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Primed to perform: Comparing different pre-performance routine interventions to improve accuracy in closed, self-paced motor tasks

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ABSTRACT

Objectives: Two experimental studies were conducted to test and compare whether different pre-performance routines (i.e., left-hand dynamic handgrip and an extensive routine) can improve (and potentially have a combined effect on) accuracy in closed, self-paced motor tasks.

Design/method: Study 1 used a standardised laboratory task to measure motor performance, while Study 2 was a field experiment measuring tenpin bowling accuracy and in-game performance as outcome variables. Both studies consisted of a pretest phase followed by one or two test phases using a group-specific pre-performance routine (PPR), or control, condition.

Results: Results of both studies indicated that the inexperienced students (Study 1) and experienced athletes (Study 2) within the intervention groups were more accurate when using the intervention than a control group (not provided an intervention). Using a combined (i.e., left-hand dynamic handgrip and extensive) PPR may not have additive performance effects. Furthermore, using a PPR intervention did not equate to better in-game performance in Study 2.

Conclusions: These studies indicate that the element of left-hand dynamic handgrip as a PPR may be comparable to control groups, but further research is needed to determine if it is comparable to extensive PPR interventions that promote concentration on the task for increased performance generally (and under pressure).

Being an elite athlete involves commitment and dedication to undertake long, deliberate training of technical and physical skills to optimise motor performance (Macnamara, Moreau, & Hambrick, 2016). Despite intensive training and well-learned motor actions, skilled performance often breaks down if the performer becomes distracted (Nideffer, 1992; Oudejans, Kuijpers, Kooijman, & Bakker, 2011), stressed (Masters, 1992), or anxious (Eysenck & Calvo, 1992; Hardy, Mullen, & Martin, 2001). To help athletes maintain task-related attention, applied sport psychologists often suggest the use of a pre-performance routine (PPR). A PPR refers to cognitive (e.g., imagery, cue words) and behavioural elements (e.g., deep breathing) an athlete systematically engages in prior to performance execution (Cotterill, 2010). In this study, we focus on testing and comparing two PPR, or preparation strategies, to facilitate performance: an extensive PPR (Mesagno & Mullane-Grant, 2010) and left-hand dynamic handgrip (Beckmann, Gröpel, & Ehrlenspiel, 2013). Testing and comparing different pre-performance preparation strategies is important because it helps to develop athletes who can thrive in competition and determine which preparation strategies may be most beneficial for performance.

Using a PPR is commonplace in self-paced, closed skill tasks, such as putting in golf (Hill, Hanton, Matthews, & Fleming, 2011), free throw shooting in basketball (Czech, Ploszay, & Burke, 2004; Lonsdale & Tam, 2008), execution of a tenpin bowling delivery (Mesagno, Hill, & Larkin, 2015), and performing a routine in gymnastics (Clowes & Knowles, 2013). Researchers have repeatedly found that using a PPR can improve performance generally, for all skill levels, with novices benefitting most from PPR development (e.g., Beauchamp, Halliwell, Fournier, & Koestner, 1996; Lidor & Mayan, 2005; McCann, Lavallee, & Lavallee, 2001). For example, Lidor and Mayan examined whether female volleyball players would benefit from PPR development prior to a self-paced, closed motor skill (i.e., volleyball serve). Results indicated that the volleyball players who developed a predominantly behavioural PPR were more accurate in retention trials than groups using either, a predominantly cognitive (i.e., mainly focused on mental skills training)

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routine, or technical instruction. The effectiveness of a PPR for experienced athletes, however, has been mixed (e.g., Cotterill, Sanders, & Collins, 2010; Czech et al., 2004; Kingston & Hardy, 2001; Mesagno et al., 2015). The equivocal results for experienced athletes may be a product of research design issues with some researchers suggesting that a PPR should be individualized with consideration for learning styles and personality in PPR development and education (see Cotterill, 2010 for a review). The subjective benefits of using a PPR may include (but are not limited to) reduced negative introspection (Beauchamp et al., 1996), lowered anxiety levels (Hazell, Cotterill, & Hill, 2014), and increased attention to the task at hand (Cotterill et al., 2010; Harle & Vickers, 2001).

Researchers have also found that using a PPR can sustain (Hazell et al., 2014; Mesagno et al., 2015) or improve (Lautenbach et al., 2015; Mesagno, Marchant, & Morris, 2008; Mesagno & Mullane-Grant, 2010) performance accuracy under pressure, with no studies to date showing negative effects (Gröpel & Mesagno, 2017). In particular, Lautenbach et al. found that tennis players showed decreased performance under pressure prior to learning a PPR, but not following PPR education. Mesagno and Mullane-Grant (2010) also investigated whether an extensive PPR, comprising of different preparation components (e.g., deep breath, cue word, and temporal consistency) has a stronger effect on performance than the respective components in isolation. This experimental study on Australian Football players found that using different preparation components in isolation was beneficial but using an extensive PPR (with many preparation strategies included) exhibited the greatest accuracy compared to a control group who received no PPR education. In another study, Mesagno et al. (2008) examined whether using an extensive PPR could help reduce performance failure in "choking-susceptible" (i.e., likely to worsen performance under pressure) athletes. Findings indicated that the athletes improved performance when using the extensive PPR and interviews after the experimental phase revealed that participants perceived an improvement in task-relevant attention under pressure in comparison to an earlier pressure phase. These combined results indicate that using different preparation components in combination may have a beneficial and cumulative effect on performance (see Gröpel & Mesagno, 2017 for a review of choking under pressure interventions that include PPR studies).

An additional behavioural, preparatory strategy that could be added to, and possibly benefit, a PPR, is left-hand dynamic handgrip (Beckmann, Gröpel, & Ehrenspiel, 2013; Gröpel & Beckmann, 2017). The basis for using left-hand dynamic handgrip within a PPR originates from researchers who found that inferior performance may be a result of self-focused attention (Beilock & Carr, 2001; Masters, 1992) and that a dominant left-hemispheric activation during performance execution underlies this self-focused attention (Babiloni et al., 2010; Crews, 2004; Gallicchio, Cooke, & Ring, 2015; Salazar et al., 1990). Notably, as reported in electroencephalographic (EEG) studies, contractions of the left hand increase the activation of the contralateral motor cortex during hand clenching (Harmon-Jones, 2006; Peterson, Shackman, & Harmon-Jones, 2008). Thus, it was suggested to decrease the detrimental left hemispheric activation through inducing right hemispheric activation with a left hand dynamic handgrip. EEG findings in fact proved that left-hand dynamic clenching activates the right hemisphere motor cortex, which then initiates an increase in the 8–12 Hz alpha band that spreads across the whole cortex including the left-hemispheric areas associated with self-focused attention. The high alpha is indicative of a state of cortical relaxation in both hemispheres after hand clenching (Cross-Villasana, Gröpel, Doppelmayr, & Beckmann, 2015), and the dominant activation in the left hemisphere is reduced. Thus, left-hand dynamic handgrip may help to attenuate self-focused attention and promote more accurate skill and performance execution. In sport, Beckmann et al. observed that experienced soccer, taekwondo, and badminton athletes who squeezed a soft ball with their left hand, approximately twice a second, for 30 s performed more accurately in a simulated competition than their counterparts in a control group who squeezed the soft ball with their right hand. Gröpel and Beckmann replicated these findings with a sample of artistic gymnasts in an actual competition.

Left-hand dynamic handgrip research, to date, is in its infancy. Research tasks use closed skills and field based experiments that examine performance accuracy and outcome without closer inspection of the performed motor skills (i.e., eye-hand coordination) or different skill levels (only highly skilled performers have been included in previous left-hand dynamic handgrip studies). Furthermore, left-hand dynamic handgrip studies have largely been tested in isolation without comparison with other preparatory strategies such as extensive PPRs. Beckmann et al. (2013) suggested integrating left-hand dynamic handgrip in athletes' existing PPRs, but there is no evidence to date of this combination strategy being investigated. Comparing different preperformance preparation strategies helps to determine which strategies may be most used for performance generally and under pressure.

1. The present research

The purpose of this research was to determine whether left-hand dynamic handgrip as a preparation strategy has effects comparable to other evidence-based PPRs (i.e., the extensive PPR; Mesagno & Mullane-Grant, 2010) in improving accuracy in closed, self-paced motor both in a simulated task and in the field. We also investigated whether combining the left-hand dynamic handgrip as a preparatory strategy in an extensive PPR intervention has a cumulative effect on performance. Accordingly, we assigned participants to one of three intervention groups (i.e., left-hand dynamic handgrip only, extensive PPR only, and combined left-hand dynamic handgrip and extensive PPR) or to a control group. We hypothesized that the intervention groups would perform better than the control group, with the combined group showing the best performance.

We tested this hypothesis in two experimental studies that both included a closed, self-paced motor task. Study 1 was a pilot test conducted in a well-controlled, laboratory setting. We used a standardized eye-hand coordination task on a computer to measure motor skill performance. The main study (Study 2) was conducted in an ecologically valid, field setting, and measured tenpin bowling accuracy in an experimental task as well as in actual competitions as outcome variables. Each study consisted of a pretest phase without a PPR intervention followed by one or two test phases. Because the benefits of PPRs have been observed both in general and under pressure in particular, we also induced pressure. The induction of pressure included combinations of features such as the presence of an audience, ego relevance, and videotaping (cf. Gröpel & Mesagno, 2017).

2. Study 1

In Study 1, we sought to address the impact of preparation strategies in a standardized "line tracing" laboratory task. Participants first practiced the task in an acquisition phase and then completed two test phases with their group-specific preparation strategy, one without pressure and the other under pressure.

3. Method

Participants. An a priori calculation with G*Power (Faul, Erdfelder, Buchner, & Lang, 2007) revealed that a sample size of at least 32 would give sufficient power (0.80) to detect significant differences at the alpha level of 0.05. We anticipated a medium-to-large effect size, which was based on previous research investigating the effectiveness of PPR (Hazell et al., 2014; Lautenbach et al., 2015; Mesagno & Mullane-Grant, 2010). Forty-eight college students participated in the study. The majority of participants self-reported as right-hand dominant, with only three participants identifying as left-hand dominant.[1] Two participants showed poor outcome performance (i.e., score below 3 *SD*), resulting in the removal of their data. The final sample consisted of 46 participants (35 female, 11 male), with a mean age of 21.5 years ($SD = 1.59$; range = 18–26 years). Prior to participating in the study, the participants were explained the experimental procedures, assured the confidentiality of their data, and their right to cease the experiment at any time without consequences. Participants provided signed informed consent in accordance with the guidelines of the Declaration of Helsinki. Ethical approval for the study was secured in line with the authors' institutional procedures.

Task and Apparatus. Participants performed the standardized Two-Hand Coordination Test, which is a part of the Vienna Test System software (Schuhfried, 2010). This test assesses eye-hand coordination and coordination between the left and right hand by manoeuvring a red dot along a given track. Participants' task was to make the red dot move as fast as possible along the track without hitting the line. The track (same in each trial) consists of both straight and curved sections. Participants performed the test on a computer using two special control knobs; the left knob made the dot move horizontally and the right knob vertically. Outcome variables were speed, operationalized as duration time, and accuracy, operationalized as the number of errors (i.e., hitting the line). Because speed and accuracy were correlated across trials ($r = -0.29$, $p = .05$), indicating that faster participants made more errors, we calculate the inverse efficiency scores (IES) as the performance variable to take the speed-accuracy trade-off into account (Bruyer & Brysbaert, 2011). These scores were derived by multiplying the duration time and the number of errors separately for each trial; +1 was added to the number of errors to avoid multiplication by zero. Lower scores thus indicated better performance.

Measures. State anxiety was measured using the Mental Readiness Form-3 (MRF-3; Krane, 1994) because it can be used in a quick, efficient manner without much disruption. The MRF-3 has three separate 100 mm (mm) continuums that are anchored between *calm* and *worried* for cognitive anxiety, *relaxed* and *tense* for somatic anxiety and *confident*, and *not confident* for self-confidence. The participant places a mark on each of the three lines to show how he or she was feeling at that moment. The measurement between the left part of, and the participant mark on, the line was the participant's score out of 100, with higher scores indicating a higher anxiety. We used only the somatic and the cognitive subscales for the analyses because they represent the central aspects of anxiety. Krane reported the correlations of the MRF-3 to the Competitive State Anxiety Inventory-2 (CSAI-2; Martens, Burton, Vealey, Bump, & Smith, 1990) to be 0.76 for cognitive anxiety and 0.69 for somatic anxiety.

Procedures. The study was performed in individual laboratory sessions. Upon arrival at the laboratory and signing informed consent, participants provided demographics information and completed the MRF-3 after being told about the procedures of the experiment. Next, participants became familiar with the Two-Hand Coordination task and the control knobs using the standardized procedure available from the software. Following the instructions on the screen, participants learned the task by moving a red dot along the track. This familiarization took approximately five minutes. Thereafter, in the acquisition phase, participants then completed 20 practice trials in five blocks of four trials. The mean performance in the last four trials represented pretest performance. Thereafter, participants moved to the first test phase.

In the first test phase (herein called the first posttest), preparation strategy interventions were introduced. We randomised participants to one of three intervention groups or to a control group. In the *left-hand dynamic handgrip* (labelled dynamic handgrip hereafter) group, participants dynamically squeezed a soft, relatively "squishy" ball in their left hand for 10 s, about twice a second, before each trial. Generally, the dynamic handgrip duration was based on cognitive psychology research evidence (e.g., Pfurtscheller & Lopes da Silva, 1999) that a single hand clench is too short for behavioural after-effects because it produced a brief alpha response that phased out whereas longer handgrip durations (e.g., 45–60 s) are effective (e.g., Baumann, Kuhl & Kazen, 2005; Harmon-Jones, 2006), but may be too lengthy as PPRs and within sport. Thus, we used a dynamic handgrip duration of 10 s (instead of 30 s used by Beckmann et al., 2013) to allow comparison with an extensive PPR that takes about 10 s (Mesagno & Mullane-Grant, 2010) and to optimise ecological validity when used in sport. In the *extensive PPR* group, participants focused on the start line of the track (i.e., external focus of attention), took three deep breaths (i.e., arousal control), and then provided a 3 s "countdown" aloud before each trial. These preparation strategies, both in isolation and in combination, have been used efficiently in existing research (Mesagno et al., 2008; Mesagno & Mullane-Grant, 2010). The extensive PPR was not individualized; participants in this group learned the same PPR. The *combined* dynamic handgrip and PPR group (hereafter labelled "combined") completed both the extensive PPR and dynamic handgrip simultaneously. While squeezing the ball in their left hand, participants focused on the start line of the track, took three deep breaths, and provided the countdown. Participants in either group were trained in the PPRs until they indicated their understanding by demonstrating the PPR to the researcher. Next, participants completed another four trials of the Two-Hand Coordination test, with their respective PPR before each trial. Participants in the *control* group completed the test without any PPR education or instructions.

In the second test phase (herein called the second posttest), participants performed the Two-Hand Coordination test with the above interventions under pressure. We induced pressure with the second part of Trier Social Stress Test (TSST; Kirschbaum, Pirke, & Hellhammer, 1993). Participants counted aloud and backward from 1022 in steps of 13 in front of a video camera (located in front, and in full view, of the participant) and two judges (a researcher and confederate). If a mistake was made, the researcher asked participants to start from the beginning. Participants completed the MRF-3 for a second time after instructions about the second posttest were read and then completed the last four trials of the Two-Hand Coordination test, with his or her respective PPR before each trial. Finally, participants were debriefed, thanked, and dismissed.

4. Results

Acquisition Phase. We split the 20 practice trials into five blocks of four to allow comparison of the acquisition and test phases (Figure 1). The results of a one-way analysis of variance (ANOVA) on the first practice block indicated that all groups had similar task performance, $F(3, 42) = 1.24$, $p = .31$, $\eta_p^2 = 0.08$. We then conducted a 4 × 5 (Group × Block) repeated measures ANOVA to examine the performance scores. The ANOVA (Box's $M = 83.10$, $p = .03$; Mauchly's $W = 0.13$, $p < .001$) revealed a main effect for Block, corrected $F(2.22, 93.41) = 34.45$, $p < .001$, $\eta_p^2 = 0.45$, and a marginal Group effect, $F(3, 42) = 2.28$, $p = .093$, $\eta_p^2 = 0.14$. Notably, there was no interaction, corrected $F(6.67, 93.41) = 1.11$, $p = .36$, $\eta_p^2 = 0.07$, indicating that learning took place over the five blocks and that a similar pattern of skill acquisition occurred in all groups. Simple paired *t*-tests revealed that performance stabilized from Block 4 to Block 5 in all groups (*ts* < 0.84, *ps* > .42); it was therefore appropriate to use Block 5 as pretest performance in subsequent analyses.

Task Performance. We conducted a 4 × 3 (Group × Phase) repeated measures ANOVA to examine the performance scores in the four groups over the three study phases: the pretest (Block 5), the first posttest, and the second posttest. The ANOVA (Box's $M = 35.83$,

[1] No left-hand dominant participant was allocated to the left-hand dynamic handgrip group; left-hand dominant participants were distributed evenly into the other groups.

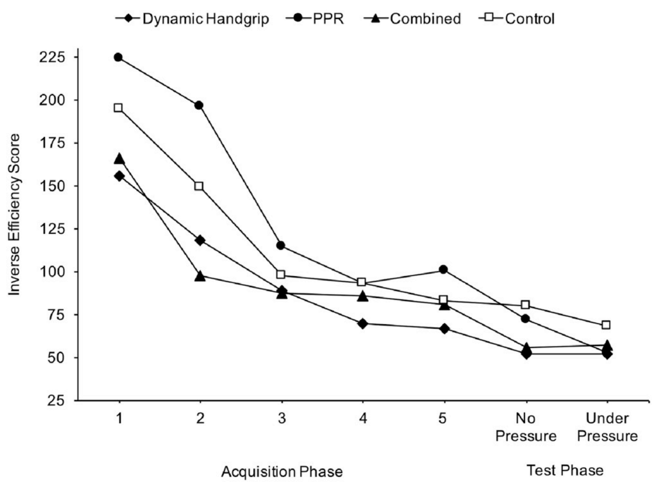

Figure 1. Mean performance score (Inverse Efficiency Score) in the acquisition and test phases for the different groups (Study 1).

$p = .03$; Mauchly's $W = 0.84$, $p = .03$) revealed a main effect for Phase, corrected $F(1.72, 72.33) = 17.78$, $p < .001$, $\eta_p^2 = 0.30$, a non-significant main effect for Group, $F(3, 42) = 1.48$, $p = .23$, $\eta_p^2 = 0.10$, and a marginal interaction, corrected $F(5.17, 72.33) = 2.03$, $p = .082$, $\eta_p^2 = 0.13$. Subsequent simple main effects analysis indicated no group differences pretest, $F(3, 42) = 1.28$, $p = .29$, $\eta_p^2 = 0.08$, a significant group difference in the first posttest, $F(3, 42) = 3.45$, $p = .025$, $\eta_p^2 = 0.20$, and no group differences in the second posttest, $F(3, 42) = 0.97$, $p = .42$, $\eta_p^2 = 0.07$. Contrast-coded analysis (-1, -1, -1, $+3$, for the three intervention groups and the control group, respectively) in the first posttest was significant, corrected $t(15.66) = 2.18$, $p = .045$, indicating that participants in the intervention groups outperformed control participants. A contrast-coded test $+1$, $+1$, -2, for the dynamic handgrip, extensive PPR, and combined groups, respectively, was not significant, $t(12.99) = 0.60$, $p = .56$, indicating that the benefits of dynamic handgrip and extensive PPR were the same irrespective of whether used in combination or in isolation.

State Anxiety. We conducted a 4 × 2 (Group × Phase) repeated measures ANOVA to examine whether the anxiety changed across the four groups from pre- to post-pressure induction. As shown in Table 1, participants exhibited significantly higher somatic, $F(1, 42) = 43.86$, $p < .001$, $\eta_p^2 = 0.51$, and cognitive, $F(1, 42) = 8.03$, $p = .007$, $\eta_p^2 = 0.16$, anxiety after pressure induction than at the commencement of the study. Neither a group effect nor an interaction were significant ($Fs < 1.59$, $ps > .21$), indicating that pressure induction effectively increased the participants' anxiety in all groups.

5. Discussion

Study 1 provided partial support for the hypothesis that participants using preparation strategies would perform better than control group participants in a motor task. Regardless of whether participants employed dynamic handgrip, extensive PPR, or these strategies combined, they improved performance more and performed better in the standardized motor task than the control group. However, these differences in performance were much less visible in the subsequent test under pressure. Furthermore, we hypothesized that the combination of dynamic handgrip and extensive PPR would have a stronger effect on performance than the two interventions in isolation, which was not supported. The benefits of dynamic handgrip and extensive PPR were the same regardless of whether used in combination or isolation.

5.1. Study 1 limitations

Even though using laboratory tasks has many benefits, including standardised conditions, high internal validity, and precise scoring, the task used also has a substantial limitation, since it is an artificial, non-specific sport task. These generic tasks are useful for initial orientation, but limited for drawing practical implications. In addition, the task was relatively simple, which may explain the non-significant performance results in the second, high-pressure posttest. Simple motor tasks are less affected by pressure and may benefit less from preparation strategies (Baumeister, 1984; Beckmann et al., 2013). Using a more complex motor task could reveal stronger effects. To allow for a stronger test and transfer to the field of sport, a complex and sport-specific task was employed in Study 2.

5.2. Study 2

Study 2 was designed to extend the findings of Study 1 by using tenpin bowling as a sport-specific task and sampling experienced bowling athletes. We tested the (additive) effect of preparation strategies on performance with bowling accuracy and in-game performance.

6. Method

Participants. An a priori sample-size calculation with G*Power (Faul, Erdfelder, Lang, & Buchner, 2007) resulted in a minimal sample size of 36 participants. Forty sanctioned moderate to highly skilled league bowlers (11 women and 29 men) with a reported bowling league average between 132 and 241 ($M = 192.15$, $SD = 21.49$) for at least 24 games, participated in the study. No restriction on bowling league averages was used. Participant ages ranged from 16 to 58 years ($M = 36.00$, $SD = 12.50$). A demographic questionnaire was completed as a screening tool for bowling experience (i.e., league average), self-reported hand dominance, and participant existing experience with sport psychology training. Identical to Study 1, only three participants identified as left-hand dominant and distributed evenly among the groups (i.e., not allocated to the dynamic handgrip group). Participants were untrained in sport psychology, with only six suggesting they had "attended group workshops with a sport psychologist", not related to performance routines; these participants were randomly (and evenly) "assigned" to the groups. The study was approved by the first author's University Research Ethics Committee.

Equipment. Standard bowling equipment and facilities similar to Mesagno et al. (2008) and Mesagno et al. (2015) were used. This included bowling balls with weights ranging between 10 lbs (4.54 kg) and 16 lbs (7.26 kg), standard approaches of 15 ft (5.57 m), bowling lane with length of 60 ft (18.29 m) from foul line to "head" pin, and bowling

Table 1
Mean and Standard Deviation (SD) for cognitive anxiety and somatic anxiety before (Pre) and after pressure induction (Post) for the different groups (Study 1).

Group	Cognitive Anxiety		Somatic Anxiety	
	Pre	Post	Pre	Post
Dynamic handgrip	18.67 (14.53)	27.83 (12.13)	23.00 (18.32)	49.92 (13.69)
PPR	24.00 (18.10)	31.64 (14.73)	23.55 (23.18)	43.91 (20.70)
Combined	24.73 (21.25)	32.82 (16.87)	31.36 (23.50)	48.73 (21.83)
Control	32.83 (24.67)	39.83 (16.20)	31.67 (16.48)	59.50 (20.27)

pins weighing approximately 6 lbs (1.5 kg) each.

Measures. Performance was measured using the accuracy task identical to that used in the Mesagno et al. (2008) and Mesagno et al. (2015) studies. Participants attempted 30 shots at a target on the bowling lane where absolute error, in millimetres (mm), from centre of the target to centre of the ball track was measured (see Mesagno et al., 2008, for logistics of measurements). Mean absolute error (MAE) for shot attempts was the dependent variable; lower MAE indicated improved accuracy.

State anxiety was measured using the same measure (i.e., MRF-3) as in Study 1.

To control for the use of PPR in competition, participants in the intervention groups rated the extent to which they applied their group-specific routine during the league games after the accuracy testing. Participants responded to the question, *How much did you use the routine you were provided for the bowling study in the 12 games of league after the accuracy test?*, on a 10-point scale ranging from 1 (*I did not use the routine at all during the 12 games of league*) to 10 (*I used the routine during all shots of all 12 games of league*).

6.1. Experimental groups

Participants were randomly allocated into one of four groups: extensive PPR only, dynamic handgrip only, combined PPR and dynamic handgrip, or wait-list control. The *extensive PPR* group involved participants developing, or modifying their existing PPR. Within the PPR, optimal arousal levels (e.g., deep breaths), behavioural steps, attentional control (e.g., focusing on a target), and cue words (when needed) were considered for inclusion into the PPR. Since the PPR was personalised for each participant (Boutcher, 1990; Cotterill et al., 2010), these steps were possible elements to include, but were not necessarily uniform across all PPR and combined groups. The first author (a certified tenpin bowling coach and sport psychology consultant) attended all testing sessions and identified appropriate components of the PPR while taking notes on each participant's routine. After conducting other bowling related studies (e.g., Mesagno et al., 2008; Mesagno et al., 2015), a common segment of participant's routine not adhered to (irrespective of bowling ability) is watching the fingers and thumb being inserted into the bowling ball before each delivery. Thus, participants in the PPR group were instructed to attend (at the least) to this part of the routine.

Participants in the *dynamic handgrip* group dynamically squeezed a soft ball in their left hand for 10 s, about twice a second, before each shot attempt. We employed 10 s of hand squeezing instead of 30 s employed by Beckmann et al. (2013) because, in bowling, the time required for the ball to return from the previous shot attempt is approximately 10 s, so squeezing the ball for 30 s would change the regular performance conditions and could therefore be perceived as disruptive. Participants commenced the dynamic handgrip prior to each delivery and placed the ball on the seat near the "ball return" before each shot. Immediately after returning from the shot attempt, participants picked up the soft ball in their left hand, and began squeezing it until the bowling ball returned and came to a complete stop on the lowest part of the ball return. At which time they placed the soft ball on the same seat and attempted another shot.

The *combined* PPR and dynamic handgrip group completed both the PPR and dynamic handgrip routine development. Participants in the combined group were always trained in the order the behavioural actions would occur normally with explanation of dynamic handgrip first and then PPR routine development last.

After routines were explained and developed, the routines were practiced to the satisfaction of both the participant and the first author (i.e., first author and participant agreed that the participant understood and could follow the steps of the PPR in order, repeatedly), and terminated when the participant performed two practice shots in a row successfully. Participants were stopped immediately if the routine was not completed as developed and planned to ensure that only two practice shots were taken. On average, this PPR development and education session was approximately 10 min ($SD = 3.52$).

The wait-list *control* group completed the accuracy test without any PPR education.

6.2. Procedures

Participants were recruited from tenpin bowling leagues ($n = 4$) by asking league officials for their consent. Volunteer bowlers were addressed prior to a league session, and those recruited also completed an informed consent form and the demographics questionnaire prior to taking part in the accuracy task. Participants completed the study independently and took part in a performance accuracy task prior to (herein called pretest) and following (called posttest) PPR development. Prior to both tests, participants performed their normal warm-up routine until they indicated their readiness to commence the "testing".

The pretest involved 30 shot attempts at a target on the bowling lane to measure accuracy, with an independent research assistant completing data collection. After the initial five shot attempts, the participant completed the MRF-3 to measure state anxiety during the accuracy test. Following the pretest (on the same day), a group-specific PPR development session was offered to each participant in the three experimental groups (i.e., extensive PPR, dynamic handgrip, or combined). The posttest was identical to the pretest with the exception that participants in each group implemented their PPR (or usual routine in the case of the control group) in the posttest. In addition, we induced pressure in the posttest by setting up a video camera adjacent (in front, and in full view, of the participants) to the bowling lane. The video camera was turned on for the duration of the posttest phase. Each participant was informed that the researchers were seeking maximum media exposure for the study and that the university media manager suggested to video record each participant during the posttest, which would be used for still photos for newspaper and video footage for television news programs. To make it more believable, the participant was informed about the collaborative grant the researchers received for this study and it was explained the video footage would be shared among the researchers for maximum international media coverage. The participant was also told that group-specific routines should be followed and accuracy measurements would be the focus of this test to emphasize the importance of the situation. During the posttest, participants in the intervention groups were monitored closely by the researcher (and video-recording) to ensure that they completed the group-specific routine accurately. In cases where the routine was not completed, the shot attempt was terminated and participants were asked to stop, reset, and complete the routine again. A total of 11 shots (i.e., 1 = PPR, 4 = dynamic handgrip, 6 = combined), out of all posttest shots for all participants were stopped, reset, and completed again due to routine non-adherence during a shot attempt.

To investigate in-game performance changes, the 12 competition (i.e., league-based) games prior to, and immediately following, the accuracy testing were obtained from the league secretary (similar to Mesagno et al., 2015). Internal consistencies (Cronbach's alpha) for the 12 competition game scores before and after the accuracy testing were 0.84 and 0.86, respectively. Finally, after the 12 games of league play following the accuracy testing, the routine use question was sent via sms (i.e., short message service) to each participant in the intervention groups to determine the amount they used their group-specific routine.

7. Results

Homogeneity of Groups. A one-way ANOVA on league average (see Table 2 for descriptive statistics) indicated no significant Group differences, $F(3, 36) = 0.55$, $p = .65$, $\eta_p^2 = 0.04$. Thus, equal group-based bowling ability was found. Similarly, there were no significant Group differences, $F(3, 36) = 0.06$, $p = .98$, $\eta_p^2 = 0.01$, for total

Table 2
Mean and Standard Deviation (SD) for reported league average, accuracy (Mean Absolute Error - MAE), and in-game performance (league average) pretest and posttest for the different groups (Study 2).

Group	League Average (SD)	Pretest MAE	Posttest MAE	Pretest League	Posttest League
Dynamic handgrip	194.00 (13.97)	26.78 (7.15)	24.69 (9.87)	190.11 (16.26)	196.58 (16.13)
PPR	186.20 (23.23)	33.98 (9.92)	28.51 (6.54)	181.29 (19.59)	185.10 (24.00)
Combined	198.20 (13.26)	28.41 (11.63)	27.18 (12.49)	196.98 (16.44)	195.48 (11.41)
Control	190.20 (31.62)	33.38 (12.03)	39.38 (16.82)	189.72 (32.52)	184.86 (26.00)

number of leagues bowled per week (ranging from one to three leagues), indicating that the amount of leagues bowled in per week should not affect performance.

Task Performance. We conducted a 4 × 2 (Group × Phase) repeated measures ANOVA to examine the accuracy scores (see Table 2). The ANOVA indicated a non-significant Phase main effect, $F(1, 36) = 0.31$, $p = .58$, $\eta_p^2 = 0.01$, a non-significant Group main effect, $F(3, 36) = 1.96$, $p = .14$, $\eta_p^2 = 0.14$, but a significant interaction, $F(3, 36) = 3.75$, $p = .02$, $\eta_p^2 = 0.24$. Subsequent simple main effects analysis indicated no group differences pretest, $F(3, 36) = 1.20$, $p = .33$, $\eta_p^2 = 0.09$, but a significant group difference posttest, $F(3, 36) = 2.91$, $p = .048$, $\eta_p^2 = 0.20$. Contrast-coded analysis (−1, −1, −1, +3, for the three intervention groups and the control group, respectively) was significant, $t(36) = 2.87$, $p = .01$, indicating that participants in the intervention groups outperformed control participants in the posttest. A contrast-coded test +1, +1, −2, for the dynamic handgrip, extensive PPR, and combined groups, respectively, was not significant, $t(36) = -0.13$, $p = .90$, indicating that the benefits of dynamic handgrip and extensive PPR used in combination were not significantly higher than interventions used in isolation.

State Anxiety. We conducted a 4 × 2 (Group × Phase) repeated measures ANOVA to examine whether the anxiety changed across the four groups from pretest to posttest (Table 3). The ANOVA revealed no Phase main effect and no interaction ($ps > .23$), indicating that participants exhibited the same anxiety levels pretest and posttest. There was only a main effect for group in somatic anxiety, $F(3, 36) = 3.55$, $p = .02$, $\eta_p^2 = 0.23$, which was due to significant group differences pretest, $F(3, 36) = 3.34$, $p = .03$, $\eta_p^2 = 0.22$.

Bowling League Performance. A 4 × 2 (Group × Phase) repeated measures ANOVA for in-game performance (see Table 2) indicated no significant Group, $F(3, 36) = 0.81$, $p = .49$, $\eta_p^2 = 0.06$ or Phase main effect, $F(1, 36) = 0.34$, $p = .56$, $\eta_p^2 = 0.01$, but a marginal interaction, $F(3, 36) = 2.34$, $p = .090$, $\eta_p^2 = 0.16$. However, subsequent simple main effects analysis did not reveal group differences either pretest or posttest ($ps > .41$).

Routine Use. Four participants (i.e., three from the dynamic handgrip and one from the PPR groups) did not reply to the SMS request about routine use, thus they were excluded from this analysis. Participants indicated regular use of their routines during league ($M = 6.81$, $SD = 2.51$). No significant Group differences, $F(2, 23) = 1.70$, $p = .21$, $\eta_p^2 = 0.13$, were found, which indicates that groups were equivalent on the amount they used the intervention during league.

8. Discussion

Study 2 provided support for the hypothesis that experienced sport participants using PPR preparation strategies would perform better on an accuracy test than a control group for a sport-specific task with all intervention groups performing more accurately from pretest to posttest than the control group. This hypothesis, however, was not supported when investigating in-game performance. It appears that using the preparation strategies may help as much in isolation as they do in combination considering there was no robust combined effect on accuracy (or in-game) performance.

8.1. Study 2 limitations

There were some limitations to Study 2 that should be mentioned. The in-game performance results may have been influenced by modifications to the oil patterns on the bowling lane throughout the eight weeks of the study, which could not be controlled in an experimental setting due to the nature of bowling leagues. This may have affected the participants' results because the oil pattern was changed for one “sport bowling” (i.e., more difficult oil patterns that change every four weeks) league. Future research should attempt to better control for oil patterns when conducting bowling-specific research especially when using in-game performance scores across many weeks.

Another limitation of Study 2 was that the anxiety manipulation was not effective for the experienced athletes. On a descriptive level, anxiety scores of the control group increased four-to-five times as much as those of the intervention groups. The athletes in Study 2 were using the intervention for five bowling trials in the posttest prior to recording their anxiety levels, which is largely different to Study 1 in this paper, and also past researchers (e.g., Beckmann et al., 2013; Lautenbach et al., 2015), which are generally recorded prior to pressure phases. Even though the interaction was not significant, the question arises of whether the interventions could have helped reduce anxiety in the posttest whereas the control participants did not have anything to help them cope under pressure. The present data are inconclusive in this regard. Thus, whether or not PPR interventions help reduce anxiety is an avenue for future research.

8.2. General discussion

The purpose of this multi-study research paper was to ascertain whether left-hand dynamic handgrip has effects comparable to other evidence-based PPR (i.e., the extensive PPR; Mesagno & Mullane-Grant, 2010) in improving accuracy in closed, self-paced motor performance

Table 3
Mean and Standard Deviation (SD) for cognitive anxiety and somatic anxiety pretest and posttest for the different groups (Study 2).

Group	Cognitive Anxiety		Somatic Anxiety	
	Pre	Post	Pre	Post
Dynamic handgrip	15.20 (13.86)	17.90 (15.40)	17.60 (17.87)	22.70 (19.26)
PPR	19.10 (16.09)	18.70 (12.80)	36.10 (22.48)	31.90 (20.86)
Combined	29.90 (24.64)	28.70 (17.17)	47.00 (25.49)	45.30 (23.71)
Control	16.50 (15.90)	27.30 (24.02)	24.70 (22.92)	45.70 (29.95)

both in a simulated and sport-specific task. We also investigated whether combining dynamic handgrip with an extensive PPR may have an additive performance effect. This was the first known research paper to compare dynamic handgrip with other PPR interventions to improve performance or examine additive performance effects.

8.3. Performance accuracy

In both studies, the intervention groups were more accurate than the control group. This result supports other general performance (e.g., Boutcher & Crews, 1987; Cohn, Rotella, & Lloyd, 1990; Marlow, Bull, Heath, & Shambrook, 1998) and performance under pressure (e.g., Gröpel & Mesagno, 2017; Lautenbach et al., 2015; Mesagno et al., 2008; Mesagno et al., 2015; Mesagno & Mullane-Grant, 2010) intervention research, which indicated that a PPR generally helps to improve performance accuracy. The general performance improvement effect was mainly exhibited in less experienced students without anxiety present (Study 1, the first posttest) and on a sport-specific task where the posttest (pressure) phase was not effective in increasing anxiety in experienced bowlers (Study 2). This also supports researchers' (e.g., Cotterill, 2010; Czech et al., 2004; Kingston & Hardy, 2001; Lidor & Mayan, 2005; Mesagno et al., 2015) views that a PPR can generally (i.e., not under increased anxiety) help athletes of all skill levels perform more accurately. This is the first study to show that the dynamic handgrip preparatory strategy is also effective in situations where no perceived anxiety increase occurs since researchers (Beckmann et al., 2013; Gröpel & Beckmann, 2017) have, to date, reported that the dynamic handgrip strategy improved performance accuracy under pressure. This positive result may indicate that dynamic handgrip could be used for performance accuracy irrespective of how much (or little) anxiety the participants' experience.

Using a combined (i.e., dynamic handgrip and extensive) PPR, however, may not have accumulative performance effects as one might assume. That is, the combined dynamic handgrip and PPR group in the current paper did not equate to better accuracy based on using both interventions together. Yet, in both studies, the combined PPR was still a better intervention for performance accuracy than having no PPR at all (i.e., control group). These results refute other researchers' results (e.g., Mesagno et al., 2015; Mesagno & Mullane-Grant, 2010) who found that using different components in a combined routine had a greater accuracy performance effect than the respective components in isolation. These differences are likely inherently design related. First, when reflecting on the comparison between studies that had similar short (i.e., 15 min) learning period intervention development (i.e., the current paper and Mesagno & Mullane-Grant, 2010), the Mesagno and Mullane-Grant study was a combination of behavior routines that seemed to fit well to help the athletes maintain focused attention. The current study, however, provided a preparation strategy to a routine that was not directly related to improving concentration (i.e., dynamic handgrip) and was relatively unfamiliar to participants. Secondly, the Mesagno et al. (2015) study was different to the current paper because the time allotted to learn the intervention was extended (i.e., 4-weeks). That is, in the current paper, there was likely not enough time (i.e., approximately 15 min) to learn the routine in a way that allowed them to become comfortable with the extra cognitive load. Perhaps participants were overwhelmed by an abundance of routine steps while combining the dynamic handgrip and extensive PPR during the accuracy test. These concerns were likely a difference in the results between Mesagno et al. and this paper, considering Mesagno et al. found, qualitatively, that participants reported that using both routines was initially distracting. Furthermore, it appears that participants in the Mesagno et al. study favoured the PPR over the post-performance routine in the combined group, which is expected since the PPR was to help with concentration before each shot. Since the post-performance routine intervention was cognitive (i.e., bowlers asked themselves evaluation questions about previous attempts) rather than behavioural in the Mesagno et al. study, there was no way of determining that it was followed precisely. This selective processing may have been the reason for the equal improvements in performance accuracy of participants in the combined and PPR groups in the Mesagno et al. study, but in the current paper, the steps of the dynamic handgrip and extensive PPR groups were mainly behavioural, overt, monitored closely, and could not be avoided.

We also note that these combined results did not change even with the slightly different design variations within the two studies in the current paper. That is, even though participants in Study 1 used dynamic handgrip *during* their extensive PPR and bowlers in Study 2 completed dynamic handgrip *prior to* the extensive PPR and shot attempt, the results remained the same that the combined groups were no better than the PPR in isolation. These results should be interpreted with caution since other factors (e.g., participant skill level) could have affected the results. Future research should explore the possible effect of different sequences of using combined PPR on performance accuracy.

8.4. In-game performance (study 2 only)

This was the first study to examine and compare the effects of dynamic handgrip and extensive PPR on in-game performance. The effect of intervention training on in-game performance was weaker compared to the results of the accuracy test, with no significant differences existing among groups. These results are contradictory to within-competition benefits experienced by other PPR studies (Gröpel & Beckmann, 2017; Mesagno et al., 2015). That is, Gröpel and Beckmann found that dynamic handgrip was more beneficial to competition performance compared to control groups in a multi-study paper and Mesagno et al. found that pre- and post-performance routine interventions were beneficial to tenpin bowling league averages over a 4-week competition period in comparison to a control group. An explanation for the weak effect for the interventions in the current paper might lie in the short education session (i.e., up to 15 min), with longer education and intervention training perhaps bringing stronger applied and real world benefits for competition (see Mesagno et al., 2015). Future research should investigate the dose-response effect of education sessions for maximum in-game benefits.

8.5. Overall limitations

Along with the already mentioned inherent study design issues, there is at least one shortfall to both studies. We did not control for, or assess, participants' coping skills, which could have helped participants cope with the pressure phase more easily in both studies. This is especially true for the moderate to experienced athletes (in Study 2) who have more experience with pressure situations in sport, and arguably better coping mechanisms, than novices (in Study 1). The more advanced coping skills may have been another reason for the limited anxiety increase for the more experienced bowlers in Study 2. Nevertheless, even if we controlled for coping skills, there would have been no way out of knowing whether coping skills or the group-specific PPR intervention were the reason for the non-significant anxiety result. Future researchers would benefit to control for coping ability in PPR research settings (under pressure) or determine if PPR education directly effects coping ability.

8.6. Future research

This study provides first insights to using dynamic handgrip as a possible element to improve movement accuracy and sport performance in the field. Future research should therefore focus on testing dynamic handgrip in comparison to other preparation strategies in other sport settings. Since most team sports do not allow for intervention breaks, single components of the sport (e.g., serves or penalty shots) could be examined in future research. Furthermore, it would be interesting to replicate these studies within various shooting sports in order to investigate whether similar effects can be found. Also, using EEG equipment to measure what brain activation might occur during different PPRs would help us understand brain functioning when using PPRs.

Additionally, researchers should explicitly address the question of optimal length of the dynamic handgrip. That is, although the dynamic handgrip improved accuracy in these studies, because of a lack of comparison between our length of hand contractions (i.e., 10 s) and Beckmann et al. (2013) studies' hand contractions length (i.e., 30 s), we cannot conclude that 10 s is as efficient as 30 s. Thus, a fruitful avenue for future research might be to determine an optimal length of left-hand contractions to improve accuracy and in-game performance.

8.7. Applied implications

The dynamic handgrip is effective in preventing motor skill failure (choking under pressure; Beckmann, et al., 2013; Gröpel & Beckmann, 2017). In this series of studies, dynamic handgrip has been effectively integrated as a preparation strategy into a PPR and is applicable to moderate to highly skill athletes. Based on Reinvestment theory (Masters, 1992) that underlies the elimination of choking under pressure, the dynamic handgrip should be effective only if (complex) motor skills have already become automated. Since dynamic handgrip does not require extensive motor learning and is easy to include into practice especially for skilled athletes, it could constitute a simple and valuable tool for coaches and athletes to implement for enhanced performance in general, or under pressure, even if they have not worked alongside a sport psychologist developing this strategy. Experienced sport psychologists could further develop PPRs with athletes and potentially combine those individually developed PPRs with the dynamic handgrip. Based on the current study and other PPR results (Mesagno et al., 2015), it may be beneficial to provide a longer education period when combining the extensive PPR and dynamic handgrip to ensure reduced cognitive load so that the execution of the PPR does not consume cognitive capacity. Furthermore, the current research used adults in both studies, yet PPRs and preparation strategies that include dynamic handgrip could be systematically developed in experienced, youth athletes. Incorporating preparation strategies, such as the ones investigated in these studies, into training and competition can help youth athletes understand to better concentrate and potentially a method of cortical relaxation at a young age, which may add to their ability to deal with the pressure of competition.

9. Conclusions

This collection of studies found that single, preparation strategies (e.g., left-hand dynamic handgrip) may be comparable to extensive PPRs when measuring performance accuracy especially when compared to a group who received no intervention. It may be questioned whether the simple embodiment technique of dynamic handgrip could, in fact, be replaced by a PPR with several components and still improve accuracy or in-game performance. The dynamic handgrip seemed to have a relaxation, or reset, function, which Cross-Villasana et al. (2015) found to induce spreading cortical relaxation, however, it may not increase concentration on the task. Increased concentration could be achieved through other elements of a PPR (e.g., cue words, behaviours, etc.). Thus, other explicit aids may be added to PPRs to focus attention, which is important for performance generally (and under pressure) in any target-based (i.e., focusing on an external cue for aiming) sports.

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