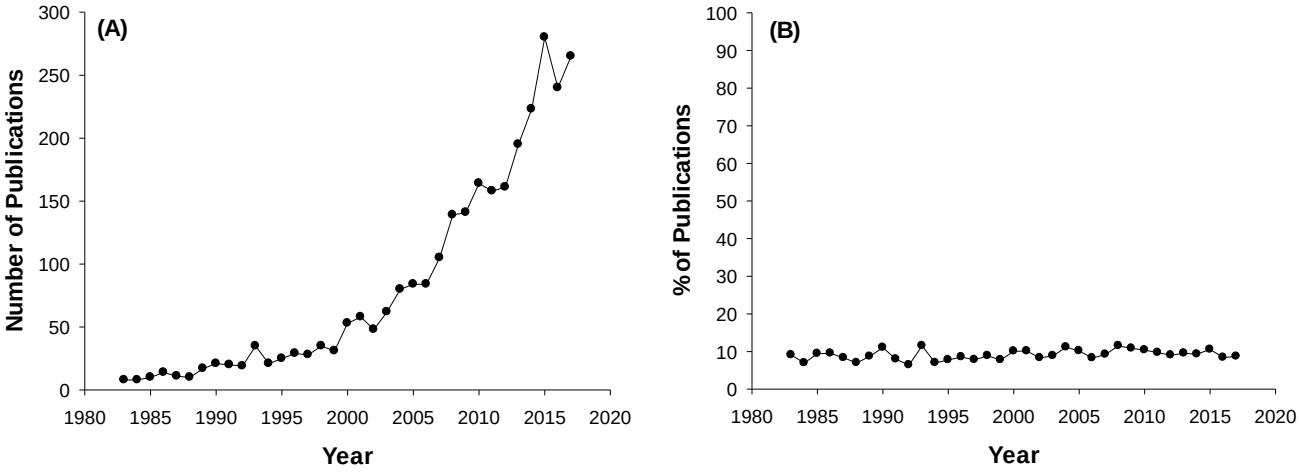
We thank Dr Maria Kavussanu for granting us the opportunity to publish this special issue, and Elizabeth Stern for her support coordinating the manuscripts.

Figure captions:

Figure 1: (A) Number of publications by year (1983-2017) identified by a search for journal articles containing the words “psychophysiology” “sport” “exercise” and “performance” on the National Center for Biotechnology Information (NCBI) database. (B) The number of publications presented in Figure 1A expressed as a percentage of the total number of publications by year (1983-2017) identified by a search for journal articles containing the words “sport” “exercise” and “performance” on the same NCBI database.[1]

[1]Identical searches performed on Google Scholar revealed very similar graphs, but a higher number of publications due to Google identifying multiple versions and some non-peer reviewed results.

Figure 1:


(A)
Number of Publications
300
250
200
150
100
50
0
1980
1985
1990
1995
2000
2005
2010
2015
2020
Year
(B)
% of Publications
100
90
80
70
60
50
40
30
20
10
0
1980
1985
1990
1995
2000
2005
2010
2015
2020
Year