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# False-performance feedback does not affect punching forces and pacing of elite boxers

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**ABSTRACT**
Prior research indicates that providing participants with positive augmented feedback tends to enhance motor learning and performance, whereas the opposite occurs with negative feedback. However, the majority of studies were conducted with untrained participants performing unfamiliar motor tasks and so it remains unclear if elite athletes completing familiar tasks respond in a similar fashion. Thus, this study investigated the effects of three different versions of false-performance feedback on punching force (N), pacing (force over time) and ratings of perceived exertion (RPE) in 15 elite amateur male boxers. Athletes completed a simulated boxing bout consisting of three rounds with 84 maximal effort punches delivered to a punching integrator on four separate days. Day one was a familiarisation session in which no feedback was provided. In the following three days athletes randomly received false-positive, false-negative and false-neutral feedback on their punching performance between each round. No statistical or meaningful differences were observed in punching forces, pacing or RPE between conditions ($P > 0.05$; ≤ 2%). These null results could stem from the elite status of the athletes involved, the focus on performance rather than learning, or they may indicate that false feedback has a less potent effect on performance than previously thought.

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**KEYWORDS**
Verbal instructions; coaching cues; boxing; punching forces; combat sport

## Introduction

Amateur boxing is an Olympic sport in which athletes attempt to score points, or knock their opponents down/out, using punches delivered in a tactical and strategic manner (Chaabène et al., 2015). Depending on gender, amateur boxing bouts consist of 3–4 rounds lasting 2–3 min with 1 min of rest between rounds (Chaabène et al., 2015). Amateur boxing has specific physiologic demands, including the ability to strike hard, fast and repeatedly (Ashker, 2011; Chaabène et al., 2015; Smith, 2006; Smith, Dyson, Hale, & Janaway, 2000). For example, Smith et al. (2000) found that elite boxers punch with more force compared to non-elite and novice boxers. Likewise, the average punching forces measured during professional boxing bouts was higher among winners, compared with losers (Pierce, Reinbold, Lyngard, Goldman, & Pastore, 2006). Such findings indicate that enhancing punching performance is of significant importance to boxers, which is commonly achieved by technical training (Blower, 2012) and strength and conditioning sessions (Lenetsky, Harris, & Brughelli, 2013).

Various practise conditions can also be manipulated to enhance punching performance. The Optimizing Motor Learning through Intrinsic Motivation and Attention for Learning (OPTIMAL) theory highlights three practise conditions that are essential for effective learning and performance (Wulf & Lewthwaite, 2016). These variables include A) an external focus of attention on the intended movement effect, B) conditions that support performers' need for autonomy, and C) enhanced expectancies for future performance. In two recent studies by our group, it was observed that utilising the first two practise conditions of the OPTIMAL theory enhances athletes punching performances. Halperin, Chapman, Martin, and Abbiss (2016a) investigated the effects of providing external, internal and neutral focused verbal instructions on punching performance. External instructions resulted in harder (2–4%) and faster (3–5%) punches, compared with the two other conditions. Halperin, Chapman, Martin, Lewthwaite, and Wulf (2017) compared the effects of providing athletes with a choice concerning the order of the delivered punches to a no choice condition in which punches were delivered in pre-determined order. Athletes punched harder (~3%) and faster (~6%) when freely choosing the order of delivered punches. To date, it remains unclear if the final practise condition of the OPTIMAL theory – enhanced expectancies of future performance – will lead to a similar positive effect on punching performance as the other two conditions.

Manipulating expectancies of future performance in either a negative or positive manner has been shown to influence both motor learning and performance in most, but not all studies. Two common ways in which expectancies for future performance have been manipulated are through the provision of positive feedback after so called "good trials", and through the provision of false comparative feedback suggesting the participant is performing better or worse than expected. On the one hand, providing participants with positive performance feedback enhanced balance (Lewthwaite & Wulf, 2010), throwing

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accuracy (Chiviacowsky & Wulf, 2007), and allowed participants to endure longer durations in a continuous submaximal force production task (Hutchinson, Sherman, Martinovic, & Tenenbaum, 2008) in comparison to negative and/or control feedback. Positive feedback also improved running economy of trained runners, compared with a control group who received no performance feedback (Stoate, Wulf, & Lewthwaite, 2012). Alternatively, studies investigating the effects of providing false feedback concerning the distance covered during running and cycling tasks (e.g., 5% slower or 5% faster) on time-trial performance and pacing (i.e., the distribution of energy expenditure throughout the task) did not observe effects on performance (Faulkner, Arnold, & Eston, 2011; Wilson, Lane, Beedie, & Farooq, 2012). Furthermore, a recent study reported no effects of positive, negative and control feedback on balance performance and learning (Ong & Hodges, 2017). The discrepancy in the literature could stem from a number of reasons such as the precise type of feedback provided, the outcome measures, and the experience that participants had with the motor task.

The effects of manipulating expectancies of future performance through positive and negative feedback have not been investigated in relation to punching performance, despite that such feedback is frequently given by boxing coaches (Halperin, Chapman, Martin, Abbiss, & Wulf, 2016b). Halperin et al., (2016b) reported that coaches in both winning and losing boxing bouts delivered a comparable amount of negative feedback (13.7% vs. 12.5%), but coaches of winning bouts provided double the amount of positive feedback (36% vs. 18.6%). It is not possible to draw any causal conclusions since positive feedback could have enhanced the boxer's performance and led them to victory, or alternatively, the boxers' successful performance led the coaches to provide the athletes with more positive feedback. Accordingly, the purpose of this study was to examine how the final practise condition of the OPTIMAL theory – performance exceptions – would influence punching performance. This was achieved by experimentally manipulating three sets of feedback (positive, negative and neutral) and examine their effects on punching impact forces (N), punch pacing (forces over time), and ratings of perceived exertion among elite level amateur boxers, using a specific punching protocol.

## Methods

### *Participants*

Fifteen elite male amateur boxers (age: 21 ± 4 y [range:17–29 y]; body mass: 71 ± 11 kg, [57–96 kg]; number of bouts 50 ± 21, [30–100]) volunteered to participate in this study. All athletes regularly competed at a national level and had participated in at least one international level event. They were considered by the national boxing coaches as the best amateur boxers in Australia. Athletes were provided with a verbal description of the study, which was carefully presented so as to not compromise the study design (description below), after which each athlete provided written informed consent. The study was approved by the relevant University Ethics committees and was conducted in accordance with the Declaration of Helsinki.

### *Procedure*

Athletes were asked to attend the laboratory on five separate occasions. On the first day they were provided with an inaccurate explanation about the purpose of the study. That is, they were instructed that the goal was to test a new punching protocol over four testing days, examine their performance in each testing day, and compared the results of each day to the first, baseline testing day. Thereafter, an overview of the protocol was provided, followed by a short practise session of the protocol on a punching bag (described below). Finally, an explanation of the Borg rating of perceived exertion (RPE) scale was provided (Borg, 1982). Athletes were asked to report their RPE for each round. During the second session the athletes performed a familiarisation session during which they were asked to punch the punching integrator (Figure 1) as fast and as forcefully as possibly. Over the next three testing days, all participants performed the same punching protocol during which they either received false-positive, false-negative and false-neutral feedback between rounds in a blocked-randomised fashion on separate days.

Prior to completing the punching protocol, athletes performed a warm up consisting of a series of 3 min activities completed in the following order: jumping rope, self-selected dynamic stretching, shadow boxing and punching the bag. Before beginning the protocol, athletes punched the punching integrator with increasing


Figure 1. The punching integrator device. The subject in this figure signed a consent form agreeing for it to be published in this article.

intensity for 30 s. The punching protocol consisted of three rounds lasting 2 min, with a 1 min break between rounds. During each round participants were required to deliver 84 maximal effort punches in a set order. Every 5 s a loud beep sound was given indicating that the athletes were required to deliver a specific combination within a 5 sec period. Specifically, participants were instructed to deliver four straight punches (alternating between a lead straight and rear straight) were delivered within the first beep, three lead hooks within the second beep, and three rear hooks within the third beep. This sequence was repeated continuously for 2 min, resulting in 84 punches. Apart from the familiarisation day, the athletes received false performance feedback on their performance and were then asked to report their RPE at the completion of each round (2–5 s after the last punch combination).

The false feedback consisted of a performance statement about the round, followed by a percent decrement or improvement relative to the baseline/familiarisation day (described below). To reduce the possibility of the athletes developing suspicions of the true purpose of the study, the percent differences provided to the athletes ranged between 6–9% and were randomised between rounds and between conditions. That is, a given round could have been 6%, 7%, 8%, or 9% lower or higher compared to the baseline round. Further, to avoid possible confounders, the average score between the positive and negative rounds was the same. For example, if in the positive feedback condition a participant was told that, compared with his baseline round, his performance was 6%, 8% and 9% greater in round 1, 2 and 3 respectively. Likewise, in the negative feedback day he was told that compared to his baseline round, his performance were lower by 7%, 7% and 9% in round 1, 2 and 3 respectively. Thus, the average score was similar (8%) between conditions. The 6–9% range was chosen based on consultation with a number of coaches and based on similar values that have been previously used in the literature (Hutchinson et al., 2008). We considered this range to be large enough to have an effect on the athletes, but not too large to elicit suspicion.

The feedback on the positive day was "Good round, your performance is 6–9% higher compared to your baseline round", on the negative day it was "This is not a very good round, your performance is 6–9% lower compared to your baseline round", and in the neutral day it was "Your performance in this round is the same as your baseline round". Note, however, that performance and pacing measures were calculated differently to what the athletes were told for the sake of deception. Apart from the single feedback statement provided by the same investigator (IH) in a noise sensitive room, no other encouragement, verbal or visual feedback was provided and a similar tone of delivery was used in all occasions. All subjects wore the same 16 ounces boxing gloves (Sting, Australia) during testing and their own hand wraps. Athletes were asked to avoid a large meal 2 h prior to testing, any strenuous exercise on the day of testing, and were tested on the same time on all days.

### *Punching forces*

All punches were delivered to a custom built punching integrator (Figure 1), which is mounted vertically and composed of a S-beam load cell with an integrated amplifier (AST brand) bolted to a metal plate which is covered with a large foam pad wrapped by leather envelope. The load cell voltage signal is collected by Data Translation 12bit USB data acquisition module using QuickDAQ software (Australia) sampling at 2000 Hz and converted to units of force (N). The conversion factor was determined by placing a range of known weights on the load cell. The punching integrator instrument reliability (coefficient of variation) has previously been determined as less than 1% for impact forces, using a protocol of dropping a rigid pendulum of known weight, and known height, on to the impact surface, on numerous occasions over several months. The high instrument reliability was maintained irrespective of the number of pendulum drops (impacts), time interval between drops, and days between tests.

### *Statistical analysis*

To improve the consistency of the pacing analysis (i.e., distribution of force over time) across rounds and between trials a similar approach was adapted as that commonly reported within the pacing literature (Abbiss & Laursen, 2008). This approach partitions longitudinal performance into analysis bins and then compares these bins for changes over time. Therefore our approach was to average impact forces of 14 punches delivered every 20 s (four alternating straights, three lead hooks and three rear hooks) and treat this combination as a data bin. Hence, each round consisted of six bins and each condition consisted of three rounds. Initially, to examine if punching performance was consistent prior to the study's manipulation being applied a two way Analysis of Variance (ANOVA) with repeated measures (conditions [4: familiarisation, control, positive and negative] x bins [6]) was conducted to compare differences between performance in only the first round across the four conditions. Second, a three way ANOVA with repeated measures (conditions [3: control, positive and negative] x rounds [3] x bins [6]) was used to compare the intervention effects on punching performance and pacing. Third, to fully explore how the feedback statements affected performance, absolute differences between round two and one, and between round three and one, were calculated per each bin for each participant and compared using a three way ANOVA with repeated measures (conditions [3] x round differences [2] x bins [6]). Finally, a two way ANOVA with repeated measures (conditions [3] x rounds [3]) was conducted to examine if differences in RPE occurred between conditions and rounds. If the assumption of Sphericity was violated, the Greenhouse–Geisser correction was performed. A Bonferroni post-hoc test was used if a main effect was identified, and paired *t*-tests with Holms-Bonferroni corrections were used if an interaction was found. Significance was accepted as $P < 0.05$. Furthermore, absolute values and differences, as well as Cohen *d* effect sizes (ES) are reported when appropriate. The magnitudes of these ES were classified as trivial (0–0.19), small (0.20–0.49), medium (0.50–0.79) and large (0.80 and greater) using the scale advocated by Cohen (1992).

## Results

After data collection was completed, athletes were informed about the true purpose of the investigation, with no athlete admitting to being suspicious of the intent.

### *First round*

Small and statistically insignificant effects were observed in punching forces over the six bins of the first round between the four conditions (familiarisation, control, positive and negative) ($p \geq 0.272$; ES≤ 0.23) (Figure 2).

### *All rounds across the three experimental conditions*

Trivial and statistically insignificant interactions were observed in punching forces between the three experimental conditions, rounds, and bins ($p \geq 0.135$). Trivial and statistically insignificant main effects were observed between the three experimental conditions ($F_{(2,26)} = 1.3$, $p = 0.286$), ES≤ 0.11) when averaging the forces across the three rounds for each condition [Positive: 2129 ± 305 N; Negative: 2093 ± 281 N; Neutral: 2120 ± 290 N (Figure 2)]. A statistically significant main effect was observed for rounds ($F_{(2,26)} = 4.4$, $p = 0.022$), however, post hoc testing revealed insignificant statistical differences and trivial-small effect sizes between rounds 1, 2 or 3 across the three experimental conditions (2081 ± 273 N, 2119 ± 290 N, 2141 ± 326 N, respectively; $p \geq 0.071$, ES≤0.19).

### *Differences in forces between round 2 and 1 and 3 and 1*

Trivial and statistically insignificant interactions or main effects ($p \geq 0.131$; ES≤ 0.12) were observed in absolute differences between round 2 and 1, and between round 3 and 1, when compared across the three conditions and the six bins (Figure 3).

### *RPE*

A trivial and statistically insignificant interaction was observed between conditions and rounds in RPE ($F_{(4,56)} = 0.7$, $p = 0.600$; ES≤ 0.18), and a trivial and statistically insignificant main effect for conditions ($F_{(2,28)} = 3.2$, $p = 0.055$; ES≤ 0.18) (Figure 4). However, a large and significant main effect was observed for RPE across rounds ($F_{(2,28)} = 69$, $p < 0.001$; ES≥ 1.0) with RPE increasing with each round (round 1: 13.8 ± 1.4; round 2: 15.6 ± 1.4; round 3: 17.0 ± 1.4).

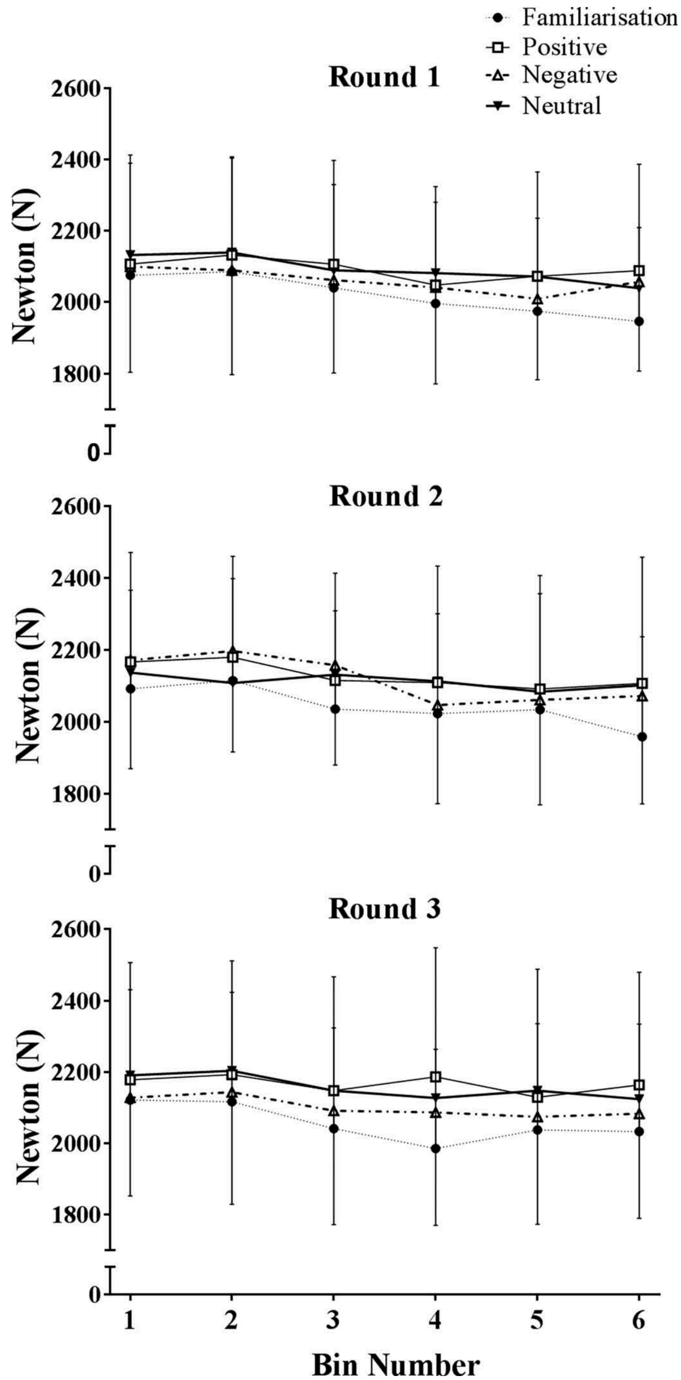


Figure 2. Punching forces in each round. The mean (SD) forces in the four conditions delivered over each round and distributed in six bins.

## Discussion

The purpose of this research was to investigate how the key practise condition proposed by the OPTIMAL theory – expectancies of future performance – will influence punching forces, pacing, and RPE in elite male amateur boxers by providing athletes with false positive, negative and neutral performance feedback. No statistical or meaningful differences were observed in punching forces and RPE between conditions with punching forces remaining relatively constant throughout a given round, between rounds, and conditions. These observations indicate that elite level boxers are not susceptible to positive and negative feedback, at least when measured with activities that require maximal efforts over time. These results suggest that perceptions of success and failure elicited by false augmented feedback may have less of an effect on performance than has been reported previously (Wulf & Lewthwaite, 2016). The lack of differences in the force data from the bins between each of the conditions demonstrate that the athletes were able to adopt an "even" pacing strategy irrespective of the feedback being provided (Abbiss & Laursen, 2008). This would suggest

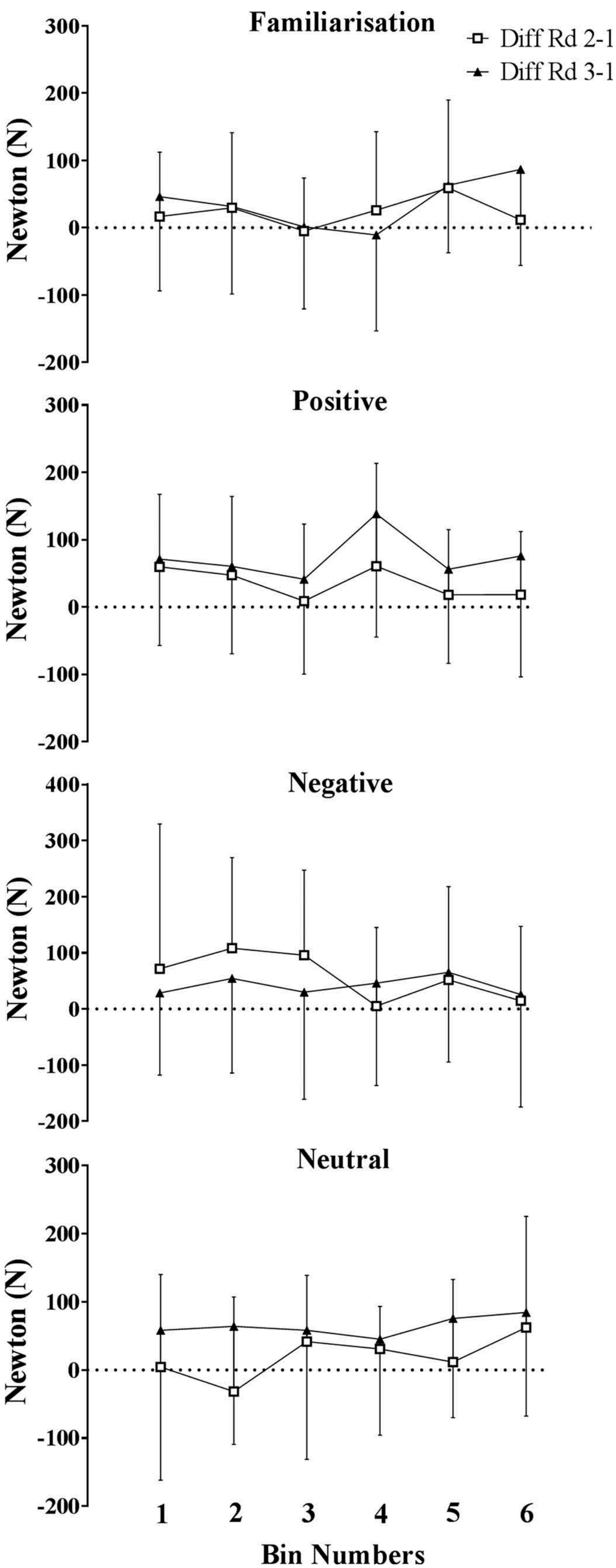


Figure 3. Between rounds punching forces. The mean (SD) differences between round two and one, and round three and one, across the four conditions in six bins.

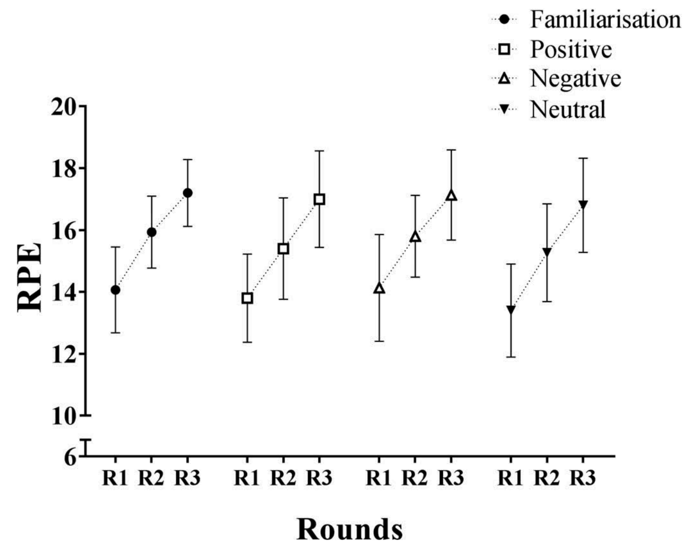


Figure 4. Rating of perceived exertion. The mean (SD) RPE scores in the four conditions across the three rounds.

that they did not fatigue to any greater or lesser extent or alter their pace in any of the conditions. As RPE increased across rounds the participants did perceive a greater level of exertion between rounds however this did not correspond with a reduction in the force measures.

The lack of performance and perceptual differences between positive, neutral and negative feedback observed in this study are in agreement with the findings of some (Faulkner et al., 2011; Ong & Hodges, 2017; Wilson et al., 2012), but not all investigations (Chiviacowsky & Wulf, 2007; Lewthwaite & Wulf, 2010; McKay, Lewthwaite, & Wulf, 2012). Specifically, most studies within motor learning typically demonstrate that positive feedback leads to superior learning, compared with negative feedback and/or a control condition (Chiviacowsky & Wulf, 2007; Lewthwaite & Wulf, 2010; McKay et al., 2012). The different results observed in the present study and those within previous studies emphasising motor learning may be explained in a number of ways. In motor learning studies, participants commonly complete a novel task in which they have little or no experience with. In contrast, the current study used a cohort of athletes completing a complex task they have vast experience with. Participants completing a task they are familiar with may be less susceptible to influence by specific types of feedback, such as positive and negative.

The main outcome measure in the present study was maximal punching forces, which could have reached a plateau through regular training. In contrast, common outcome measures in motor learning studies include task accuracy (i.e., golf putting) and balance (i.e., reducing centre of gravity sway), which could be affected more easily. Noting however, that a recent study by Ong and Hodges (2017) examined the effects of performance feedback on motor learning and performance of a balance task and did not observe any effects. This suggests that other factors are involved in mediating the effects other than the outcome measure. Motor learning studies commonly examine learning by utilising delayed retention and transfer tests, whereas in the present study only immediate performance was measured. In a larger number of studies, the experimental interventions did not influence immediate performance, but various effects were identified in the delayed retention and transfer tests (Chiviacowsky & Wulf, 2007; Kantak & Winstein, 2012). Hence, it is possible that effects were not present in the current study only because immediate performance was measured.

It is also plausible that the lack of statistical and practical effects observed in the present study is because the performance of athletes is less affected by positive and negative feedback, compared with non-athletes. Most studies which have not found an effect for positive and negative performance feedback examined moderately to highly trained athletes (Faulkner et al., 2011; Wilson et al., 2012). Supporting this, athletes have greater levels of mental toughness compared to non-athletes (Guillén & Laborde, 2014), and demonstrate superior inhibitory control and mental fatigue resistance compared to recreational athletes (Martin et al., 2016). The study of psychological resilience, which seeks to understand why some individuals are able to respond in a positive manner to setbacks, obstacles and failures (Galli & Gonzalez, 2015), offers possible insights in explaining the results of the current study. Elite athletes report encountering a wide range of sport and non-sport related stressors and failures which they believe were essential for their success (Sarkar et al., 2015). The ability to stay focused and maintain high levels of motivation, have been proposed to protect elite level athletes against the various sport and non-sport related stressors and failures (Fletcher & Sarkar, 2012). The athletes in this study may have developed the ability to block out negative stressors, such as the negative feedback, and may have followed our request to punch as hard as they possibly could with every punch leaving little possibility for improvement with the positive feedback. To conclude, the lack of statistical and practical effects observed in this study could stem from the possibility that perceptions of success and failure caused by false feedback have a smaller and/or variable effect on performance (and perhaps learning, see Ong & Hodges, 2017) than previously reported, as effects may vary within and between individuals and be modified by interactions between parameters under various conditions.

There are number of limitations in this study worthy of discussion. Since this is the first study to investigate pacing during a punching protocol, it was decided to tightly control several variables. Within this study we controlled for the timing and type of delivered punching combination. As such, we decided to measure pacing through the fluctuations of punching forces within and between rounds. Given the importance of punching force within combat sports we believe that this methodology was appropriate. Understandably, individuals have greater freedom of choice as to when to punch during competition. However, within this study participants were still able to self-regulate force and thus total energy expended within and between rounds. While this methodology may reduce external validity of the study (i.e., the extent to which the results of a study can be generalized to other situations), it nevertheless increases the degree of internal validity (i.e., the degree of confidence we can place in the results). Accordingly, future studies could also investigate how feedback influences punching performance and pacing when the timing and type of punches are freely chosen.

In this study we examined the global pacing profile during a punching task in which a combination of four different punches were averaged into bins and compared within and between rounds and days. Conducting a secondary analysis of individual punch type would have provided greater insight regarding the results as each of the four punches is associated with varying degrees of force (see Figure 5 for an illustration of all punches delivered during each day and round of a single participant). This analysis was unfortunately impossible to conduct because the structure of the output files produced by the measuring apparatus would have required all participants to complete the entire protocol without a single error in the punch order. While there were minimal errors present it is important to note that some participants performed some combinations in a slightly different order than instructed. This would have minimal influence on average force produced in each bin but makes determination of punch force for each individual punch type not possible from the present data. Future research on pacing in boxing should also examine pacing within each punch type rather than just combinations as done in the present study. The sample size of this study was relatively small ($n = 15$), which increases the possibility of a type 2 error. However, the participants within the current study were a homogenous group of highly elite competitive athletes. Given this sample size, we controlled for as many confounding variables as possible (Halperin, Aboodarda, Basset, Byrne, & Behm, 2018), included a familiarisation session, and collected a relatively large sample of data points to confirm consistency of the results. While direct and conceptual replication studies are needed to verify if the results of this study are consistent, the present study is important as it contributes and expands upon the growing literature on the topic and will allow for balanced future meta-analysis.

Whereas running and cycling activities have been thoroughly investigated in relation to pacing (Faulkner et al., 2011; Wilson et al., 2012), boxing offers a challenging new avenue to investigate pacing as it greatly differs from running and cycling activities. Mainly, boxing is an open skill sport, in which the environment is less stable and predictable compared to the more closed skill sports of cycling and running. While more difficult to examine, open skill sport such as boxing may expand our understanding of pacing in unstable and unpredictable environments and situations. To the best of our knowledge this is the first study to investigate the effects of feedback on pacing in a boxing task among elite level competitive boxers. While conducted in a relativity controlled environment, we hope that the results will lead to future, more complex study designs shedding further light on pacing in open skill sport in general, and boxing in particular, in environments which mimic actual competitions to a greater extent.

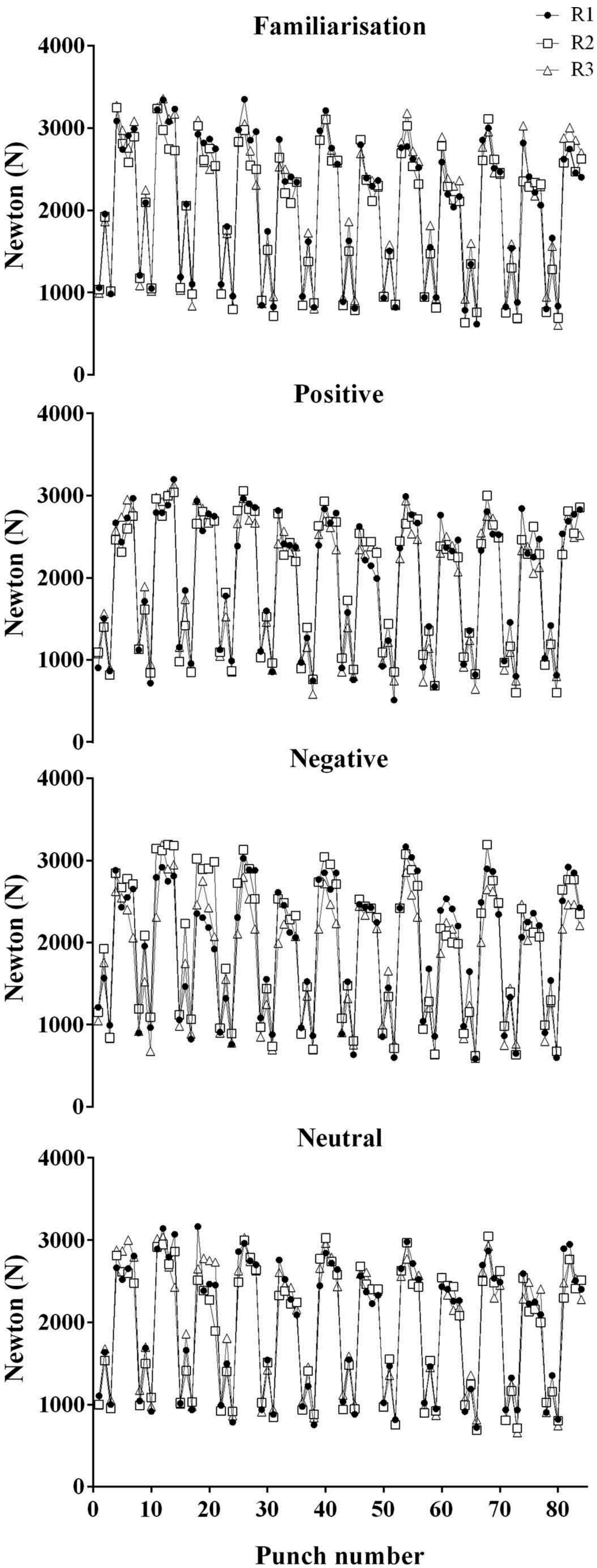


Figure 5. Individual punches. Data set of all delivered punches across rounds and days of a single participant. Each sign (square, circle and triangle) represents a single punch delivered in one round.

## Conclusion

The results of this study suggest that elite athletes completing a familiar motor task, in which they have attained a high degree of mastery, are not effected by negative and positive performance feedback during repeated bouts of maximal efforts of the investigated task. However, it is unclear how such feedback would influence athletes completing tasks which they are less familiar with, or those that require different physical and/or cognitive qualities. For example, the pace of learning and implementing a new technical and/or tactical move, as observed in various motor leaning studies. Further investigations on this topic are warranted, especially those comparing the effects of negative and positive feedback on athletes and non-athletes, as well as on familiar and non-familiar outcome measures and under fatigued and non- fatigued conditions. Such studies would clarify whether the lack of effect observed in this study was due to the investigated sample, the outcome measure, state of fatigue, and an interaction between the three.

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## Disclosure statement

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