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The heat is on: Investigating the effect of psychological pressure on competitive performance in elite surfing

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ABSTRACT

Competitive sport often creates a high-stake and thus a high-pressure environment for its athletes. In the past, research has pointed to the negative effect that competitive pressure might have on skills and movement executions that have been perfected through prior practice. The Attentional Control Theory: Sport (ACTS) suggests that specifically high situational pressure and prior performance failures may negatively affect an athlete's subsequent performance. This study aimed to investigate the influence of situational pressure and previous performance errors on performance (i.e., wave score) in elite surfing while considering various contextual factors. A total of 6497 actions, performed by 80 elite surfers (female $n = 28$; male $n = 52$), were annotated based on video recordings of the 2019 World Championship Tour (WCT). A multi-level model was used to analyse the effect of pressure, previous errors and other contextual factors on the wave scores of individual surfers (i.e., events were nested within athletes). Partially confirming previous research, prior errors caused a significant decrease in surfing performance on the following ride. However, neither a significant effect of situational pressure on performance nor inter-individual differences in how prior-errors and situational pressure affected performance were found.

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Wave riding; coping with pressure; coping with failure; choking; anxiety

1. Introduction

1.1. Background

The inclusion of surfing at the Tokyo 2020 Olympic Games, as well as the sport's growth and ongoing professionalization offer interesting new avenues for scientists to explore. While some factors that influence surfing performance, such as environmental conditions (e.g., wave height and frequency) (Farley et al., 2017) or the execution of certain manoeuvres (Ferrier et al., 2018; Lundgren et al., 2014) has been investigated, research on psychological factors is scarce (Klingner et al., 2022). Hence, to support practitioners and researchers, further investigations into the determinants of elite performance in surfing are needed.

Due to its unique competitive structures and environmental characteristics, surfing indeed provides an interesting opportunity for research into how psychological factors influence competitive success. In surfing competitions, the athletes surf in head-to-head bouts against one, two or sometimes more opponents. These so-called *heats* are time restricted, usually lasting between 30 and 50 minutes. Within those time constraints, athletes are trying to achieve the highest total score, by performing a variety of manoeuvres. For each ridden wave, the surfer receives scores in the range from 0 to 10 points by a panel of judges. The two highest-scoring waves are combined, resulting in the total heat score of each athlete (World Surf League, 2020). The highest-scoring surfers within a heat then advance to the next rounds. Although surfers are not limited in the number of waves per heat, on average only 4% of the heat is spent surfing. Most of their time (i.e., 51%) is spent with paddling in order to be in the "right" spot, and in a stationary position (i.e., 42% of the time) to assess approaching waves and identify those with the highest scoring potential (Mendez-Villanueva et al., 2006). While the amount of scoring attempts that can be made by each athlete is unrestricted within the given time constraints, they are limited mostly by athlete's heat strategies (Barlow et al., 2016) and the environmental conditions during the competition (Farley et al., 2017). This highlights that skills like decision-making but also the quality of movement executions are crucial for success in surfing.

Most importantly, however, surfers have to apply these skills, not only in a highly variable and dynamic environment (i.e., the ocean), but also under the constraints of professional sports competitions. Hence, successfully performing under competitive pressure is considered one of the most important psychological skills in elite athletes (Hill et al., 2010; Wilson, 2012). The term *pressure* can be defined as "the presence of situational incentives for optimal, maximal, or superior performance" (Baumeister & Showers, 1986). Naturally, the perception of competitive stakes is inter-individually diverse and may consider a range of factors, anywhere between internal ego-driven goals, to external (e.g., monetary or honorary) rewards that the athlete hopes to accomplish or receive (Clancy et al.,

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2016; Gillet et al., 2009). As in principle the physical task for athletes remains the same regardless of the stakes that are at play, it is often the cognitive appraisal and emotional processing of these stakes and pressures that influences an athlete's performance in competition (Eysenck & Wilson, 2016; Lazarus, 2000).

That is, when athletes find themselves in a high-stakes situation, they may experience an increase of psychological pressure, which is perceived as so threatening that substantial anxiety is created from it (Nieuwenhuys et al., 2008; Payne et al., 2019). Elevated anxiety then disrupts the athlete's attention, which reduces the available capacity to focus on the task, and thereby causing a potential breakdown in performance (Nieuwenhuys & Oudejans, 2012; Roberts et al., 2019). The *Attention Control Theory: Sport (ACTS)* explains this loss of performance under competitive pressure due to a shift in the athlete's attention, away from task-related cues and towards threat-related cues (Cocks et al., 2016; Corbetta & Shulman, 2002; Eysenck & Wilson, 2016).

The ACTS assumes that the occurrence of anxiety is mainly influenced by the perceived probability of a future performance failure, as well as the perceived cost of it (see Figure 1). Furthermore, it suggests that this appraisal is based on the athlete's previous performance and the experienced situational pressure. Therefore, previous performance errors (e.g., a failed scoring attempt caused by mental or physical errors) have a direct link to the perception of an increased probability of future performance failure (i.e., *how likely is another failure?*), whereas high situational pressure is connected to a perceived increase of the costs of losing (i.e., *what is at stake?*). Crucially, these feedback loops establish a bi-directional relationship between performance and perceived psychological pressure. That is, increased pressure may lead to a deterioration of performance, but vice versa performance failures may also lead to an increase of perceived psychological pressure. Indeed, past research has shown that performance and perceived pressure may partially depend on the success or failure of previous performance (Arkes, 2016; Harris et al., 2019; Iso-Ahola & Dotson, 2014). Two studies specifically tested the predictions of ACTS and illustrated that situational pressure and previous performance errors both significantly predicted the outcome of field goal kicks in American football (Harris et al., 2019) and points in tennis (Harris et al., 2021). Most crucially, and as predicted by ACTS, both studies found an interaction effect between situational pressure and previous performance errors on the outcome of the subsequent action. Hence, the odds of a negative performance outcome were even further elevated when both factors (i.e., pressure and prior failure) were increased. Considering this research, the ability to cope and perform when it matters the most can be considered essential for elite athletes. Although Harris et al. (Harris et al., 2021) highlighted that winners and losers of tennis matches were equally affected by psychological pressure, it remains unclear if there are differences in how athletes of different skill-levels (e.g., based on season-ranking) perform under these conditions. Thus, by investigating potential skill-related differences of responses to pressure in competitive surfing, our study might extend the existing literature.

Investigating the predictions of the ACTS in surfing is also an interesting undertaking for several other reasons. For one, competitive surfing is less interactive in nature than previously researched sports, such as American Football (Harris et al., 2019) and Tennis (Harris et al., 2021). That means that a sudden loss in performance can be attributed more clearly to the failures of the athlete, rather than the actions of an opponent. Therefore, we might be able to get a better insight into the relationship between situational pressures and performance outcomes (Eysenck & Wilson, 2016). Additionally, and as pointed out earlier, competitive surfers spend only a marginal time of a competitive round actually surfing the wave. Therefore, in competitions, there should be sufficient time for attentional distractions, and thus for athletes to create worries that potentially affect performance (Eysenck & Wilson, 2016). The effects of psychological pressure on performance might also show in surfing, as athletes in individual sports report higher levels of anxiety and threat perception compared to team sport athletes, with both being more amplified in female athletes (Dias et al., 2010). Finally, compared to a dichotomous

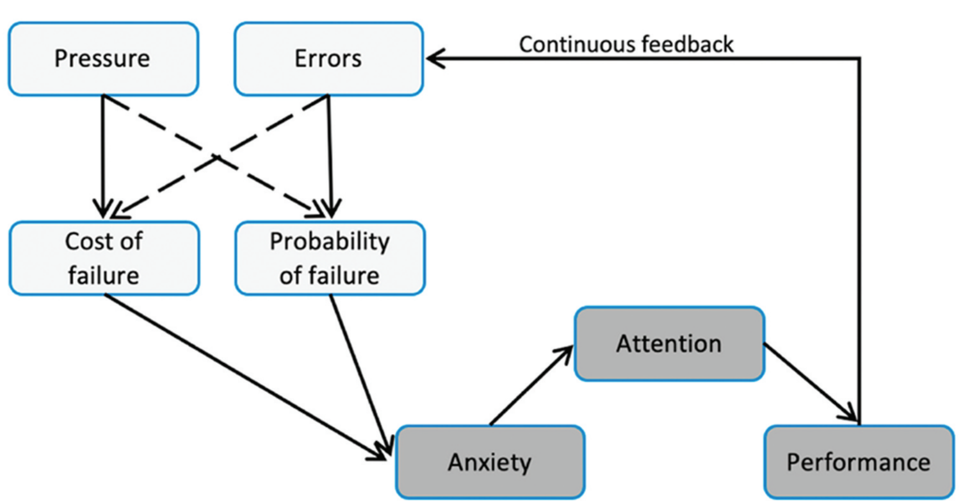

Figure 1. Illustration of the bi-directional pressure–performance relationship outlined in the Attentional Control Theory: Sport as used in Harris et al., (2021). Reprinted from Harris et al., (2021, p.2) with permission from Elsevier.

scoring system (i.e., score vs non-score) surfing might allow us to quantify a loss of performance more completely, as wave rides are scored on a scale, based on several criteria. Therefore, suboptimal performance at every stage (i.e., wave-selection and wave-ride) would be easier to measure. For example, pressure-induced anxiety may alter the way in which athletes scan their environment and perceive task-relevant information [26], which in surfing could lead to a selection of lower quality waves and movement options, or to insufficiently executed manoeuvres. All of which would result in a lower scored wave. Thus, we could expect to see strong signs of a bi-directional pressure performance relationship in surfing, as predicted by the ACTS, despite the sport's highly variable competitive environment.

1.2. Aim of research

With most research into performance under pressure in sports being conducted in experimental settings, recent studies illustrate the need for more field-based investigations (Hill et al., 2010), for example, by using play-by-play data for further data analysis (Harris et al., 2019, 2021; Hsu et al., 2019). Therefore, the aim of this research is to investigate the influence of situational pressure and previous performance errors on performance under the consideration of contextual factors, by using a play-by-play data set of men's and women's elite competitive surfing. Furthermore, following the approach of previous research (Harris et al., 2021) this research also aims to explore potential performance differences between differently skilled athletes, as an indicator for differential responses to psychological pressure.

2. Methods

2.1. Participants

A total of 80 international elite surfers (female $n = 28$; male $n = 52$) were included in this study, whose mean age was calculated at the first event of the season (female mAge = 24.0 ± 4.7; male mAge = 25.9 ± 5.3). To explore potential differences in how differently ranked athletes perform, all surfers were divided into one of the two groups. That is, the top 25% (female $n = 7$; male $n = 13$) were considered high-ranking surfers (HR) and the bottom 75% (female $n = 21$; male $n = 39$) low-ranking surfers (LR). This ranking was based on the average placement which each surfer achieved across all events that they participated in. The split (i.e., top 25% vs bottom 75%) was chosen to ensure a comparable number of actions across all competitions (i.e., female top 25% $n = 913$ vs female bottom 75% $n = 877$; male top 25% $n = 2056$ vs male bottom 75% $n = 2651$). The two groups, which imply different levels of expertise, are reflected in the variable *surferrank*, which is used as a predictor in the multilevel model (see 2.3. Statistical Analysis).

2.2. Data collection

Data was obtained from video recordings of 19 events of the 2019 *World Championship Tour* (WCT). This included all ocean-based events of the men's ($n = 10$) and women's ($n = 9$) competition. Data collection was carried out by a total of five raters between the months of February and April 2021. The video recordings were accessed via the *Heat Analyzer* feature on the *World Surf League* (WSL) website (World Surf League, 2021), which allows to re-watch the official live broadcast of the competitions in high-definition quality. The five raters systematically watched the entire broadcast of each heat, annotating details such as the time, score or the use of priority for each wave ride and attempted wave-ride (i.e., unsuccessful paddling for a wave) in a *Google spreadsheet* (see Table S1 in supplementary file). It is important to note that the data collection focused solely on 1-versus-1 elimination heats, where only one of the two participating surfers advances to the next round. We thereby excluded all non-elimination heats that consist of three simultaneously competing surfers, to allow a more precise evaluation of the implications that one surfer's action has on the other's competitive situation. A total of 6497 actions were annotated across all 445 heats, including a total of 80 international elite surfers.

2.3. Reliability of data annotations

The inter-rater reliability of the annotated competition data was assessed, after a 2-week training period, via a trial test which included a total of 70 heat sequences for all five raters. The trial focused on key variables of the data annotations. The raters identified the surfer who performed an action, as well as the action that was performed (i.e., wave-ride, failed paddle attempt or interference based on official ruling). Additionally, the raters annotated (i.e., based on official WSL broadcasting) the level of priority that a surfer possessed, whether the priority changed after the performed action, and what score the surfers received from the judges for the respective action. The inter-rater reliability yielded a Fleiss' kappa value larger than 0.960 for all variables, which can be considered an almost perfect agreement (Landis & Koch, 1977).

2.4. Data processing

To be able to allocate each action to specific pressure categories several data modifications were made. For each annotated action, the two highest, previously recorded, wave scores were calculated for every surfer in each unique heat. Subsequently, a current heat score total for each surfer, score differences, as well as the score requirements for a lead change were created for each action. Lastly, a percentage of the remaining time in a heat was also recorded for each annotation.

2.5. Contextual factors in surfing

2.5.1. Situational pressure

The categorization of *situational pressure* was based on previous studies (Harris et al., 2019; Hsu et al., 2019). They suggested that pressure is mainly influenced by (1) the time left in the competition and (2) the respective scoring situation. For competitive surfing, this means that the information of how far a surfer leads or trails an opponent at a given time in the heat can be used to categorize situational pressure. Based on this, the pressure categories for

Table 1. Categorization of situational pressure in competitive surfing.

% of total time left	Live rank	Score requirement	3-category pressure
100–50%	1	Leads by > 10.0	Low
50–25%	1	Leads by > 10.0	Low
25–0%	1	Leads by > 10.0	Low
100–50%	1	Leads by ≥ 5.0 & ≤10	Low
100–50%	1	Leads by < 5.0	Low
50–25%	1	Leads by ≥ 5.0 & ≤10	Low
100–50%	2	Needs <5.0	Medium
50–25%	1	Leads by < 5.0	Medium
25–0%	1	Leads by ≥ 5.0 & ≤10	Medium
100–50%	2	Needs ≥5.0 & ≤10	Medium
50–25%	2	Needs <5.0	Medium
25–0%	1	Leads by < 5.0	Medium
100–50%	2	Needs >10.0	High
50–25%	2	Needs ≥5.0 & ≤10	High
25–0%	2	Needs <5.0	High
50–25%	2	Needs >10.0	High
25–0%	2	Needs ≥5.0 & ≤10	High
25–0%	2	Needs >10.0	High

this study are defined in Table 1. Our definition of situational pressure was discussed and agreed on by three practitioners who all work as coaches or managers on an international level in competitive surfing. One of the consulting practitioners is also a graduated sports psychologist. As this was a purely observational study, it should be noted that situational pressure is only an indicator of actually perceived pressure.

2.5.2 Priority rule

An important aspect of heat strategies is how surfers utilize the *priority rule*, which is the continuously changing right for an athlete to choose any wave, giving them an advantage over other competitors for the time-being. The priority is passed on to the next surfer, only if the surfer in possession exercises their priority right and chooses a wave. In that case, another surfer cannot ride the same wave if doing so hinders the scoring potential of the surfer with priority (World Surf League, 2020). It therefore increases a surfer's chance to select and ride waves with the highest scoring potential while at the same time keeping their competitors from doing so.

2.5.3 Performance errors

As surfing does not have a dichotomous outcome measure (e.g., goal vs no goal, hit vs miss) performance errors were operationalized as an action where a surfer:

(1) with priority fails at a paddling attempt and subsequently loses priority
(2) with priority and in second place only receives a poor wave score (i.e., <2.0 as defined by WSL (World Surf League, 2020)) and subsequently loses priority
(3) commits a priority interference (i.e., by infringing the priority rule) and is subsequently penalized by annulment of their second scoring wave.

All three types of errors are the likely result of suboptimal decision-making or flawed movement execution without any direct influence of the athlete's opponent. If any of these situations occurred, then the respective action was coded as *performance error*.

2.5.4. Wave type

Each surf location is associated with different environmental variables which affect the quality, length and shape of the breaking wave. The wave type is one of the most influential factors and is often separated into three distinct categories depending on the nature of the beach's shape and make-up of the seabed (i.e., Beach break; Reef Break; Point Break). Previous research has shown that the type of wave influences the choice of manoeuvres and thus may also affect the associated wave scores (Lundgren et al., 2014). In the included 19 events all three wave types were represented (beach $n = 8$; reef $n = 6$; point $n = 5$).

2.6. Data analysis

In surfing, many external influences of the environment (e.g., type of wave, weather conditions during the event) affect performance substantially (Mendez-Villanueva et al., 2010). Therefore, any statistical analysis that investigates the relationship between psychological pressure and performance needs to acknowledge these contextual factors. As the venue may make the wave scores of individual surfers more similar to each other, it violates the assumption of independence. We therefore choose to use a multilevel analysis, which allows us to investigate the relationships between two or more predictors and an outcome measure (Patterson et al., 2005), while addressing the issue of violating the assumption of independence.

In this study, the individual events of the 2019 WSL season were nested within the individual surfers. The multi-level model was used to analyse the effect that pressure, previous errors and other contextual factors have on the wave scores of individual surfers. The multilevel analyses followed two steps: (1) modelling the two-levels (i.e., events nested within surfers), in the outcome variable (i.e., wave score), and (2) predicting the variability in the outcome measure with multiple contextual predictors (i.e., gender, previous error, pressure, ranking of the surfer, wave type, possession of priority, rounds, as well as the interactions between previous errors with gender, previous errors with surfer ranking and pressure with surfer ranking).

The statistical steps of data entry, screening and cleaning, as well as assumptions testing, and descriptive statistics were performed using IBM® SPSS Statistics for Windows, version 26.0 (IBM Corp., Armonk, NY). The multilevel analyses were run in MLwiN 3.00 (Charlton et al., 2017). The level of significance was set at $p < 5\%$ for all analyses.

3. Results

3.1. Performance after errors and under pressure

Descriptive data show that in general the absolute number of observed performance errors is small, with only 701 of 6497 annotated actions being rated as one. Performance errors that followed directly after a prior error were observed even less frequently, making up as little as 1.8% of all annotated actions. In general, surfers indeed score lower on waves that follow after a performance error (see Table 2 for detailed descriptive of wave scores per group). Their score also decreases as pressure increases, however, that observation is only made when the surfer is not in possession of the priority right. Consequently, the multilevel model (see Table 3) shows that having made a performance error on the previous wave ride is a significant predictor of a decrease in subsequent performance, while pressure is not. Additionally, all five contextual factors were found to be significant predictors of wave scores (see Table 3). For one, having priority significantly influences the wave score, with surfers achieving higher scores when having the opportunity to choose any wave over their competitor. In the same manner, the type of wave is also a significant predictor of wave scores, with higher scores being awarded at *point break* waves (i.e., *point break* > *reef break* > *beach break*). Additionally, the regression coefficients were significant for gender, with females achieving higher wave scores than males, as well as for the competitive round, where surfers scored higher in the later rounds (i.e., quarterfinals, semi-finals and finals), compared to earlier rounds. Lastly, and most crucially, the cross-level interactions between previous errors and pressure, previous errors and wave type, as well as for previous error and gender were not statistically significant (see Table 3).

3.2. Skill-related differences

Across all levels of situational pressure and prior performance errors, higher-ranked surfers outscore those with a lower end-of

Table 2. Descriptive data of wave scores in the WSL men's and women's 2019 season, presented as mean scores ± SD.

	Top 25%			Bottom 75%		
	Women ($n = 7$)	Men ($n = 13$)	Total ($n = 20$)	Women ($n = 21$)	Men ($n = 39$)	Total ($n = 60$)
Wave Score (with priority)						
High Pressure	3.61 ± 2.87	3.69 ± 2.91	**3.67 ± 2.89**	3.24 ± 2.28	3.21 ± 2.56	**3.22 ± 2.48**
Medium Pressure	3.62 ± 2.57	3.58 ± 2.71	**3.59 ± 2.66**	2.74 ± 2.29	3.04 ± 2.42	**2.96 ± 2.39**
Low Pressure	4.01 ± 2.61	3.68 ± 2.86	**3.79 ± 2.78**	3.11 ± 2.24	3.13 ± 2.45	**3.12 ± 2.40**
Wave Score (no priority)						
High Pressure	2.18 ± 2.26	2.39 ± 2.56	**2.35 ± 2.50**	1.86 ± 1.97	2.09 ± 2.08	**2.05 ± 2.06**
Medium Pressure	3.59 ± 2.45	2.60 ± 2.51	**2.85 ± 2.53**	2.46 ± 2.04	2.20 ± 2.07	**2.25 ± 2.07**
Low Pressure	3.44 ± 2.50	2.75 ± 2.55	**2.93 ± 2.55**	2.60 ± 2.21	2.68 ± 2.32	**2.66 ± 2.29**
Wave Score (regardless of priority)						
High Pressure	3.23 ± 2.79	3.17 ± 2.85	**3.19 ± 2.83**	2.86 ± 2.28	2.80 ± 2.42	**2.81 ± 2.41**
Medium Pressure	3.61 ± 2.54	3.24 ± 2.68	**3.36 ± 2.64**	2.67 ± 2.23	2.78 ± 2.35	**2.75 ± 2.32**
Low Pressure	3.71 ± 2.56	3.13 ± 2.72	**3.30 ± 2.69**	2.81 ± 2.23	2.87 ± 2.39	**2.86 ± 2.35**
Wave score						
Error as prior action	3.08 ± 2.63	2.50 ± 2.47	**2.68 ± 2.53**	2.62 ± 2.21	2.45 ± 2.34	**2.50 ± 2.30**
Non-error as prior action	3.63 ± 2.59	3.22 ± 2.74	**3.35 ± 2.70**	2.80 ± 2.25	2.86 ± 2.40	**2.84 ± 2.37**

Table 3. Multi-level model predicting the surf score.

Model Surf score (0 - . . .)	Predictor	Coëfficient	SE	P	Log Likelihood (χ^2)
	Intercept	2.622	0.076		30470.532
	Gender[a]	− 0.170	0.071	.004	30462.375
	Pressure	-	-	.300	30459.966
	Previous error[b]	− 0.451	0.109	<.001	30445.978
	Surferrank[c]	0.488	0.064	<.001	30390.124
	Wavetype[d]	-	-		30248.834
	Reef break	0.635	0.073	<.001	
	Point break	0.890	0.083	<.001	
	Round[e]	0.196	0.075	.009	30242.068
	First priority[f]	0.707	0.063	<.001	30118.465
	Previous error x gender	-	-	.518	30118.047
	Previous error x surferrank	-	-	.273	30117.261
	Previous error x pressure	-	-	.632	30117.547
	Previous error x wave type	-	-	.492	30117.044
	Pressure x surferrank	-	-	.176	30114.985
	Level 1 constant (between surfers) Level 2 constant (within surfers)				

Note. Superscript Letters a–f indicate in which order the predictor variables were added to the model.

-season ranking (see Table 2). In the multilevel analysis, the season rank of a surfer has a significant influence on surfing performance, with athletes that belong to HR outscoring LR on average by 0.584 points. However, the cross-level interactions between previous error and surfer ranking, and pressure and surfer ranking were not statistically significant (see Table 3).

4. Discussion

4.1. General discussion of results

Using play-by-play data from the highest competitive level of surfing, this study aimed to investigate the influence of situational pressure and previous performance errors on performance under the consideration of various contextual factors. Additionally, we aimed to explore potential performance differences between differently skilled athletes.

4.1.1. Performance after errors

In line with existing research (Harris et al., 2019, 2021) and partly with predictions of the ACTS (Eysenck & Wilson, 2016), performance errors in elite surfing competitions cause a significant decrease in performance (i.e., lower scores) on the athlete's subsequent wave. This suggests that, as in other sports, performance in competitive surfing is also affected by negative feedback (i.e., previous performance errors) within athletes, which may lead them to perceive an increase in the probability of failure.

Previous studies argued that the time that is spent between actions may influence the relationship between prior errors and subsequent performance (Harris et al., 2021). Accordingly, the more time athletes have between actions, the more likely it might be that they recover post-error. This is because with more time they might be able to successfully interrupt the performance feedback cycle, allowing them to be more focused on the task at hand. In surfing, the wave type often influences the amount of time that surfers have in between waves. For example, previous research (Farley et al., 2017; Mendez-Villanueva et al., 2006) as well as our dataset suggest that surfers spend more time between actions at point breaks than, for example, at beach breaks. That is because compared to other wave types, the so-called take-off zone, where a surfer commonly starts riding a wave, is a lot more concentrated at point breaks. Additionally, a point break wave generally breaks over a much greater distance, thereby allowing longer wave rides. Both factors lead to longer continuous bouts of paddling after a wave ride, to get back to the take-off zone. In theory, this increases the time between actions (i.e., wave rides) and, therefore, may positively affect the post-error recovery. Based on descriptive statistics of the present study, point breaks do indeed show the smallest decrease in scores from waves that followed a successful wave ride compared to those that followed a performance error (i.e., drop of scores at point break: −5%; at reef break: −14%; at beach break: −18%). However, the interaction between wave type and previous errors turned out to be non-significant, which indicates that the wave type does not have a strong impact on how athletes respond to prior performance failures. It might be that the existing time differences between the different wave types are not long enough to elicit such an effect.

4.1.2 Performance under situational pressure

Contrary to previous research (Harris et al., 2021), increasing levels of situational pressure did not significantly affect the performance of international elite surfers. While the non-significant effect of pressure is surprising, it might be explained in that competitive surfing already shows a larger performance variability than other sports due to the varied external influences (Mendez-Villanueva et al., 2010). Higher variability does not only make uncertainty a more regular occurrence for surfers, but it also allows them to attribute their competitive situation more easily to the unpredictable and most importantly external conditions. Doing so might help athletes to preserve their confidence throughout the ups and downs of a heat without believing that their subsequent wave-ride is influenced by the cost of a potential failure (i.e., situational pressure). Research has indicated that having an optimistic explanatory style, where athletes attribute performance failures to unpredictable and external influences, indeed leads to improved psychological resilience (Sarkar & Fletcher, 2014). Similarly, due to consistent exposure to an ever-changing and uncontrollable competitive environment, elite surfers may have also developed elaborate self-regulatory resources, which could decrease the effect that pressure and anxiety have on performance (Englert & Bertrams, 2015).

4.1.3. Skill-related differences

When exploring potential skill-related differences, we found that across the 2019 season HR did perform significantly better than LR in terms of wave scores. However, the non-significant interaction effects with pressure levels and previous errors indicate that HR are not affected by these two factors any differently than LR. Our interpretation also corresponds to the results of Harris et al. (Harris et al., 2021), who found that subsequent winners of a tennis match did not significantly differ from match losers in their response to pressure and previous performance errors. The authors argued that "individuals commonly thought to be 'clutch' players – Michael Jordan, Tom Brady, Wayne Gretsky – might well perform at important moments simply because of their general superiority, not because they are immune to the effects of pressure" (Harris et al., 2021, p.7). While the research by Harris et al. (Harris et al., 2021) was limited in the way that better tennis players were defined (i.e., based on the outcome of individual matches rather than based on season-ranking), the results of our study add further weight to this hypothesis.

4.1.4 Applicability of ACTS in surfing

Overall, the results of this study may question the applicability of the ACTS in outdoor sports such as surfing, where performance is greatly influenced by diverse environmental factors. This statement is also supported by the fact that the model only explains 5.6% of the variance in surf performance (i.e., wave scores). Yet, it may still be that the ACTS also holds true in surfing, but that a decrease in surf performance is less obvious and may need to be defined differently than just through the score of a wave. Due to the various influences of the environment in surfing, it is harder to determine when a decrease in performance was truly caused by the behaviour, movements or choices of an athlete. Drawing such a conclusion seems easier in a repetitive and rarely changing task, such as free-throws in basketball (Zheng Cao & Stone, 2011) or a putt in golf (Hickman & Metz, 2015). Hence, future research may develop more precise outcome measures such as an expected wave score based on the potential and build-up of the wave. They may also focus on performance under pressure in a competitive environment where surf conditions are more consistent (i.e., artificial wave pools). In such a controlled setting, environmental and tactical influences would be almost eliminated from the equation, allowing a more detailed analysis of the impact that previous errors and psychological pressure have on the performance of surfers.

4.2. Practical implications

Our findings confirm that surf performance is to some degree negatively affected by negative performance feedback, regardless of skill-level. Hence, some of the practical implications that can be derived from this study include the recommendation that practitioners should work with strategies that help athletes to interpret and react to competitive failures in a more helpful way (Wilson et al., 2019). Research has suggested that interventions which reduce interpretative bias about situational pressure and prior errors can improve athletic performance (Wood et al., 2018). In a similar way, mindfulness training might also be useful in reducing state anxiety and promoting flow experiences in athletes (Noetel et al., 2019; Ong & Chua, 2021; Scott-Hamilton et al., 2016). Rather than attempting to alter the internal experience of pressure-induced emotions, mindfulness can help athletes to accept these internal states with present-moment awareness, which in turn may lead to more automaticity in skill executions and less attention to threat-related cues (Birrer et al., 2012; Gardner & Moore, 2012; Noetel et al., 2019). Lastly, interventions which aim to improve attentional control and thereby reduce the detrimental effects that anxiety has on sporting performance have also been shown to be beneficial for competitive athletes (Ducrocq et al., 2017; Vine et al., 2014).

4.3. Limitations

The results should also be considered with a few limitations in mind. First, compared to other studies in this field (Harris et al., 2021; Hsu et al., 2019; Zheng Cao & Stone, 2011), our data sample was relatively small with a total of 6497 observations. However, given that there is no previous research concerning this aspect of surfing and the time-consuming creation of play-by-play data in this sport, an exploratory approach seems justified. Furthermore, as this was a purely observational study that relied on third-party video recordings, the influence of all environmental conditions was not fully accounted for in the analysis. This consideration seems important, as a surfer may perceive the consequences of a performance error differently in a heat where the frequency of scoring opportunities (i.e., quality waves) is high, compared to when it is low. In the same manner, this study did not determine the athlete's actual experience of pressure but merely assumes that pressure and subsequently anxiety were perceived based on situational factors (i.e., time and score). Lastly, the reliability of our investigation into whether there are inter-individual differences between how surfers perform under pressure might have been decreased by grouping all athletes into one of the only two groups.

5. Conclusion

The results of our study partially confirm previous research (Harris et al., 2021) and the assumptions of the ACTS (Eysenck & Wilson, 2016) in that performance errors caused a significant breakdown in subsequent performance in elite surfing athletes. However, the present study did not find a significant effect of situational pressure on surfing performance, nor inter-individual differences in how surfers of different performance levels responded to negative performance feedback and situational pressure. Our study highlights that compared to other sports, performance in surfing is influenced by a multitude of factors, which may weaken or at the very least blur the effect that psychological pressure has on competitive performance. Future research may want to further investigate the predictions of ACTS in surfing, under more controlled conditions (i.e., lower influence of environmental conditions). Yet, since our study shows that surfing athletes are potentially negatively affected by the perceived probability of failure (i.e., prior performance errors), practitioners should aim to develop strategies with athletes that break the negative performance feedback loops.

Highlights

- Performance errors have a negative effect on subsequent performance in elite surfing.
- High levels of situational pressure do not significantly impact scores in elite surfing competitions.
- High- and low-ranking elite athletes show similar patterns in how they respond to the investigated psychological pressure factors.

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Data availability statement

The data that support the findings of this study are openly available in figshare at https://doi.org/10.6084/m9.figshare.21899019.v1 (Klingner, 2023).

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