Journal of Sports Sciences, 2015
Vol. 33, No. 9, 945–959, http://dx.doi.org/10.1080/02640414.2014.977940

My heart is racing! Psychophysiological dynamics of skilled racecar drivers

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(*Accepted 10 October 2014*)

Abstract
Our purpose was to test the multi-action plan model assumptions in which athletes' psychophysiological patterns differ among optimal and suboptimal performance experiences. Nine professional drivers competing in premier race categories (e.g. Formula 3, Porsche GT3 Cup Challenge) completed the study. Data collection involved monitoring the drivers' perceived hedonic tone, accuracy on core components of action, posture, skin temperature, respiration rate and heart rate responses during a 40-lap simulated race. Time marks, gathered at three standardised sectors, served as the performance variable. The A1GP racing simulator (Allinsport, Modena) established a realistic race platform. Specifically, the Barcelona track was chosen because of its inherently difficult nature characterised by intermittent deceleration points. Idiosyncratic analyses showed large individual differences in the drivers' psychophysiological profile, as well as distinct patterns in regards to optimal and suboptimal performance experiences. Limitations and future research avenues are discussed. Action- (e.g. attentional control) and emotion (e.g. biofeedback training)-centred applied sport psychology implications are advanced.

Keywords: *map model, psychophysiology, motorsport, peak performance*

Research on expertise in sport has been directed at identifying psychophysiological mechanisms underlying consistently high performance levels (Ericsson, 2006; Hanin & Hanina, 2009). Although nomothetic frameworks are essential to the development of general guidelines on expertise, idiosyncratic models are paramount in applied sport psychology (Bertollo et al., 2012; Hanin & Hanina, 2009; Robazza, 2006). To this extent, various idiosyncratic frameworks have been adopted by practitioners working with athletes to enhance performance. Recently, Bortoli, Bertollo, Hanin, and Robazza (2012) proposed the multi-action plan (MAP) model which, like other models in applied sport psychology (e.g. mindfulness–acceptance–commitment approach, individual zones of optimal functioning and optimal experience), reflects an idiosyncratic and multidimensional approach to performance enhancement in sport (Gardner & Moore, 2004; Hanin, 2007; Kimiecik & Jackson, 2002). The unique contribution of the MAP model pertains to its parsimonious 2 × 2 conceptualisation on how performance levels interact with attentional control levels. Parsimonious models are important because under competitive pressure, athletes are more likely to attend to simple and clear instructions rather than complex and difficult information (Tenenbaum, Basevitch, Gershgoren, & Filho, 2013).

The MAP model's 2 × 2 organisation (see Figure 1) has been conceptualised to offer clear "multi-performance enhancement plans" according to four performance types. Type 1 performance is characterised by automatic attentional control and optimal performance. This state involves optimal, flow-like performance experiences and low overt conscious control on the action. Type 2 performance is typified by attentional focus directed at athletes' core components of action and functional performance. This performance is attained through consciously focused attention on critical components of the task, such as pedalling rate in cycling or aiming in shooting sports. Type 3 performance is characterised by serial processing/over-controlled attention and dysfunctional performance. The excessive reinvestment of attention on the task in the attempt to control execution undermines automaticity and ultimately leads to poor performance. Type 4

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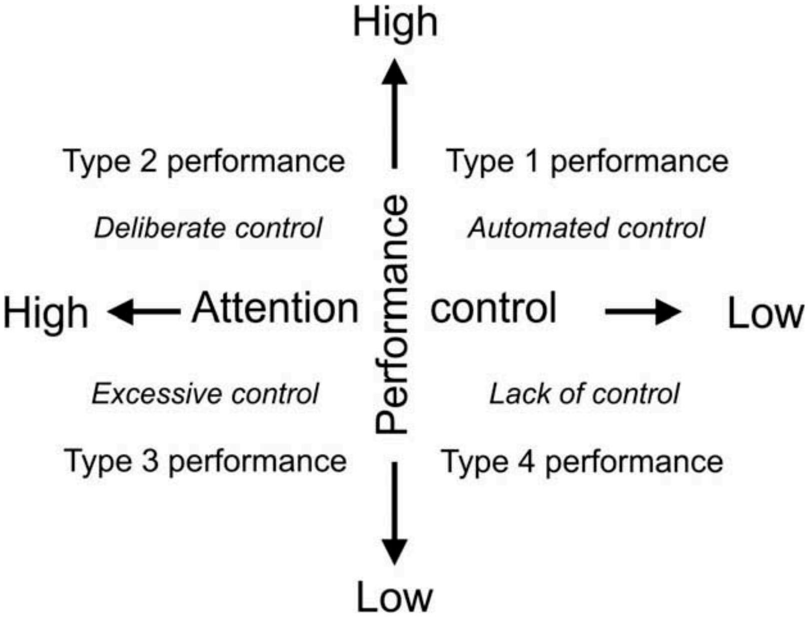

Figure 1. Performance and attention control interaction according to the multi-action plan (MAP) model.

performance is typified by low-level or task-irrelevant attentional focus, insufficient energies deployed to complete the task and dysfunctional performance.

Previous empirical research on the MAP model reinforces the notion that addressing the "performance-attentional control linkage" may be instrumental in the development of multi-plans for performance enhancement during competition. For instance, Comani, Di Fronso, et al. (2014) observed that action strategies directing athletes' attentional focus to previously identified core components of action, such as cycling pace and pedalling rate, lead to performance improvement in endurance cycling. In a study with skilled pistol and rifle shooters, Robazza, Bertollo, Hanin, Filho, and Bortoli (2014) found different probability curves (see Kamata, Tenenbaum, & Hanin, 2002) linked to the four different performance typologies proposed in the MAP model. Moreover, Bertollo et al. (2013) observed that skilled shooters' heart rate and skin conductance level were lower for Type 1 performance when compared to suboptimal performance types. Finally, in another psychophysiological study, Comani, Bortoli, et al. (2014) observed that the neural correlates underlying the MAP model's 2 × 2 performance were different, with optimal performance states (Type 1 and Type 2) characterised by the quiescence of the motor cortex in agreement with the *neural efficiency hypothesis*. According to this hypothesis, skilled performance is characterised by fewer unnecessary communications among brain cortices, resulting in less energy expenditure and interference in motor responses (see Comani, Bortoli, et al. 2014; Del Percio et al., 2009).

It is important to note that previous research on the MAP model has targeted objective performance measures of skilled shooting and endurance cycling athletes (Bortoli et al., 2012; Comani, Bortoli, et al., 2014; Comani, Di Fronso, 2014). To this extent, Hanin (2007) observed that objective performance measures allow for reliable estimates of one's moment-to-moment performance fluctuations, as related to a myriad of psychophysiological variables. Furthermore, skilled athletes show greater awareness of their idiosyncratic core components of action linked to peak performance in sports (Ericsson, 2006; Hanin & Hanina, 2009). Specific to objectively measured sports, skilled racecar drivers have shown greater awareness of strategic (e.g. route timing and journey) and tactical (e.g. manoeuvring, compensatory breaking) knowledge linked to safety and optimal performance (Fuller, 2005). In the present study, we tested the MAP model assumptions among highly skilled racecar drivers. We considered an objective performance measure and a multimodal approach by targeting multiple psychophysiological variables. In this regard, Bertollo et al. (2013) recently emphasised the importance of testing the MAP model assumptions in sport modalities other than self-paced sports, such as dart throwing, rifle and pistol shooting, and especially in open and complex skill sports.

In addition to testing the MAP model assumptions in a new sport modality, the present study addressed the need for further research in motorsports (Potkanowicz & Mendel, 2013). Compared to other traditional sports (e.g. cycling, track and field athletics, water sports), few studies exist in racecar driving (Yamakoshi, Matsumura, Yamakoshi, Hirose, & Rolfe, 2010). Data collection during actual racing may interfere with one's safety, thus imposing a challenge to scholars interested in motorsports (Fuller, 2005). However, relatively recent advances in bioengineering have allowed scholars to safely use portable electro-physiological sensors in the real-time monitoring of racecar drivers (Katsis, Katertsidis, Ganiatsas, & Fotiadis, 2008; Potkanowicz & Mendel, 2013). In fact, recent studies on simulated racecar driving have focused on recording racecar drivers' psychophysiological signals, including heart rate, respiration rate and body temperature (Edmonds, Tenenbaum, Mann, Johnson, & Kamata, 2008; Mullen, Jones, Faull, & Kingston, 2012; Yamakoshi et al., 2010).

Previous psychophysiological studies on racecar drivers have centred on monitoring: (a) heart rate dynamics, (b) thermal stress and (c) body posture intrinsically related to the cars' ever changing momentum resulting from acceleration and braking (Katsis et al., 2008). Specifically, heart rate has been shown to be positively related to various psychophysiological stressors common to motorsports, including exercise intensity, risk-taking behaviour, arousal and dehydration (Brearley & Finn, 2007; Yamakoshi et al., 2010). Respiratory rate is another psychophysiological marker of arousal regulation, and as such, breathing control exercises are among the most common forms of biofeedback training (Giggins, Persson, & Caulfield, 2013). Thermal stress has also been studied in racecar driving (Walker, Dawson, & Ackland, 2001). The numerous safety garments and layers of clothing worn by drivers, in addition to the heat generated by the car engine, create a microenvironment that can reach 50°C and compromise drivers' thermoregulation capability (Katsis et al., 2008). Finally, drivers' body posture is influenced by the cars' ever changing momentum resulting from acceleration and braking. Posture data can be either positive or negative and is usually measured on more than one axis, such as body flexion–extension and arms abduction/adduction (Potkanowicz & Mendel, 2013). In the present study, we expanded upon prior research by simultaneously monitoring skilled drivers' heart rate response, body temperature and posture movement.

Although research has shown that psychophysiological monitoring is important to understand racecars' performance, sport scientists also widely agree that it is essential to consider drivers' perceived emotional states (Edmonds et al., 2008; Fuller, 2005). Specifically, there is a general agreement that perceived psychological states influence performance, which in turn affect individuals' emotional states (for a review, see Tenenbaum et al., 2013). Relying only on objective data may misrepresent various situational factors outside one's control, including bad weather, injury, mechanical problems and outstanding performance by opponents. Furthermore, given that racecar drivers sit alone in the cockpit during races, Potkanowicz and Mendel (2013) noted that behavioural observations (from spectators, coaches and scientists) are limited, and self reports are paramount in assessing drivers' inner thoughts. Holland, Geraghty, and Shah (2010) highlighted that perceived control predicts driving behaviour among male and female drivers. Edmonds et al. (2008) found that perceived affective states (i.e. arousal and hedonic tone) were reliable predictors of optimal, moderate and poor performance in a simulated car racing study. Fuller (2005) observed that perceived performance and subjective risk appraisal influence compensatory speed reductions, which in turn affects performance and safety in motorsports. In particular, Fuller noticed that drivers tend to drive faster when they perceive poor performance times. In the present study, we were interested in drivers' perceived accuracy on their core components of action and hedonic tone (i.e. pleasantness level ranging from very low to very high; see Russell, Weiss, & Mendelsohn, 1989), given that these variables have been shown to be associated with performance and attentional focus in motorsports (Edmonds et al., 2008; Fuller, 2005; Mullen et al., 2012).

In summary, we subscribed to an idiosyncratic multi-modal approach by considering psychophysiological and perceived emotional states of skilled racecar drivers. Specifically, we conducted a multi-case study to test the MAP model's general assumption in which different psychophysiological characteristics underlie four different performance types (Figure 1). We considered an objective performance measure and a multimodal approach by targeting multiple psychophysiological variables. Consistent with previous research (Bertollo et al., 2013; Bortoli et al., 2012), we hypothesised that (a) performance categories (Type 1, Type 2, Type 3 and Type 4) would differ according to athletes' self reports (perceived performance, emotional states) and physiological recordings (heart rate response, respiratory rate, skin temperature and posture) and (b) drivers' psychophysiological responses would show idiosyncratic patterns, akin to previous idiographic research in sport psychology (Edmonds et al., 2008; Hanin, 2007; Johnson, Edmonds, Moraes, Filho, & Tenenbaum, 2007; Robazza, 2006).

Method

Participants

Ten male professional racecar drivers participated in the study. The participants ranged in age from 19 to 46 years ($M = 29.1$, $s = 10.3$) and had on average 9.9 years ($s = 4.75$) of driving experience. We used a *criterion sampling approach* given that sample size is not crucial in idiosyncratic analyses (Hanin, 2007; Patton, 2002; Robazza, 2006). Specifically, we selected participants on the basis of their competitive experience and professional achievements in major racecar events. All participants were skilled drivers, consistent with the importance of studying *information rich cases* to advance knowledge on the underlying mechanisms of excellence across domains of human performance, such as attentional control through *fixation* and *duration* of visual scan strategies (see Tenenbaum et al., 2013; Vickers, 2006). Furthermore, skilled athletes, as opposed to novices, are more knowledgeable about the core components (i.e. chain of events, mediating factors) of skilled performance (Hanin & Hanina, 2009). More specifically, the participants competed in premier categories including Formula 3, Formula 3 Open, Formula 3000, Lamborghini Super Series, Maserati World Series Championship and Porsche GT3 Cup Challenge. Participants' career highs included winning overall seasons and top-3 placements in the aforementioned events, as well as serving as Ferrari test-drivers on the Formula-1 team.

Instrumentation

Pre-task assessment: verbal reports on core-components of action. Participants were asked to identify the core components of their driving action. Initially, the participants were encouraged to provide a rich and detailed description of the chain of actions linked to their best performances (i.e. fastest race laps). The participants were instructed to *think aloud* while describing in a step-by-step mode the cognitive, motor, emotional and environmental aspects of their optimal driving behaviour (Ericsson, 2006). Think aloud protocols have been successfully used to study expert performance across domains (Ericsson, 2006; Williams & Ericsson, 2005). In particular, this methodology is based on the notion that experts are able to verbalise their cognitive processes linked to the successful completion of a given task. In the present study, we used the think aloud method as a means to identify the participants' core components of action. The verbal report sessions were conducted individually in an informal brainstorming tone to develop rapport. Upon finishing the description of the chain of actions linked to their unique performance dynamics, the participants were asked to select those elements (i.e. the core components) viewed as crucial in differentiating optimal from suboptimal performance. The specific probe was "What are the actions or behaviours that, when executed in a less accurate manner, cause your performance time to drop from optimal to suboptimal levels?" We explained to the participants that core components of actions are idiosyncratic and not necessarily the technical or tactical aspects emphasised by the press, coaches or their peers. We also explained that core components of action can be supervised with more or less conscious control depending on whether one is experiencing functional (Type 1 and Type 2) or dysfunctional performance (Type 3 and Type 4) (see Bertollo et al., 2013; Bortoli et al., 2012).

Driving task. Three driving tasks were established after two in-person peer debriefing meetings involving the authors of this study and a former professional racecar driver whom is currently a senior driving coach. The peer debriefing meetings, based on the notion of *cognitive task analysis* (Ericsson, 2006), were aimed at identifying a reliable and challenging task able to capture high-skilled performance in a realistic context. The authors and coach selected the Barcelona race track because of its inherently difficult nature with numerous turns and intermittent deceleration points. This race track is considered an important racecar circuit in Europe and well-known by all participants. The Barcelona track has a total length of 4.65 km and is used by various Formula-1 teams as a testing circuit because of its sectorial characteristics. Specifically, this race track has three distinct sectors of comparable length with five braking points of similar difficulty.

Noteworthy, the driving task was operationalised through the Allinsport 1 Grand Prix racing simulator (Allinsport, Italy). This virtual reality simulator is a replica of a real racecar with a seat, steering wheel and pedals (brake and accelerator) built in real-world dimensions. The participants were able to regulate the height as well as the distance of their seats from the steering wheel. Of note, the Allinsport 1 Grand Prix does not have G-force simulating capability. However, the Allinsport 1 Grand Prix racing simulator creates a realistic race platform through the combination of multi-media technology (sound, video and kinematic interfaces) projected during real-time on a rounded (180°) high-definition screen monitor. The participants were asked to drive 40 uninterrupted laps (approximately 1 h simulation). Performance data was recorded at the end of each of the three sectors (i.e. three times per lap) for the 40 laps, and thus a total of 120 data points were collected per participant. This is consistent with the central limits theory and previous idiosyncratic research in sport psychology (Filho, Moraes, & Tenenbaum, 2008; Kamata et al., 2002), in which a minimum of 30 data points per performance category should be initially considered for analysis.

Performance measure. The total time to complete each sector was automatically recorded by the racing simulator and represented the performance measure in this study.

Attentional control. In addition to performance data, the drivers' perceived attentional control on their core components of the action was collected to allow for the establishment of the four performance categories described in the MAP model. Throughout the driving task, the participants were asked to rate their control levels by using a modified 11-point Borg scale (see Borg, 2001) ranging from 0 (*extremely inaccurate*) to 11 (*extremely accurate*). More specifically, the verbal anchors of the scale, developed to avoid floor and ceiling effects, were 0 = *nothing at all*, 0.5 = *very, very little*, 1 = *very little*, 2 = *little*, 3 = *moderately*, 5 = *much*, 7 = *very much*, 10 = *very, very much*, 11 = *maximal possible*. No verbal anchors were used for 4, 6, 8 and 9. Of note, this scale has been successfully used in psychophysiological research in sport and exercise psychology (Bertollo et al., 2012, 2013).

Accuracy of core components of action. As presented herein, subjective accuracy reports are important in idiosyncratic research in applied psychology (Robazza, 2006; Tenenbaum et al., 2013). Accordingly, participants' perceived accuracy of the execution of their core components of action were also assessed on the modified 11-point Borg scale. Correlation coefficients between individual's perceived accuracy ratings and lap times ranged from 0.58 to 0.84 (mean r = 0.69), thus indicating a moderate to high criterion-related validity and suggesting that perceived accuracy of core components was related to performance.

Hedonic tone. Driver's hedonic tone was also collected throughout the driving task using the modified Borg scale ranging from −11 (*extremely unpleasant*) to 11 (*extremely pleasant*), with a 0 score denoting neither a pleasant nor unpleasant state. Negative scores are attributed to unpleasant states (Hanin, 2007; Robazza, 2006).

Psychophysiological data. Each driver's heart rate, respiratory rate, posture data and skin temperature were monitored throughout the driving task A BioHarness belt device (Zephyr Technology) wirelessly connected to a data acquisition device (Powerlab 16/30, ADInstruments, Australia) and a laptop computer with Labchart 7.1 software (ADInstruments) captured the participant's heart rate frequency (beats per min), respiratory rate (number of breaths per min), temperature (°C) and posture data on the longitudinal axis relative to the sternum (i.e. body flexion–extension with positive values representing movements frontwards and negative values for movements backwards). Physiological data collection were synchronised with the simulator via a Bayonet Neill–Concelman cable directly connected between the brake and the Powerlab data acquisition system.

Procedure

One of the authors, with extensive professional networking in motorsports, contacted potential participants through phone calls and email correspondence. During these initial correspondences, the participants were briefed on the overall purposes of the study and had their concerns and questions fully addressed. Those drivers interested in taking part in the study were invited to the driving centre where the study took place over the course of two visits. During their first visit to the driving centre, the participants received additional information regarding the study's overarching purpose and signed a written informed consent approved by the author's university ethical review board. The participants were then individually asked about their core components of action related to their best performance experiences in racecar driving, with each session lasting approximately 1 h. The verbal report sessions were conducted in a quiet and safe meeting room to ensure the comfort and privacy of the participants. Upon completion of each idiosyncratic verbal report, the drivers were given approximately five trial laps in the racing simulator. All drivers were accustomed to practicing in driving simulators. Thus, this driving routine was particularly conceived to allow the participants to become familiar with the study's data collection procedures.

During their second visit to the driving centre, the participants were given three additional familiarisation laps prior to the commencement of the actual driving simulation. After these three initial familiarisation laps, the actual simulation started and the participants were asked to drive for a total of 40 uninterrupted laps, totalling approximately 1 h of a driving simulation. They wore their personal racing suits but did not wear helmets to facilitate the collection of verbal reports during the simulated race. In particular, while driving, the participants were asked to verbally report (at the end of each sector) their perceived levels of control, hedonic tone and accuracy on their core components of action. Gathering verbal reports during, rather than before or after, sporting events has been encouraged in the literature to reduce ecological validity threats (Filho et al., 2008; Hanin, 2007; Kamata et al., 2002). Moreover, collecting verbal reports during racecar simulation is ecologically valid as brief verbal communication among racecar drivers and their racing team is common practice during race events (see *The perfect lap,* documentary feature by McLaren Formula 1, 2013).

Furthermore, while performing the driving task, the participants had their heart rate, respiratory rate, skin temperature and postural data monitored. Baseline data on all physiological measures were gathered for 5 minutes before the start of the driving task to ensure that the participants' physiological responses were within normal ranges. A BioHarness lightweight strap, mounted directly below each driver's chest, was used to capture and transmit heart and respiratory rate to a wirelessly connected laptop. The BioHarness strap is portable technology similar to a standard polar heart rate monitor. This strap is able to capture heart rate, respiratory rate, temperature and posture data. Noteworthy, three trained researchers collected the data, with two monitoring the BioHarness equipment and Powerlab software and one monitoring the driving simulator and recording the drivers' verbalised self-report data (i.e. control, hedonic tone and perceived accuracy on core components of action).

Data analysis

The data analyses procedures consisted of three steps. First, the psychophysiological data were organised using the Labchart software version 7.1 and in respect to the three sectors of the race. Given that the unit of analysis was the race sector, the psychophysiological data were averaged accordingly. The performance data for each participant were standardised (Z-transformation) across the three sectors of the race track, thus resulting in 120 data points per participant. We also multiplied the performance data by −1 (given that a shorter time racing corresponds to a better performance) to allow for ease of interpretation.

The second step of the data analyses procedures consisted of coding the data in respect to the MAP model's 2 × 2 categorisation (performance × control). The leading and last author coded the data, discussing any potential disagreement until reaching a consensus. Performance and control median scores were computed for each participant to conduct an idiosyncratic analysis. Of note, median values were used because mean values are more susceptible to the influence of outliers, particularly in idiographic analysis. Accordingly, values above the median for performance, and below the median for control, were coded "as optimal/automatic" experiences (i.e. Type 1 performance). Values higher than the median for both of these variables were coded as "optimal/controlled" (i.e. Type 2 performance). Values lower than the median for performance and higher than the median for control represented "suboptimal/over-controlled" experiences (i.e. Type 3 performance).

Finally, values lower than the median for both performance and control were coded as "suboptimal/under-controlled" experiences (i.e. Type 4 performance). This coding procedure is in agreement with general guidelines on idiosyncratic research on peak performance (Bortoli et al., 2012; Kamata et al., 2002). Furthermore, the coding procedure is intended to increase the likelihood of an approximately even frequency distribution across different functional (Type 1 and Type 2) and dysfunctional (Type 3 and Type 4) performance experiences. The final step consisted of comparing the drivers' psychophysiological and self-report data in regards to the coded data based on the MAP model's 2 × 2 conceptualisation. Specifically, one-way ANOVAs with the four MAP model's categories as the between factors was run for all psychophysiological and self-report variables considered in this study.

Results

We present the data from nine participants. We excluded one driver from the participant pool because a malfunctioning wireless connection interfered with his data acquisition. Respiratory rate from two drivers (Driver 3 and Driver 7) showed unreliable patterns (i.e. unrealistic and chaotic ranges) and were thus excluded from further analysis. It is important to note that these intercurrences are proper to psychophysiological studies in motorsport because of drivers' natural movements and various layers of clothing, among other factors (e.g. vibrations from the car simulator; see Yamakoshi et al., 2010). Altogether, we limited our analysis to the data collected and recorded reliably and present our findings for each hypothesis.

Core components of action

Participants' final selection of core components of action included "acceleration after the curve" (n = 3), "braking modulation" (n = 2), "braking point" (n = 2), "car speed", "racing line" and "turning in point". These results suggest that there is some variability in what racecar drivers consider to be a key factor for optimal performance in motorsports. The ability to properly use the brakes as well as regaining speed "after the curve" were emphasised as important aspects of performance by various drivers.

Hypothesis 1 Descriptive and inferential statistics for each driver's perceived and psychophysiological responses are presented in Tables I and II, respectively. A series of one-way ANOVAs with Bonferroni post hoc tests was used to identify

Table I. Descriptive and inferential analysis of drivers' accuracy on core components of action (CCA) and hedonic tone.

Driver	Type 1 (T1)	Type 2 (T2)	Type 3 (T3)	Type 4 (T4)	F (3, 117)	d	Post hoc
1	$n = 35$	$n = 25$	$n = 38$	$n = 22$			
Accuracy CCA	6.23 (1.39)	5.28 (2.30)	5.55 (1.45)	6.52 (1.12)	3.50*	0.31	T2 < T4
Hedonic Tone	5.66 (2.66)	4.32 (3.87)	5.08 (2.63)	6.35 (1.92)	2.80		
2	$n = 15$	$n = 45$	$n = 21$	$n = 39$			
Accuracy CCA	6.67 (1.40)	8.22 (0.97)	6.48 (2.27)	4.33 (2.07)	36.56**	0.14	T1 > T3; T1 > T4; T2 > T3
Hedonic Tone	1.27 (5.40)	5.84 (2.90)	2.57 (5.98)	−3.41 (6.51)	22.54**	1.39	T1 < T2; T2 > T4
3	$n = 38$	$n = 26$	$n = 32$	$n = 24$			
Accuracy CCA	6.79 (1.17)	6.69 (2.11)	4.56 (2.67)	4.67 (3.36)	7.58**	0.71	T1 > T3; T1 > T4; T2 > T3; T2 > T4
Hedonic Tone	6.13 (3.54)	4.38 (5.31)	0.78 (6.50)	3.38 (5.03)	6.56**	0.78	T1 > T3
4	$n = 38$	$n = 22$	$n = 26$	$n = 34$			
Accuracy CCA	7.42 (0.83)	7.09 (1.66)	6.38 (1.30)	6.97 (1.06)	4.00**	0.51	T1 > T3;T1 > T3; T1 > T4;
Hedonic Tone	5.00 (2.05)	5.09 (1.57)	2.92 (2.62)	2.62 (2.84)	9.46**	0.69	T2 > T3; T2 > T4
5	$n = 51$	$n = 09$	$n = 09$	$n = 51$			
Accuracy CCA	2.41 (1.79)	3.78 (1.30)	2.67 (2.35)	0.63 (1.55)	15.09**	0.65	T1 > T4; T2 > T4; T3 > T4
Hedonic Tone	−0.22 (1.36)	0.78 (0.83)	−1.56 (3.71)	−0.71 (1.88)	3.10**	0.93	T2 > T3
6	$n = 35$	$n = 25$	$n = 38$	$n = 22$			
Accuracy CCA	6.23(1.40)	5.28 (2.30)	5.55 (1.45)	6.64 (1.00)	3.97**	0.30	T2 < T4
Hedonic Tone	5.66 (2.66)	4.32 (3.87)	5.08 (2.63)	6.45 (1.90)	2.47		
7	$n = 31$	$n = 29$	$n = 38$	$n = 22$			
Accuracy CCA	7.94 (1.61)	7.66 (0.86)	6.32 (2.00)	7.41 (1.62)	6.79**	0.58	T1 > T3; T2 > T3
Hedonic Tone	7.87 (1.76)	7.31 (1.14)	3.95 (4.60)	6.27 (3.34)	10.74**	0.74	T1 > T3; T2 > T3; T3 < T4
8	$n = 16$	$n = 42$	$n = 30$	$n = 32$			
Accuracy CCA	4.06 (3.06)	6.20 (1.94)	6.43 (1.77)	0.18 (5.77)	22.76**	0.09	T1 > T4; T2 > T4; T3 > T4
Hedonic Tone	−0.31(0.79)	−0.07 (0.89)	0.07 (0.87)	0.24 (0.97)	1.58		
9	$n = 35$	$n = 25$	$n = 47$	$n = 13$			
Accuracy CCA	9.17 (1.48)	6.58 (2.59)	5.77 (2.91)	6.15 (3.24)	12.90*	1.22	T1 > T2; T1 > T3; T1 > T4
Hedonic Tone	4.86 (2.96)	2.08 (3.43)	1.04 (3.49)	1.00 (4.08)	9.40*	1.03	T1 > T2; T1 > T3; T1 > T4

Note: $^{*}P < .05$; $^{**}P < .01$.

Table II. Descriptive and inferential analysis of drivers psychophysiological variables.

Driver	Type 1 (T1)	Type 2 (T2)	Type 3 (T3)	Type 4 (T4)	*F* (3, 117)	*d*	Post-hoc
1	*n* = 35	*n* = 25	*n* = 38	*n* = 22			
HR	99.77 (3.06)	101.00 (2.20)	103.97 (2.27)	96.95 (17.96)	3.85*	0.16	T3 > T4
RR	21.47 (2.56)	22.90 (2.49)	24.08 (2.35)	22.76 (4.30)	4.90**	0.66	T1 < T3
ST	36.67 (0.89)	36.74 (0.09)	36.00 (0.67)	36.54 (0.26)	24.65**	0.78	T1 > T3; T2 > T3; T3 < T4
PT	−17.03 (0.86)	−17.39 (0.97)	−19.23 (1.36)	−16.72 (3.88)	11.23**	0.52	T1 > T3; T2 > T3; T3 < T4
2	*n* = 15	*n* = 45	*n* = 21	*n* = 39			
HR	70.83 (4.14)	72.53 (3.61)	70.75 (2.36)	68.34 (5.63)	4.08**	0.04	T2 > T4
RR	14.78 (6.40)	16.05 (5.49)	15.54 (4.99)	15.74 (4.43)	2.70*	0.70	T1 < T2
ST	34.94 (0.79)	34.93 (0.89)	34.87 (0.15)	34.87 (0.12)	2.86		
PT	−15.05 (1.63)	−15.22(1.43)	−16.21(2.13)	−16.11(1.71)	3.34*	0.42	T2 > T4
3	*n* = 38	*n* = 26	*n* = 32	*n* = 24			
HR	87.45 (7.98)	82.54 (5.15)	84.72 (7.41)	84.93 (5.35)	2.77*	0.52	T1 > T2
RR†							
ST	36.02 (0.31)	35.74 (0.39)	35.72 (0.49)	35.81 (0.40)	4.08**	0.67	T1 > T3
PT	−9.22 (1.50)	−10.10 (1.48)	−10.32 (2.24)	−9.59 (1.63)	2.70*	0.47	T1 > T3
4	*n* = 38	*n* = 22	*n* = 26	*n* = 34			
HR	88.47 (5.15)	90.61 (5.28)	82.39 (3.69)	83.95 (5.72)	15.20**	0.64	T1 > T3; T1 > T4; T2 > T3; T2 > T4
RR	15.26 (3.17)	13.93 (2.21)	15.35 (2.46)	15.00 (2.41)	1.45		
ST	36.68 (0.23)	36.56 (0.56)	35.42 (1.15)	36.26 (0.82)	16.54**	0.82	T1 > T3; T2 > T3; T3 < T4
PT	−21.29 (0.81)	−21.53 (0.80)	−20.82 (0.48)	−20.88 (0.71)	5.88**	0.35	T2 < T3; T2 < T4
5	*n* = 51	*n* = 09	*n* = 51	*n* = 09			
HR	76.61 (5.22)	76.22 (3.22)	79.40 (3.65)	74.85 (4.42)	2.95*	0.21	T3 > T4
RR	21.74 (1.80)	22.60 (1.70)	22.22 (2.09)	21.33 (2.30)	1.37		
ST	36.44 (0.20)	36.34 (0.20)	36.27 (0.21)	36.44 (0.19)	2.53		
PT	−26.50 (0.20)	−27.03 (0.67)	−27.08 (0.69)	−26.59 (0.83)	2.08		
6	*n* = 35	*n* = 25	*n* = 38	*n* = 22			
HR	105.60 (1.77)	101.87 (1.49)	100.90 (2.39)	97.9 (1.88)	64.23**	2.40	T1 > T2; T1 > T3; T1 > T4; T2 > T4; T3 > T4
RR	15.43 (2.50)	23.35 (2.01)	23.11 (2.20)	19.71(2.90)	14.53**	1.22	T1 < T4; T2 < T4; T3 < T4
ST	34.55 (0.62)	36.79 (0.06)	36.69 (0.04)	36.58 (0.02)	50.41**	2.46	T1 < T2; T1 < T3; T1 < T4
PT	−21.96 (0.84)	−18.12 (0.63)	−16.87 (0.59)	−16.48 (0.77)	131.81**	3.87	T1 < T2; T1 < T3; T1 < T4; T2 < T3; T2 < T4
7	*n* = 31	*n* = 29	*n* = 38	*n* = 22			
HR	85.08 (7.33)	87.20 (6.81)	84.35 (6.35)	82.27 (4.21)	2.57		
RR†							T2 > T4
ST	35.99 (0.27)	36.02 (0.22)	35.70 (0.50)	35.55 (0.41)	10.31**	1.12	T1 > T3; T1 > T4; T2 > T3; T2 > T4
PT	−9.17 (1.28)	−9.06 (1.22)	−10.45 (2.37)	−10.60 (1.51)	6.49**	0.50	
8	*n* = 16	*n* = 42	*n* = 30	*n* = 32			
HR	77.58 (2.55)	78.77 (2.65)	77.55 (3.21)	78.77 (2.51)	1.83		
RR	19.74 (4.91)	18.98 (3.95)	18.52 (3.34)	20.26 (4.15)	1.15		

(*continued*)

Table II. (*Continued*).

Driver	Type 1 (T1)	Type 2 (T2)	Type 3 (T3)	Type 4 (T4)	*F* (3, 117)	*d*	Post-hoc
ST	36.48 (0.15)	36.56 (0.16)	36.53 (0.17)	36.58 (0.15)	1.78		
PT	−23.16 (0.48)	−23.24 (0.42)	−23.03 (0.53)	−23.21 (0.40)	1.43		
9	*n* = 35	*n* = 25	*n* = 47	*n* = 13			
HR	101.91 (3.23)	102.72 (2.79)	101.83 (2.84)	101.78 (3.60)	0.56		
RR	18.73 (3.29)	19.66 (4.67)	19.70 (3.36)	18.57 (3.62)	0.72		
ST	36.48 (0.14)	36.31 (0.47)	35.98 (0.69)	36.30 (0.28)	7.21**	0.71	T1 > T3; T2 > T3
PT	−19.81 (1.42)	−20.06 (1.17)	−20.39 (2.17)	−23.22 (1.29)	0.81		

Notes: *$P < .05$; **$P < .0 1$.
Heart rate (HR), respiratory rate (RR), skin temperature (ST) and posture (PT). †Missing data.

potential differences among the MAP model's categories and in respect to each driver's data. The magnitude of observed differences is reported (Cohen's *d*) for overall effects. Specific effects can be derived from the descriptive statistics presented in Tables I and II. Overall, the data analyses revealed that all drivers exhibited different accuracy and hedonic tone responses for the MAP model's optimal (Type 1 and Type 2) suboptimal categories (Type 3 and Type 4). Differences between optimal/automatic (Type 1) and optimal/controlled (Type 2) categories were observed for driver 9 only (both accuracy and hedonic tone). Differences between suboptimal/over-controlled (Type 3) and suboptimal/under-controlled (Type 4) experiences were observed for drivers 5 (accuracy), 7 (hedonic tone) and 8 (accuracy).

Drivers' psychophysiological responses also varied according to the MAP model's categorisation (Table II). At least one psychophysiological marker was found to differ across drivers, with some drivers exhibiting differences in all analysed variables (i.e. Drivers 1, 2, 3 and 6). In fact, differences among optimal (Type 1 or Type 2) versus suboptimal performance experiences (Type 3 or Type 4) were observed for all drivers. Differences between optimal/automatic (Type 1) and optimal/controlled (Type 2) categories were observed for Drivers 3 and 6 for heart rate only. Differences between suboptimal/over-controlled (Type 3) and suboptimal/under-controlled (Type 4) experiences were observed for heart rate (Drivers 1, 5 and 6), respiratory rate (Driver 6), skin temperature (Drivers 1 and 4) and posture (Driver 1). Altogether, these results are congruent with the notion that the MAP model's categories are associated with different perceived and psychophysiological states. However, it is important to note that most of the observed differences were in the performance (optimal/suboptimal) factor.

Hypothesis 2 The drivers presented idiosyncratic intensities and ranges of perceived and psychophysiological responses related to the different MAP model's categories (see Figures 2–4). As presented in Tables I and II, the magnitude of these differences varied greatly from driver to driver (see Cohen's *d* ranging from 0.09 to 3.87). Finally, although the number of performance experiences classified as functional (Type 1 and Type 2) and dysfunctional (Type 3 and Type 4) was approximately even for all drivers, they still differed in the frequency of experiencing Type 1, Type 2, Type 3 and Type 4 performances. Collectively, these results are in agreement with our second hypothesis, in which drivers' self-reports and physiological recordings would show large inter-individual differences.

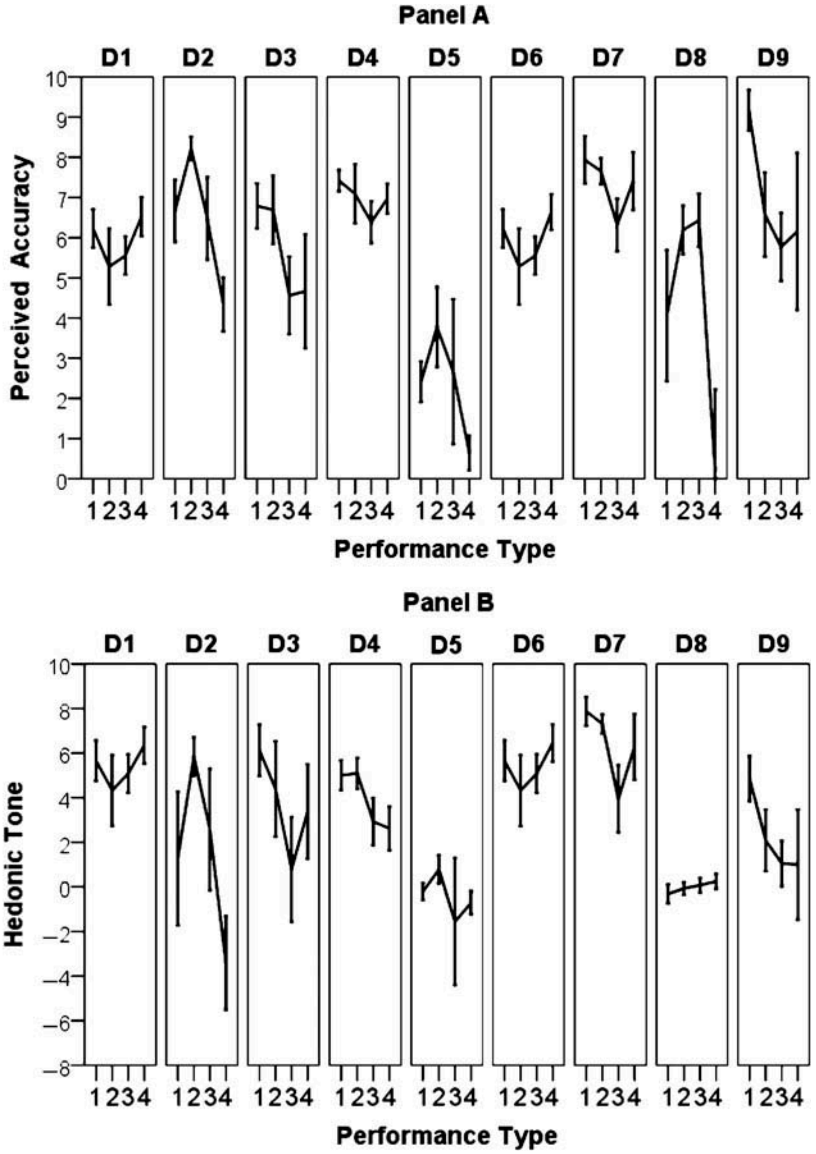

Figure 2. Drivers' perceived accuracy on core components of action (upper panel) and hedonic tone (lower panel) based on the MAP model framework.

Note. "*D*" stands for "Driver". X-axis: Performance Type-1, Type-2, Type-3 and Type-4.

Discussion

Our purpose was to test the MAP model assumptions in which athletes' psychophysiological patterns are thought to differ among optimal/automatic (Type 1), optimal/controlled (Type 2), suboptimal/over-controlled (Type 3) and suboptimal/under-controlled (Type 4) performance experiences. Data from the verbal reports suggest that "braking control" and "acceleration after the curve" are important for skilled performance in driving. Thus, in line with the expert performance approach (Williams & Ericsson, 2005), scholars should consider analysing the kinematic and psychophysiological mechanism of braking modulation and acceleration dynamics among skilled racecar drivers. Further, results support the notion that different perceived and psychophysiological states underlie the different MAP model categories. Specifically, we found differences among all MAP model categories for the drivers' perceived emotional states and psychophysiological responses. However, it is important to note that the majority of the differences observed in the presented study were in the performance factor as related to optimal (Type 1 and/or Type 2) versus suboptimal performance experiences (Type 3 and/or Type 4). Overall, there is a general agreement that best and worst performance experiences are easier to distinguish (as opposed to differentiating near-optimal performance from optimal performance) because

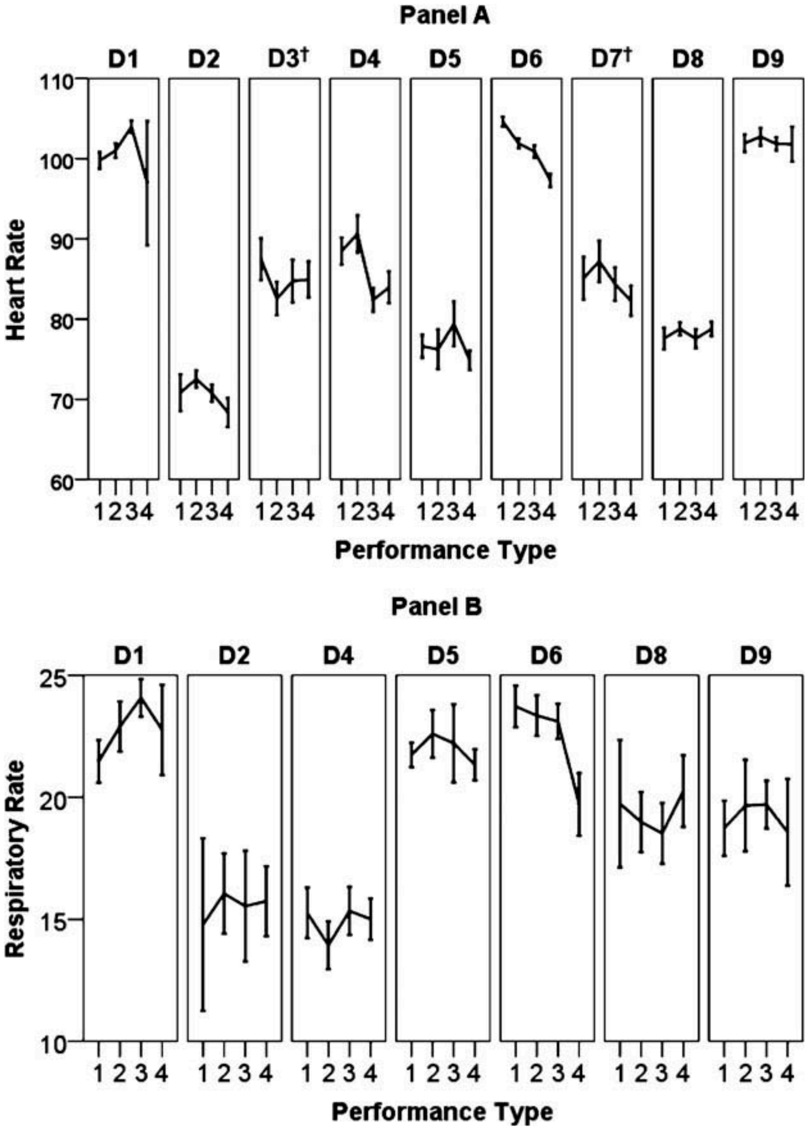

Figure 3. Drivers' heart rate (HR; bpm) and respiratory rate (RR; breaths per min) based on the MAP model framework.
Notes. "*D*" stands for "Driver". X-axis: Performance Type-1, Type-2, Type-3 and Type-4. †Missing data.

they are marked by distinct psychophysiological states expressed through different psychophysiological markers (e.g. muscle tension, heart rate; see Hanin, 2007; Robazza, 2006).

Hypothesis 1: MAP's model performance types

Differences in all variables were observed when comparing suboptimal/over-controlled (Type 3) and suboptimal/under-controlled (Type 4) performance experiences. Although a trend could not be established (because drivers' psychophysiological responses varied greatly), it was evident that performance of Types 3 and 4 was characterised by different levels of accuracy on core components of action, hedonic tone and psychophysiological responses. From an applied sport standpoint, profiling the dynamics of suboptimal performance experiences is crucial to increase the frequency of best performances. For instance, action-centred strategies (e.g. relaxation techniques) or attentional focused oriented strategies (e.g. attentional span and focus training) may be used to alter posture behaviour according to one's Type 1 performance profile (see Bertollo et al., 2013). For example, high levels of controlled focused attention could be beneficial to Driver 7 in maintaining a higher frequency of optimal performance experiences. Conversely, less attentional control as indicated by a more relaxed posture tone (i.e. leaning backwards as suggested by increased negative values) could help Driver 6 in moving from suboptimal performance types (Type 3 and Type 4) toward optimal performance states (Type 1 and Type 2). Additional applied strategies

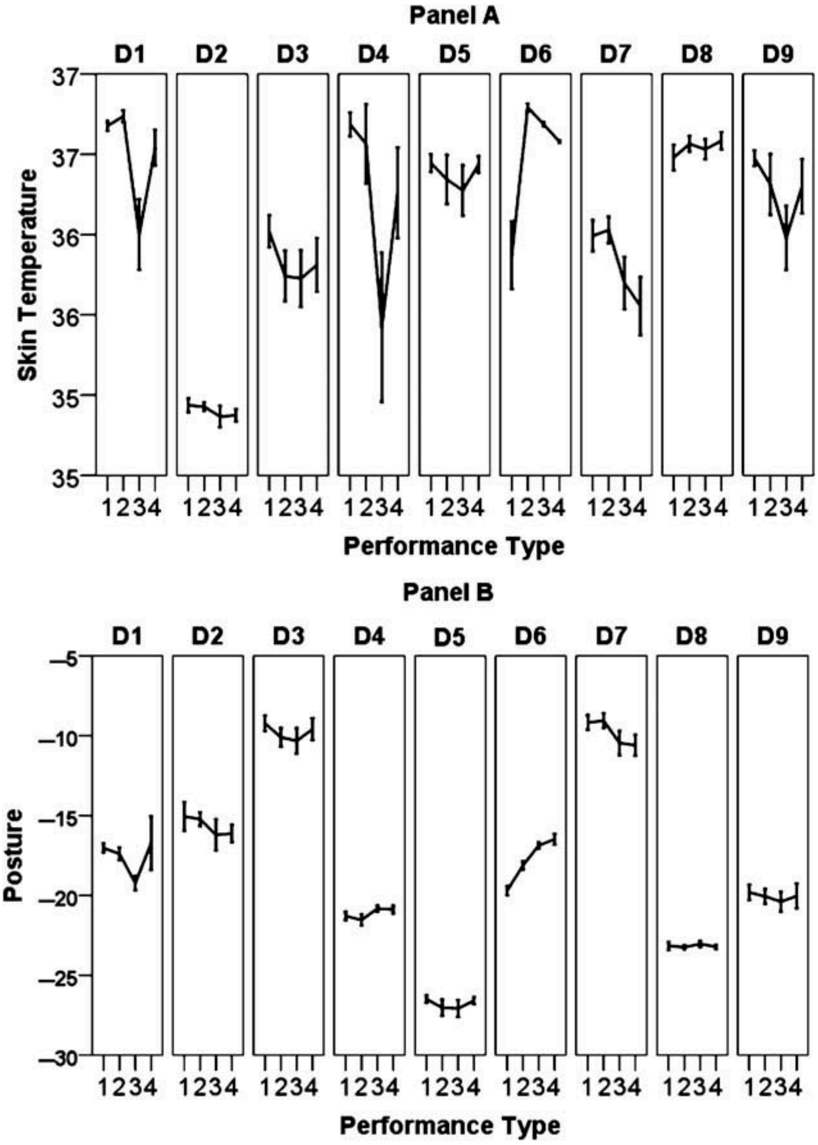

Figure 4. Drivers' skin temperature (ST; Celsius) and posture (PT) based on the MAP model framework.
Note. "*D*" stands for "Driver". X-axis: Performance Type-1, Type-2, Type-3 and Type-4.

that can help athletes cope with fatigue feelings during long duration sport events, such as racecar driving, include associative and dissociative imagery (Hutchinson & Karageorghis, 2013; Razon, Mandler, Arsal, Tokac, & Tenenbaum, 2014). Overall findings suggest that increasing awareness on the accuracy of core components of action is beneficial to performance as this factor was significant for all drivers. Understanding the chain of events associated with optimal performance is paramount for the development of expert performance in sports (Ericsson, 2006).

Differences between Type 1 and Type 2 performance were observed for accuracy on core components of action and heart rate only. Again, differences among various degrees of optimal performance states are usually subtle (Robazza, 2006). Furthermore, Type 1 performance states (optimal/automatic, flow-feeling like experiences) are rare occurrences and difficult to induce in totality, particularly in a laboratory setting. Perhaps key to help athletes moving toward Type 1 performance experiences are mindfulness approaches aimed at focusing on the moment ("here and now") and at reducing judgmental thinking (Bortoli et al., 2012; Masters & Maxwell, 2008). In effect, optimal-automatic performance experiences occur without overt conscious control through efficient parallel processing in the motor cortex (Comani, Bortoli, et al., 2014; Del Percio et al., 2009). Finally, given that most athletes showed unique heart rate and respiratory rate patterns linked to Type 1 performance, heart rate variability training could be beneficial in increasing the likelihood of peak performance experiences. Indeed, this biofeedback technique has been used to alter heart and respiratory functions to optimise performance in various domains of human performance, including sports, physical rehabilitation and military (Giggins et al., 2013).

Hypothesis 2: drivers' idiosyncratic psychophysiological responses

In agreement with extant idiosyncratic research in sport psychology (Edmonds et al., 2008; Filho et al., 2008), we observed large individual differences among the drivers. Specifically, the differences were in the intensity, variability and magnitude of the drivers' subjective and psychophysiological recordings. These results are in accordance with the overarching principle of individualisation in athletic training. In this regard, some psychophysiological markers (most noticeably respiratory rate and skin temperature) were predictors of performance experiences for only a few drivers. In fact, Hanin's (2007) pentagram conceptualisation within the individual zones of optimal functioning model predicts that different athletes are more or less sensitive to different forms of psychophysiological intervention. Therefore, we reinforce the importance of idiosyncratic research in sport psychology, particularly among skilled athletes. Adhering to normalised standards and nomothetic analysis (averaging data across participants) can be misleading in identifying the unique core components of optimal performance for a given athlete (Edmonds et al., 2008; Filho et al., 2008; Kamata et al., 2002). In all, we echo the notion that multimodal assessment plans and intervention protocols should be designed to allow athletes to choose among MAPs depending on situational factors and the task at hand.

Limitations and future directions

It is important to highlight that the present study has limitations. First, it is difficult to induce Type 1, flow-like performance in laboratory settings (Kimiecik & Jackson, 2002). Peak performance experiences are rare, and hence pose a challenge to scholars and practitioners interested in its nomological network. Second, the diversity in age and competitive background of the sampled athletes may explain part of the variability found in their subjective and psychophysiological responses. Third, testing for interactions among the variables was beyond the scope of this study, which focused on identifying the unique psychophysiological channels linked to optimal and suboptimal performance experiences in racecar driving. Examining the moderating and mediating linkage among various physiological measures, such as heart rate, skin conductance and electroencephalographic patterns, represents the next step in advancing research on bio-neurofeedback training protocols. Finally, although we used a professional race simulator, it is not possible to fully replicate an actual racecar competition. In fact, athletes and their staff are usually less inclined to participate in "real-world" data collection due to the inherently dangerous nature of motorsports (Fuller, 2005). When available, G-force simulators should be used to better replicate the physical properties of real-world races.

Notwithstanding these limitations, our study expands research in motorsports through a multimodal yet idiosyncratic approach. Most previous studies in motorsports have integrated only two psychophysiological measures and performance data. In the present study, we used four measures while simultaneously assessing drivers' performance (Katsis et al., 2008). Additionally, we expanded research on the MAP model, which in the past has been primarily conducted in self-paced sports (Bertollo et al., 2013; Bortoli et al., 2012). Moreover, we were able to monitor highly skilled racecar drivers, whose career highs included top-3 placements in major European competitions. As alluded to previously, it is crucial to study skilled athletes to advance research on the mediating mechanisms (e.g. physiological markers, memory structures) of expert performance in sports (Ericsson, 2006). Also noteworthy, this study adds to the literature in motorsports. Motorsports are less studied in comparison to other sports because of their dangerous nature and because drivers are not perceived as athletes by those who believe that the car is the most important factor in racing (Potkanowicz & Mendel, 2013). This study also adds to the extant literature on optimal performance experiences in sport psychology, especially in regards to the underpinning subjective and psychophysiological mechanisms differentiating optimal from suboptimal performance experiences.

Experimental trials are needed to advance knowledge on the MAP model's 2 × 2 (performance × attentional focus) categorisation. Future studies should assess changes in the ability of maintaining a Type 1 performance state after an action-centred and attention-focused training regime. Qualitatively contrasting athletes' and coaches' mental models on the core components of action in a given sport may help in the development of applied strategies aimed at enhancing performance in sports. Nomothetic research based on large samples may help to describe the psychophysiological mechanisms explaining the variability on drivers' raw performance data and psychophysiological responses. For instance, nomothetic research may help to explain why heart rate patterns are higher for some drivers and lower for other drivers across performance types. Kinematic and high-definition video analysis may be used to objectively evaluate athletes' core components of action in both closed and open skill sports. Finally, as outlined elsewhere (Del Percio et al., 2009), scholars should continue to explore the neural-efficiency hypothesis (common in optimal-automatic experiences) through the use of electroencephalographic and near-infrared spectroscopy methodologies.

Conclusion

In summary, our findings are consistent with previous research on the MAP model in which athletes' psychophysiological states were found to differ as a function of distinct performance levels (i.e. optimal-suboptimal) and attentional demands (i.e. automatic-controlled). Results are also aligned with applied research in sport psychology in regards to the importance of developing idiosyncratic and multimodal plans for performance optimisation in sports. Specifically, developing action-centred strategies (e.g. brake modulation control) and attention-focused strategies (e.g. attentional focus directed at the "racing line") may help athletes move toward less controlled, more pleasant and overall better performance states in racecar driving. Further, bio-neuro-feedback training regimes may help athletes regulate their psychophysiological states, thus increasing their probability of peak performance.

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