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ORIGINAL ARTICLE

Choices enhance punching performance of competitive kickboxers

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Abstract While self-controlled practice has been shown to enhance motor learning with various populations and novel tasks, it remains unclear if such effects would be found with athletes completing familiar tasks. Study 1 used a single case-study design with a world-champion kickboxer. We investigated whether giving the athlete a choice over the order of punches would affect punching velocity and impact force. Separated by 1 min of rest, the athlete completed 2 rounds of 12 single, maximal effort punches (lead straight, rear straight, lead hook and rear hook) delivered to a punching integrator in a counterbalanced order over six testing days. In one round the punches were delivered in a predetermined order while in the second round the order was self-selected by the athlete. In the choice condition, the world champion punched with greater velocities (6–11 %) and impact forces (5–10 %). In Study 2, the same testing procedures were repeated with 13 amateur male kickboxers over 2 testing days. Similar to Study 1, the athletes punched with significantly greater velocities (6 %, $p < 0.05$) and normalised impact forces (2 %, $p < 0.05$) in the choice condition. These findings complement research on autonomy support in motor learning by demonstrating immediate advantages in force production and velocity with experienced athletes.

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Introduction

Being able to determine one's own actions, having choices, and having control over one's environment—that is, being autonomous—is essential to well-being and quality of life (e.g., Rodin, & Langer, 1977). Indeed, autonomy is considered a fundamental psychological need (Deci, & Ryan, 2000, 2002; White, 1959), and even a biological necessity (Leotti & Delgado, 2011; Leotti, Iyengar, & Ochsner, 2010). Humans (Tiger, Hanley, & Hernandez, 2006) and other animals (Catania, 1975; Voss, & Homzie, 1970) prefer to have choices, even if having choices requires greater effort than no choices. This suggests that exercising control is inherently rewarding (Leotti, & Delgado, 2011). Autonomy-supportive environments that provide individuals with choices—even seemingly inconsequential ones (e.g., Tafarodi, Milne, & Smith, 1999)—have been shown to increase their motivation and performance in a variety of situations.

This includes exercise behaviour (for a review, see Teixeira, Carraça, Markland, Silva, & Ryan, 2012). In one recent investigation (Wulf, Freitas, & Tandy, 2014), participants chose the order of five calisthenics exercises to be performed (choice group), or were told they would complete the exercises in a specified order (control group). The two groups were then asked to decide on the number of sets and repetitions they would like to complete in each of the five exercises. Despite similar fitness baselines, participants who were allowed to choose the order of exercises completed 60 % more repetitions overall. Thus, a simple choice increased individuals' motivation to exercise.

Supporting learners' need for autonomy, for instance by giving them choices, has also been found to facilitate motor skill learning. In the motor learning literature, numerous studies have shown enhanced learning when individuals are allowed to make decisions related to certain aspects of the practice conditions (for reviews, see Sanli, Patterson, & Bray, 2013; Wulf, 2007). Initial investigations reported more effective learning in participants who were allowed to choose when to receive movement-related feedback relative to yoked control groups (e.g. Janelle, Barba, Frehlich, Tennant, & Cauraugh, 1997; Janelle, Kim, & Singer, 1995). Even though both choice (so-called self-control) and control (yoked) groups in those studies received the same amount of feedback (yoked participants' feedback was matched to that of participants who chose feedback after certain trials), the choice groups consistently demonstrated more effective learning. More recently, similar learning benefits were reported when participants were allowed to choose the duration of the practice sessions (Lessa, & Chiviacowsky, 2015; Post, Fairbrother, & Barros, 2011), the timing of provided verbal feedback (Ali, Fawver, Kim, Fairbrother, & Janelle, 2012; Lim et al., 2015) and video model presentations (Aiken, Fairbrother, & Post, 2012; Wulf, Raupach, & Pfeiffer, 2005), when to use assistive devices, such as poles during balance tasks (Hartman, 2007; Wulf, & Toole, 1999), or the order of tasks to be completed (Wulf, & Adams, 2014). Interestingly, the positive effects of the self-controlled practice occurred when the choices were incidental to the completed tasks. For example, even choosing the colour of golf balls enhanced golf putting accuracy compared to a prescribed colour yoked group (Lewthwaite, Chiviacowsky, Drews, & Wulf, 2015). Given the beneficial effect of practice conditions in which performers are provided choices, learner autonomy is a key variable in the OPTIMAL (Optimising Performance Through Intrinsic Motivation and Attention for Learning) theory of motor learning (Wulf, & Lewthwaite, 2016).

The positive effects of choice on motor skill learning have been reported for a wide range of populations, including children (Chiviacowsky, Wulf, de Medeiros, Kaefer, & Tani, 2008), young (Post et al., 2011) and older adults (Lessa, & Chiviacowsky, 2015), as well as participants with motor impairments (Chiviacowsky, Wulf, Lewthwaite, & Campos, 2012). An interesting and yet unexplored question is whether the benefits of providing choices would also be seen in the performance of highly skilled and trained athletes. The present study addressed this question. Given that a learning study, with a traditional practice and retention or transfer tests (Schmidt, & Lee, 2011), would seem inappropriate for high-skill performers, we used a within-participant design. While benefits of autonomy-supportive practice conditions, relative to control groups, are typically seen on tests of motor learning (retention, transfer), to our knowledge this is the first attempt to examine possible immediate differences in performance as a function of autonomy support versus no support within the same participants and task. Study 1 was a case study with a world-class kickboxer, and Study 2 involved amateur kickboxers. In both studies, participants were, or were not, given a choice regarding the order of different punches. We measured punching performance under each of those two conditions.

Thus, the present studies differed from previous ones in various respects: (1) We tested skilled athletes rather than untrained or unskilled individuals. (2) The athletes performed a skill with which they had attained a medium to high level of mastery, rather than learning a novel motor task. (3) We measured maximum force production and movement velocity, which could have reached a plateau through regular training, rather than movement accuracy or form for which there may be more room for change. (4) Rather than examining delayed effects on learning resulting from extended practice with or without choice, we examined immediate effects of choice on performance. If the hypothesised performance advantages of choice were found in highly skilled performers, those results would have interesting implications for the coaching of athletes.

Study 1

Punching velocities and impact forces are important qualities in combat sports (Smith, Dyson, Hale, & Janaway, 2000; Chaabène et al., 2014). These qualities are commonly improved upon by specific technical training (e.g., punching a heavy bag or pads) and non-specific training (e.g., resistance training) (Turner, Baker, & Miller, 2011). In Study 1, we investigated whether autonomy-supportive conditions would enhance punching performance of a current kickboxing world champion. We examined whether providing him with a choice concerning the order of punches to be delivered would affect punching velocities and impact forces.

Participant

An elite male kickboxer (age: 26 years, weight: 60 kg, height: 165 cm) participated in this case study. At the time of the investigation he was the amateur K-1 league kickboxing world champion, and the professional kickboxing world titleholder with the International Sport Kickboxing Association (ISKA) in the 57 kg division. His professional fighting record consisted of 21 wins and 10 losses. The athlete had been training competitively for the past 7 years, and regularly participated in 6–10 training sessions per week with total training hours per week of 8–16 h. The athlete's programme varied with the schedule of upcoming competitions and was periodised for volume and intensity to achieve optimal physical adaptations. The athletes were provided with a verbal description of the study, carefully formulated so as to not compromise the study design, and then provided a written informed consent. The study was approved by the Australian Institute of Sports Ethics Committee.

Apparatus

All punches were delivered to a custom built punch integrator (Fig. 1), which was mounted vertically and composed of a load cell with an integrated amplifier (AST brand) bolted to a metal plate covered with a large foam pad that was wrapped by leather envelope. The load cell voltage signal was collected by Data Translation 12bit USB data acquisition module using QuickDAQ software (Australia) sampling at 1000 Hz and converted to units of force (N). Punch velocity (m s^{-1}) was determined by recording the time interval (Agilent oscilloscope) between activation of two phototransistor infrared LED light gates (Vishay) with one gate located 0.01 m from the striking surface and the other 0.05 m. Velocity was then calculated by dividing the distance (0.04 m) by the time interval between the two beams being broken. The punch integrator instrument reliability was previously determined to be higher than 99 % for both impact forces and velocity, using a protocol that involved repeated dropping of a pendulum of known weight, and known height, on to the impact surface. High instrument reliability was maintained irrespective of the number of pendulum drops (impacts), time interval between drops, and days between tests.

Fig. 1 The punching integrator device

Task and procedure

The athlete completed a total of six testing sessions. The sessions were separated by 2–4 days in which the choice (A) and control (B) conditions were completed in a counterbalanced order on 6 days (AB-BA-AB-BA-AB-BA). All data collection was carried out in a quiet room by the same investigator (IH) and at approximately the same hour in each session to control for possible circadian rhythm effects. The athlete was asked to avoid heavy meals 2 h prior to testing. He wore the same 16 oz boxing gloves (Sting, Australia) and applied his own standard underwraps during testing. The athlete was instructed to “Focus on punching the pad as fast and as forcefully as you possible can.” This instruction was found to elicit the greatest impact forces and punching velocities (Halperin, Chapman, Martin, & Abbiss, 2016a) by promoting an external focus of attention (Wulf, 2013).

On the first testing day, the athlete was familiarised with the punching protocol. He was provided with an explanation of how the test would be conducted and then performed a light, sub-maximal trial of each condition. Once understood, the athlete completed a 10–15 min self-selected warm-up, and then performed the punching protocol in each testing session under two conditions (in an alternating order): Control and choice. In the control condition, a standard punching performance test was used (see Halperin, Chapman, Martin, & Abbiss, 2016a), consisting of 12 single, maximal effort punches delivered in the following order: lead straight, rear straight, lead hook, rear hook, each of which was delivered 3 times in a row. In other words, the athletes delivered three lead straights, three rear straights, three lead hooks and three rear hooks with approximately 5 s of rest between each punch. This protocol was chosen to serve as the control condition as it has been regularly used to monitor competitive boxer’s progress over time, and has been used for research purposes as well (see Halperin, Chapman, Martin, & Abbiss, 2016a; Halperin, Hughes, & Chapman, 2016b). In the choice condition, the athlete delivered the same number and type of punches, but was able to choose the order of delivery throughout the completion of the protocol. That is, the athlete was not required to select the punch order prior to initiating of the protocol, but rather, he chose the order of punches as he was progressing through it. In cases in which the athletes were not sure of the number or type of punches left to perform, they were reminded by the investigator. One minute of rest was provided between the control and choice rounds. Due to a technical limitation of the measurement device (punch integrator), there were 5-s pauses between punches in both conditions. Finally, based on observations that athletes occasionally strike the punching integrator off centre, thereby reducing the recorded impact forces, an a priori decision was made to analyse only the two punches with the greatest impact forces and their associated velocities in each category.

Data analysis

To determine performance differences between conditions, we implemented Kinugasa's (2013) general guidelines for analysis of a single-subject case study design in elite athletes. The effects of the choice condition were investigated in regards to the 4 punch types. Cohen's *d* effect sizes (ES) (Cohen, 1992) were calculated for the mean differences between conditions for the punch type, using the pooled standard deviation of the specific punches. Additionally, percent differences between conditions are reported. The smallest worthwhile change (smallest meaningful change) was determined for both punch force and velocity to appropriately ensure that where differences existed, they were of a meaningful magnitude (Hopkins, 2004). The smallest worthwhile change score was calculated by multiplying the overall pooled standard deviation of each dependent variable (punch force and punch velocity) across punch type and condition by 0.2. This score was then compared to the absolute difference between conditions for each day.

Results

Punch order in choice condition

The order of punch types chosen by the participant was different across all six testing days, as can be seen in Table 1.

Velocity

Greater punching velocities were found on the following punches: Lead straight (8 %; ES = 1.14), rear straight (4 %; ES = 0.42), lead hook (6 %; ES = 0.79), and rear hook (6 %; ES = 0.81) (Fig. 2b). In all four punches the differences in favour of the choice condition were equal or greater than double the size of the calculated smallest worthwhile change.

Force

Greater punching impact forces were found on the following punches: Lead straight (8 %; ES = 0.89), rear straight (6 %; ES = 0.84), lead hook (5 %; ES = 0.83), and rear hook (6 %; ES = 0.68) (Fig. 2a). In all 4 punches the differences in favour of the choice condition were equal or greater than double the size of the calculated smallest worthwhile change.

Table 1 Order of punches in the control condition, and on each of the 6 days in the choice condition (Study 1) for the expert athlete

Control	Choice Day 1	Choice Day 2	Choice Day 3	Choice Day 4	Choice Day 5	Choice Day 6
LS	LH	RS	RH	LS	LH	LS
LS	RH	LH	LH	RS	RS	LS
LS	LH	RS	RS	LS	RS	RS
RS	LH	LS	LH	LS	LS	RH
RS	RH	RS	RS	RS	LS	RS
RS	RH	LS	LS	RS	LH	RS
LH	LS	LH	LH	RH	LH	LH
LH	LS	LH	LS	RH	RH	LH
LH	RS	RH	RS	LH	RH	RH
RH	LS	RH	RH	LH	RH	LH
RH	RS	RH	LS	RH	RH	RH
RH	RS	LS	RH	LH	LS	LH

LS lead straight, *RS* rear straight, *LH* lead hook, *RH* rear hook

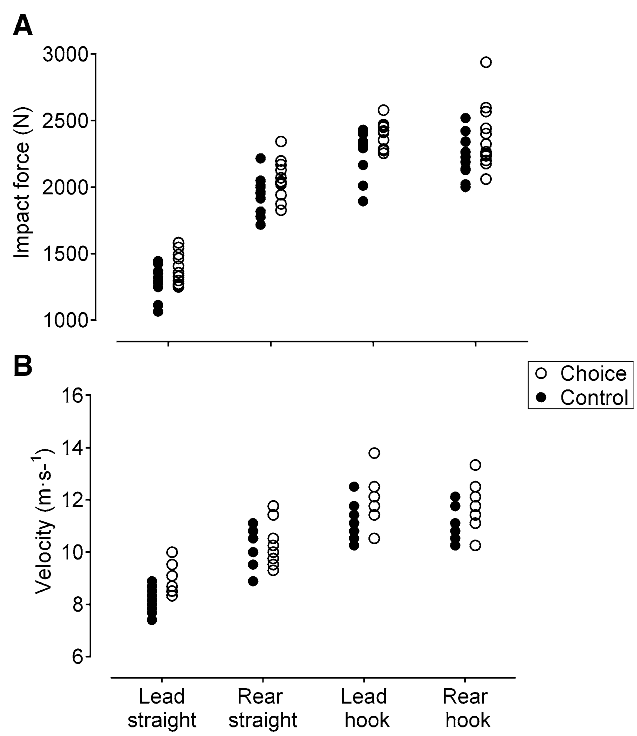

Fig. 2 Impact force (**a**) and punching velocity (**b**) of the world champion in the control and choice conditions. Each data point represent a single punch

Discussion

The results showed that the effects of choice—even relatively small ones such as the order of punches—had a meaningful positive effect on the performance of a world-class athlete who would be expected to have reached a state of mastery in his field. Indeed, it is interesting to consider the relatively large positive effect of the choice condition on the athlete, in view of the great number of maximal effort punches delivered over his training career. This finding supports the view that satisfying the need for autonomy is beneficial even for elite athletes. The finding also suggests that the simple act of providing choices can be used as additional training strategy aiming to improve not just learning, but also performance of well-established motor patterns requiring both speed and power. This is especially so considering that achieving significant improvements in punching performance is a challenging task with athletes at a world-class level.

Study 2

The findings of Study 1 demonstrated a beneficial effect of autonomy support on the performance of well-practiced motor tasks in a world champion. In Study 2, we sought to provide additional evidence for this effect by using a larger sample size. We examined whether providing amateur kickboxers with a choice of punch order would have similar influences on punching velocities and impact forces.

Participants

Thirteen amateur kickboxers volunteered to participate in this study (age: 25 ± 5 years, weight: 74 ± 10 kg). The athletes were categorised as amateur as they had only competed in national-level events, and had participated in a minimum of 1 and a maximum of 6 competitive national-level bouts. All athletes had been training for a minimum of 1 year (range 1–3 years), at least 3 times a week, and completed between 5 and 7 weekly sessions when preparing for competition. Similar to Study 1, the athletes were provided a written informed consent after provided with an explanation of the study. The study was approved by the Australian Institute of Sports Ethics Committee.

Apparatus, task, and procedure

The apparatus and task were the same as in Study 1. However, in this study the athletes completed only two testing sessions separated by 2–4 days performed in a counterbalanced order (AB-BA or BA-AB).

Data analysis

Due to the large range of body weights of the athletes, the impact force values were normalised to body weight (N/kg). Normalised forces and velocity ($m \cdot s^{-1}$) were analysed in a 2 (conditions: choice, control) × 4 (type of punch: lead straight, rear straight, lead hook, rear hook) × 2 (day) × 2 (trial) repeated-measures analyses of variance. Bonferroni adjustments were made for all post hoc tests and the associated partial eta-squared effect size reported. Furthermore, when appropriate, Cohen's *d* effect sizes and percentage differences are reported.

Results

No athlete punched in the same order in the two testing days under the choice condition. The sequence of punches did not follow any particular order, and was dissimilar between and within the athletes as confirmed by the experimenter who recorded and compared the order of delivered punches.

Velocity

Due to a technical error, velocity measures from 1 participant were missing. Thus, the reported results are derived from 12 participants. When athletes were able to choose the order of punches, velocities were higher than they were in the control condition (see Fig. 3b). The main effect of condition was significant, $F\ (1,\ 11) = 11.69$, $p < 0.01$, $\eta_p^2 = 0.51$. Specifically, the differences between conditions in the lead hook were minimal (0.5 %; ES = 0.04), and more substantial with the rear straight (6 %; ES = 0.42), lead hook (6 %; ES = 0.33) and rear hook (7 %; ES = 0.45). Also, as expected, velocities varied as a function of punch type, $F\ (3,\ 33) = 32.21$, $p < 0.001$, $\eta_p^2 = 0.74$. The rear hook resulted in the highest velocities, while the lead straight was associated with lowest velocities (Fig. 3b). There were no main effects of day, $F\ (1,\ 11) < 1$, or trial, $F\ (1,\ 11) = 1.69$, $p > 0.05$, and no significant interaction effects.

Impact force

Impact forces as a function of condition are shown in Fig. 3a. Forces were generally larger in the choice relative to the control condition. The main effect of condition was significant, $F\ (1,\ 12) = 4.89$, $p < 0.05$, $\eta_p^2 = 0.29$. Specifically, the differences between conditions in the lead hook were minimal (0.3 %; ES = 0.01), and more substantial with the lead straight (2 %; ES = 0.10), rear straight (2 %; ES = 0.11), and rear hook (2 %; ES = 0.17) (Fig. 3a). Similar to velocities, there were also differences among punch types, $F\ (3,\ 36) = 84.51$, $p < 0.001$, $\eta_p^2 = 0.88$. The rear hook resulted in the greatest force, while the lead straight was associated with the smallest force. All punch types differed from each other (ps < 0.001), except for the rear straight and lead hook ($p > 0.05$). On the first day of testing (36.95 N/kg), impact

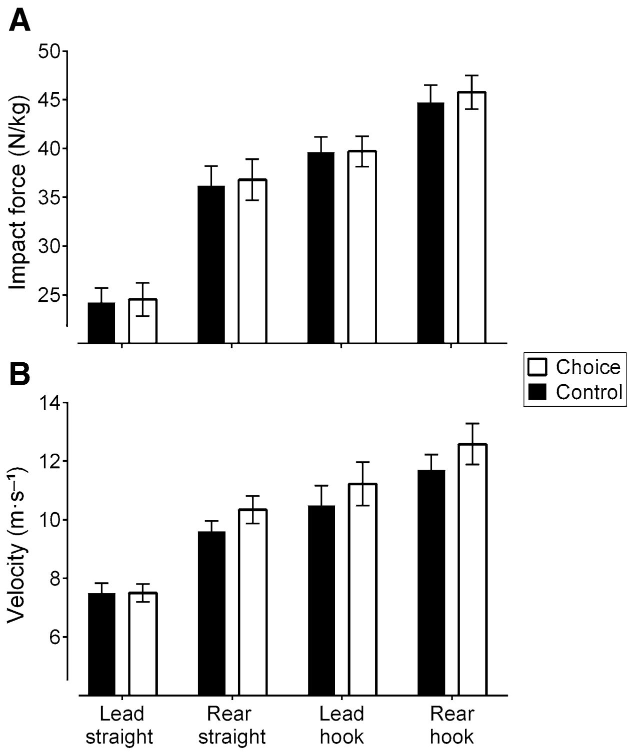

Fig. 3 Normalised mean (±SEM) impact forces (**a**) and punching velocity (**b**) of the amateur kickboxers in the control and choice conditions

forces were somewhat higher than they were on the second day (35.95 N/kg). The main effect of day was significant, $F\,(1, 12) = 5.04, p < 0.05, \eta_p^2 = 0.30$. There were no other significant main or interaction effects.

Discussion

Providing amateur athletes with a choice about the order of delivered punches enhanced punching velocity and impact forces, compared to the predetermined order of punches. It is unlikely that the choice condition somehow led to a physiological advantage relative to the predetermined order of punches. This is because all punches were delivered as singles, and not in combinations, due to the 5-s rest interval between punches. Further, the order of delivered punches was dissimilar across the testing days. For these reasons, the possibility of a preferred order of delivered punches and muscle fatigue, which might affect performance, can be discounted. While it is possible that the novel aspect of the choice protocol somewhat influenced the results, we argue that the positive effect observed in the choice condition was mostly caused by an enhanced sense of autonomy and competency, which consequently improved performance (see general discussion).

General discussion

The goal of these two studies was to examine if the benefits of self-selected practice programmes are generalizable to amateur athletes, as well as a world-class athlete, performing a well-practiced motor task. Providing the athletes with a choice over the order of delivered punches enhanced their performance. It was found that the elite athlete punched both harder and faster with the self-selected protocol. Similarly, amateur athletes punched faster and harder when they were able to choose the order of punches. The present findings extend the literature by showing that giving performers choices enhances not only the learning of novel tasks (e.g., Wulf, & Adams, 2014), but can improve even the performance of both skilled and highly skilled athletes who have extensive experience in a given task.

This finding is of value to striking combat sports as fast and forceful punches have been identified as an important contributing factor to success in such sports (Davis, Benson, Pitty, Connorton, & Waldock, 2015; Pierce, Reinbold, Lyngard, Goldman, & Pastore, 2006; Smith et al., 2000). Improving punching performance is commonly achieved by sport-specific (e.g., punching the heavy bag) and non-specific training (e.g., strength sessions) (Turner, Baker, & Miller, 2011). However, the results of this study, together with previous work, point to opportunities for self-selected practice as another strategy to achieve this goal. The results suggest that granting athletes varying degrees of control in the training session and/or programme could enhance performance, even in well-practiced motor tasks. This should be of particular interest to striking combat sports coaches who normally prescribe the order of delivered punches/kicks as a training strategy.

There are a number of possible explanations for the results. The self-selected protocol, relative to the prescribed order, may have permitted the athletes to punch in an order compatible with their optimal performance. This explanation, however, confronts difficulties. First, the sequence of punches was interrupted by 5 s of rest, thus preventing the delivery of a preferred continuous combination, which potentially could enhance punching performance. Second, the order of punches in the self-selected rounds was different across the days (see Table 1), thus excluding the possibility of an optimal sequence of punches. Also, the control condition may have inflicted muscle fatigue due to the short (5-s) rest periods between the delivered three similar punches. Yet, this possibility is unlikely because published work from our laboratory (Halperin et al., 2016a) demonstrates that the implemented protocol does not lead to a significant increase in fatigue. Indeed, the intraclass correlation of the control protocol are high for all punches (0.85–0.95) pointing to the non-fatiguing nature of the protocol (Halperin et al., 2016a).

It is possible that the novel aspect of the self-selected condition can account for some of the results. This is because the elite athlete in Study 1, and four athletes in Study 2 were familiar with the control condition. However, despite the familiarity of the elite athlete with the control condition, in all six testing days punching performance was superior with the self-selected condition. It can be argued that if novelty per se played a key role in the results, then the effects might be expected to fade across the testing days. Yet, this was not the case. Additionally, while the four participants in Study 2 previously completed the control condition, they performed it approximately 5 months prior to the present study. Most likely, the athlete's perception of choice increased their sense of autonomy and competence and subsequently enhanced performance. Though a sense of autonomy and competence were not assessed here, this last hypothesis is supported by a recent study indicating that providing even incidental choices can enhance motor learning (Lewthwaite et al., 2015).

Underlying neuromodulatory mechanisms may be consistent with and explain the potentiating effect of autonomy support on motor performance (Wulf, & Lewthwaite, 2016). Leotti and Delgado (2011) reported that the anticipation of choice was associated with greater activity in the brain regions involved in affective and motivational processes. Lee and Reeve (2013) found that imagery of self-determined task engagement, including the notion of acting autonomously, was related to activation in a brain region (anterior insula) associated with a sense of agency, a state associated with dopamine release (Aarts et al., 2012). Further, kinematic and kinetic advantages in rapid force production movements have been found in Parkinson disease when dopamine agonists are administered (Foreman et al., 2014).

The present study is not without limitations. First, while punching velocity and impact forces are important in combat sports, they are commonly delivered in combinations rather than single punches as delivered in this study. This limitation was enforced due to technical limitation of the punch integrator, which only allows for single punches to be recorded. Accordingly, it would be of interest to further investigate this topic with punching combinations to better illustrate how punches are mostly delivered in combat sports. Second, the sample size of these studies was relativity small. In an attempt to overcome the sample size limitation, the study included a relatively large number of data points, reflecting 560 analysed punches between the two studies (280 per condition). Additionally, in Study 1 we tested the athlete over six testing sessions to insure that the effects, if present, are consistent across days. Finally, special attention was given to eliminate confounding variables, such as the type and number of instructions, number and gender of observers, as well as the time of testing and the intensity of the warm-up (Halperin, Pyne, & Martin, 2015).

In summary, to our knowledge this is the first study to investigate the effects of choice conditions on competitive athletes performing a familiar motor task, including a world-champion athlete. The results are in line with previous research demonstrating a positive effect on motor performance when participants are able to make choices about various aspects of practice conditions, even if the choices are relatively small. Given the observed effects and their consistency, we believe that the results are meaningful. Future studies utilising larger sample sizes and other outcome measures would be a fruitful endeavour given the potential practical implications of the findings for the coaching of athletes.

Compliance with ethical standards

Funding No funding was required for this study.

Conflict of interest Israel Halperin declares that he has no conflict of interest. Dale Chapman declares that he has no conflict of interest. David Martin declares that he has no conflict of interest. Rebecca Lewthwaite declares that she has no conflict of interest. Gabriele Wulf declares that she has no conflict of interest.

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. This article does not contain any studies with animals performed by any of the authors.

Informed consent Informed consent was obtained from all individual participants included in the study.

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