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Mesagno, C., Beckmann, J., Wergin, V. V., & Gröpel, P. (2019). Primed to perform: Comparing different pre-performance routine interventions to improve accuracy in closed, self-paced motor tasks. *Psychology of Sport and Exercise*, 43, 73–81.

Which has been published in final form at:
<https://doi.org/10.1016/j.psychsport.2019.01.001>

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1 Running head: PRE-PERFORMANCE INTERVENTIONS

2

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

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12 Accepted Manuscript into the journal: *Psychology of Sport and Exercise*

13 Please reference this article:

14 Mesagno, C., Beckmann, J., Wergin, V. V., & Gröpel, P. (2019). Primed to perform: Comparing
 15 different pre-performance routine interventions to improve accuracy in closed, self-paced motor
 16 tasks. *Psychology of Sport and Exercise*, 43(4), 73-81.

17 Doi link: <https://doi.org/10.1016/j.psychsport.2019.01.001>

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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 standardized 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).

Keywords: Extensive routine, left-hand contractions, skilled performance, pre-shot, choking

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Highlights

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- Left-hand dynamic handgrip and extensive routines were compared in two studies.

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- Motor performance was tested on both inexperienced students and skilled athletes.

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- All pre-performance routine groups improved accuracy compared to a control.

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- Combining routines had no greater effect than using the routine in isolation.

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- No differences in groups were apparent for in-game performance in Study 2.

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

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

17 Using a PPR is commonplace in self-paced, closed skill tasks, such as putting in golf (Hill,
 18 Hanton, Matthews, & Fleming, 2011), free throw shooting in basketball (Czech, Ploszay, &
 19 Burke, 2004; Lonsdale & Tam, 2007), execution of a tenpin bowling delivery (Mesagno, Hill, &
 20 Larkin, 2015), and performing a routine in gymnastics (Clowes & Knowles, 2013). Researchers
 21 have repeatedly found that using a PPR can improve performance generally, for all skill levels,
 22 with novices benefitting most from PPR development (e.g., Beauchamp, Halliwell, Fournier, &
 23 Koestner, 1996; Lidor & Mayan, 2005; McCann, Lavalley, & Lavalley, 2001). For example,
 24 Lidor and Mayan examined whether female volleyball players would benefit from PPR
 25 development prior to a self-paced, closed motor skill (i.e., volleyball serve). Results indicated

1 that the volleyball players who developed a predominantly behavioural PPR were more accurate
 2 in retention trials than groups using either, a predominantly cognitive (i.e., mainly focused on
 3 mental skills training) routine, or technical instruction. The effectiveness of a PPR for
 4 experienced athletes, however, has been mixed (e.g., Cotterill, Sanders, & Collins, 2010; Czech
 5 et al., 2004; Kingston & Hardy, 2001; Mesagno et al., 2015). The equivocal results for
 6 experienced athletes may be a product of research design issues with some researchers
 7 suggesting that a PPR should be individualized with consideration for learning styles and
 8 personality in PPR development and education (see Cotterill, 2010 for a review). The subjective
 9 benefits of using a PPR may include (but are not limited to) reduced negative introspection
 10 (Beauchamp et al., 1996), lowered anxiety levels (Hazell, Cotterill, & Hill, 2014), and increased
 11 attention to the task at hand (Cotterill et al., 2010; Harle & Vickers, 2001).

12 Researchers have also found that using a PPR can sustain (Hazell, Cotterill, & Hill, 2014;
 13 Mesagno, Hill, & Larkin, 2015) or improve (Lautenbach et al., 2015; Mesagno, Marchant, &
 14 Morris, 2008; Mesagno & Mullane-Grant, 2010) performance accuracy under pressure, with no
 15 studies to date showing negative effects (Gröpel & Mesagno, 2017). In particular, Lautenbach et
 16 al. found that tennis players showed decreased performance under pressure prior to learning a
 17 PPR, but not following PPR education. Mesagno and Mullane-Grant (2010) also investigated
 18 whether an extensive PPR, comprising of different preparation components (e.g., deep breath,
 19 cue word, and temporal consistency) has a stronger effect on performance than the respective
 20 components in isolation. This experimental study on Australian Football players found that using
 21 different preparation components in isolation was beneficial but using an extensive PPR (with
 22 many preparation strategies included) exhibited the greatest accuracy compared to a control
 23 group who received no PPR education. In another study, Mesagno et al. (2008) examined
 24 whether using an extensive PPR could help reduce performance failure in “choking-susceptible”
 25 (i.e., likely to worsen performance under pressure) athletes. Findings indicated that the athletes

1 improved performance when using the extensive PPR and interviews after the experimental
 2 phase revealed that participants perceived an improvement in task-relevant attention under
 3 pressure in comparison to an earlier pressure phase. These combined results indicate that using
 4 different preparation components in combination may have a beneficial and cumulative effect on
 5 performance (see Gröpel & Mesagno, 2017 for a review of choking under pressure interventions
 6 that include PPR studies).

7 An additional behavioural, preparatory strategy that could be added to, and possibly
 8 benefit, a PPR, is left-hand dynamic handgrip (Beckmann et al., 2013; Gröpel & Beckmann,
 9 2017). The basis for using left-hand dynamic handgrip within a PPR originates from researchers
 10 who found that inferior performance may be a result of self-focused attention (Beilock & Carr,
 11 2001; Masters, 1992) and that a dominant left-hemispheric activation during performance
 12 execution underlies this self-focused attention (Babiloni et al., 2010; Crews, 2004; Gallicchio,
 13 Cooke & Ring, 2015; Salazar et al., 1990). Notably, as reported in electroencephalographic
 14 (EEG) studies, contractions of the left hand increase the activation of the contralateral motor
 15 cortex during hand clenching (Harmon-Jones, 2006; Peterson, Shackman, & Harmon-Jones,
 16 2008). Thus, it was suggested to decrease the detrimental left hemispheric activation through
 17 inducing right hemispheric activation with a left hand dynamic handgrip. EEG findings in fact
 18 proved that left-hand dynamic clenching activates the right hemisphere motor cortex, which then
 19 initiates an increase in the 8-12 Hz alpha band that spreads across the whole cortex including the
 20 left-hemispheric areas associated with self-focused attention. The high alpha is indicative of a
 21 state of cortical relaxation in both hemispheres after hand clenching (Cross-Villasana, Gröpel,
 22 Doppelmayr, & Beckmann, 2015), and the dominant activation in the left hemisphere is reduced.
 23 Thus, left-hand dynamic handgrip may help to attenuate self-focused attention and promote more
 24 accurate skill and performance execution. In sport, Beckmann et al. observed that experienced
 25 soccer, taekwondo, and badminton athletes who squeezed a soft ball with their left hand,

1 approximately twice a second, for 30 seconds performed more accurately in a simulated
 2 competition than their counterparts in a control group who squeezed the soft ball with their right
 3 hand. Gröpel and Beckmann replicated these findings with a sample of artistic gymnasts in an
 4 actual competition.

5 Left-hand dynamic handgrip research, to date, is in its infancy. Research tasks use closed
 6 skills and field based experiments that examine performance accuracy and outcome without
 7 closer inspection of the performed motor skills (i.e., eye-hand coordination) or different skill
 8 levels (only highly skilled performers have been included in previous left-hand dynamic
 9 handgrip studies). Furthermore, left-hand dynamic handgrip studies have largely been tested in
 10 isolation without comparison with other preparatory strategies such as extensive PPRs.

11 Beckmann et al. (2013) suggested integrating left-hand dynamic handgrip in athletes' existing
 12 PPRs, but there is no evidence to date of this combination strategy being investigated.

13 Comparing different pre-performance preparation strategies helps to determine which strategies
 14 may be most used for performance generally and under pressure.

15 **The present research**

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

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1 only three participants identifying as left-hand dominant¹. Two participants showed poor
 2 outcome performance (i.e., score below 3 *SD*), resulting in the removal of their data. The final
 3 sample consisted of 46 participants (35 female, 11 male), with a mean age of 21.5 years (*SD* =
 4 1.59; range = 18–26 years). Prior to participating in the study, the participants were explained the
 5 experimental procedures, assured the confidentiality of their data, and their right to cease the
 6 experiment at any time without consequences. Participants provided signed informed consent in
 7 accordance with the guidelines of the Declaration of Helsinki. Ethical approval for the study was
 8 secured in line with the authors' institutional procedures.

9 **Task and Apparatus.** Participants performed the standardized Two-Hand Coordination
 10 Test, which is a part of the Vienna Test System software (Schuhfried, 2010). This test assesses
 11 eye-hand coordination and coordination between the left and right hand by manoeuvring a red
 12 dot along a given track. Participants' task was to make the red dot move as fast as possible along
 13 the track without hitting the line. The track (same in each trial) consists of both straight and
 14 curved sections. Participants performed the test on a computer using two special control knobs;
 15 the left knob made the dot move horizontally and the right knob vertically. Outcome variables
 16 were speed, operationalized as duration time, and accuracy, operationalized as the number of
 17 errors (i.e., hitting the line). Because speed and accuracy were correlated across trials ($r = -.29$, p
 18 $= .05$), indicating that faster participants made more errors, we calculate the inverse efficiency
 19 scores (IES) as the performance variable to take the speed-accuracy trade-off into account
 20 (Bruyer & Brysbaert, 2011). These scores were derived by multiplying the duration time and the
 21 number of errors separately for each trial; +1 was added to the number of errors to avoid
 22 multiplication by zero. Lower scores thus indicated better performance.

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.

1 **Measures.** State anxiety was measured using the Mental Readiness Form-3 (MRF-3;
2 Krane, 1994) because it can be used in a quick, efficient manner without much disruption. The
3 MRF-3 has three separate 100 millimetre (mm) continuums that are anchored between *calm* and
4 *worried* for cognitive anxiety, *relaxed* and *tense* for somatic anxiety and *confident*, and *not*
5 *confident* for self-confidence. The participant places a mark on each of the three lines to show
6 how he or she was feeling at that moment. The measurement between the left part of, and the
7 participant mark on, the line was the participant's score out of 100, with higher scores indicating
8 a higher anxiety. We used only the somatic and the cognitive subscales for the analyses because
9 they represent the central aspects of anxiety. Krane reported the correlations of the MRF-3 to the
10 Competitive State Anxiety Inventory-2 (CSAI-2; Martens, Burton, Vealey, Bump, & Smith,
11 1990) to be 0.76 for cognitive anxiety and 0.69 for somatic anxiety.

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

21 In the first test phase (herein called the first posttest), preparation strategy interventions
22 were introduced. We randomized participants to one of three intervention groups or to a control
23 group. In the *left-hand dynamic handgrip* (labelled dynamic handgrip hereafter) group,
24 participants dynamically squeezed a soft, relatively “squishy” ball in their left hand for 10 s,
25 about twice a second, before each trial. Generally, the dynamic handgrip duration was based on

1 cognitive psychology research evidence (e.g., Pfurtscheller & Lopes da Silva, 1999) that a single
 2 hand clench is too short for behavioural after-effects because it produced a brief alpha response
 3 that phased out whereas longer handgrip durations (e.g., 45-60 s) are effective (e.g., Baumann,
 4 Kuhl & Kazen, 2005; Harmon-Jones, 2006), but may be too lengthy as PPRs and within sport.
 5 Thus, we used a dynamic handgrip duration of 10 s (instead of 30 s used by Beckmann et al.,
 6 2013) to allow comparison with an extensive PPR that takes about 10 s (Mesagno & Mullane-
 7 Grant, 2010) and to optimise ecological validity when used in sport. In the *extensive PPR* group,
 8 participants focused on the start line of the track (i.e., external focus of attention), took three
 9 deep breaths (i.e., arousal control), and then provided a 3 s “countdown” aloud before each trial.
 10 These preparation strategies, both in isolation and in combination, have been used efficiently in
 11 existing research (Mesagno et al., 2008; Mesagno & Mullane-Grant, 2010). The extensive PPR
 12 was not individualized; participants in this group learned the same PPR. The *combined* dynamic
 13 handgrip and PPR group (hereafter labelled “combined”) completed both the extensive PPR and
 14 dynamic handgrip simultaneously. While squeezing the ball in their left hand, participants
 15 focused on the start line of the track, took three deep breaths, and provided the countdown.
 16 Participants in either group were trained in the PPRs until they indicated their understanding by
 17 demonstrating the PPR to the researcher. Next, participants completed another four trials of the
 18 Two-Hand Coordination test, with their respective PPR before each trial. Participants in the
 19 *control* group completed the test without any PPR education or instructions.

20 In the second test phase (herein called the second posttest), participants performed the
 21 Two-Hand Coordination test with the above interventions under pressure. We induced pressure
 22 with the second part of Trier Social Stress Test (TSST; Kirschbaum, Pirke, & Hellhammer,
 23 1993). Participants counted aloud and backward from 1022 in steps of 13 in front of a video
 24 camera (located in front, and in full view, of the participant) and two judges (a researcher and
 25 confederate). If a mistake was made, the researcher asked participants to start from the

1 beginning. Participants completed the MRF-3 for a second time after instructions about the
 2 second posttest were read and then completed the last four trials of the Two-Hand Coordination
 3 test, with his or her respective PPR before each trial. Finally, participants were debriefed,
 4 thanked, and dismissed.

5 **Results**

6 **Acquisition Phase.** We split the 20 practice trials into five blocks of four to allow
 7 comparison of the acquisition and test phases (Figure 1). The results of a one-way analysis of
 8 variance (ANOVA) on the first practice block indicated that all groups had similar task
 9 performance, $F(3, 42) = 1.24, p = .31, \eta_p^2 = .08$. We then conducted a 4×5 (Group $\times$ Block)
 10 repeated measures ANOVA to examine the performance scores. The ANOVA (Box's $M = 83.10$,
 11 $p = .03$; Mauchly's $W = .13, p < .001$) revealed a main effect for Block, corrected $F(2.22, 93.41)$
 12 $= 34.45, p < .001, \eta_p^2 = .45$, and a marginal Group effect, $F(3, 42) = 2.28, p = .093, \eta_p^2 = .14$.
 13 Notably, there was no interaction, corrected $F(6.67, 93.41) = 1.11, p = .36, \eta_p^2 = .07$, indicating
 14 that learning took place over the five blocks and that a similar pattern of skill acquisition
 15 occurred in all groups. Simple paired t -tests revealed that performance stabilized from Block 4 to
 16 Block 5 in all groups ($ts < .84, ps > .42$); it was therefore appropriate to use Block 5 as pretest
 17 performance in subsequent analyses.

18 **Task Performance.** We conducted a 4×3 (Group $\times$ Phase) repeated measures ANOVA to
 19 examine the performance scores in the four groups over the three study phases: the pretest
 20 (Block 5), the first posttest, and the second posttest. The ANOVA (Box's $M = 35.83, p = .03$;
 21 Mauchly's $W = .84, p = .03$) revealed a main effect for Phase, corrected $F(1.72, 72.33) = 17.78, p$
 22 $< .001, \eta_p^2 = .30$, a non-significant main effect for Group, $F(3, 42) = 1.48, p = .23, \eta_p^2 = .10$, and
 23 a marginal interaction, corrected $F(5.17, 72.33) = 2.03, p = .082, \eta_p^2 = .13$. Subsequent simple
 24 main effects analysis indicated no group differences pretest, $F(3, 42) = 1.28, p = .29, \eta_p^2 = .08$, a
 25 significant group difference in the first posttest, $F(3, 42) = 3.45, p = .025, \eta_p^2 = .20$, and no

1 group differences in the second posttest, $F(3, 42) = .97, p = .42, \eta_p^2 = .07$. Contrast-coded
 2 analysis $(-1, -1, -1, +3, \text{ for the three intervention groups and the control group, respectively})$ in
 3 the first posttest was significant, corrected $t(15.66) = 2.18, p = .045$, indicating that participants in
 4 the intervention groups outperformed control participants. A contrast-coded test $+1, +1, -2$, for
 5 the dynamic handgrip, extensive PPR, and combined groups, respectively, was not significant,
 6 $t(12.99) = .60, p = .56$, indicating that the benefits of dynamic handgrip and extensive PPR were
 7 the same irrespective of whether used in combination or in isolation.

8 **State Anxiety.** We conducted a 4×2 (Group $\times$ Phase) repeated measures ANOVA to
 9 examine whether the anxiety changed across the four groups from pre- to post-pressure
 10 induction. As shown in Table 1, participants exhibited significantly higher somatic, $F(1, 42) =$
 11 $43.86, p < .001, \eta_p^2 = 0.51$, and cognitive, $F(1, 42) = 8.03, p = .007, \eta_p^2 = 0.16$, anxiety after
 12 pressure induction than at the commencement of the study. Neither a group effect nor an
 13 interaction were significant ($F_s < 1.59, p_s > .21$), indicating that pressure induction effectively
 14 increased the participants' anxiety in all groups.

15 Discussion

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

Study 1 Limitations

Even though using laboratory tasks has many benefits, including standardized 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.

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.

Method

Participants. An a priori sample-size calculation with G*Power (Faul et al., 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

1 “attended group workshops with a sport psychologist”, not related to performance routines; these
 2 participants were randomly (and evenly) “assigned” to the groups. The study was approved by
 3 the first author’s University Research Ethics Committee.

4 **Equipment.** Standard bowling equipment and facilities similar to Mesagno et al. (2008)
 5 and Mesagno et al. (2015) were used. This included bowling balls with weights ranging between
 6 10 lbs (4.54 kg) and 16 lbs (7.26 kg), standard approaches of 15 ft (5.57 m), bowling lane with
 7 length of 60 ft (18.29 m) from foul line to “head” pin, and bowling pins weighing approximately
 8 6 lbs (1.5 kg) each.

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

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

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

22 **Experimental Groups**

23 Participants were randomly allocated into one of four groups: extensive PPR only, dynamic
 24 handgrip only, combined PPR and dynamic handgrip, or wait-list control. The *extensive PPR*
 25 group involved participants developing, or modifying their existing PPR. Within the PPR,

1 optimal arousal levels (e.g., deep breaths), behavioural steps, attentional control (e.g., focusing
 2 on a target), and cue words (when needed) were considered for inclusion into the PPR. Since the
 3 PPR was personalised for each participant (Boutcher, 1990; Cotterill et al., 2010), these steps
 4 were possible elements to include, but were not necessarily uniform across all PPR and
 5 combined groups. The first author (a certified tenpin bowling coach and sport psychology
 6 consultant) attended all testing sessions and identified appropriate components of the PPR while
 7 taking notes on each participant's routine. After conducting other bowling related studies (e.g.,
 8 Mesagno et al., 2008; Mesagno et al., 2015), a common segment of participant's routine not
 9 adhered to (irrespective of bowling ability) is watching the fingers and thumb being inserted into
 10 the bowling ball before each delivery. Thus, participants in the PPR group were instructed to
 11 attend (at the least) to this part of the routine.

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

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

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

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

9 **Procedures**

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

17 The pretest involved 30 shot attempts at a target on the bowling lane to measure accuracy,
 18 with an independent research assistant completing data collection. After the initial five shot
 19 attempts, the participant completed the MRF-3 to measure state anxiety during the accuracy test.
 20 Following the pretest (on the same day), a group-specific PPR development session was offered
 21 to each participant in the three experimental groups (i.e., extensive PPR, dynamic handgrip, or
 22 combined). The posttest was identical to the pretest with the exception that participants in each
 23 group implemented their PPR (or usual routine in the case of the control group) in the posttest. In
 24 addition, we induced pressure in the posttest by setting up a video camera adjacent (in front, and
 25 in full view, of the participants) to the bowling lane. The video camera was turned on for the

1 duration of the posttest phase. Each participant was informed that the researchers were seeking
 2 maximum media exposure for the study and that the university media manager suggested to
 3 video record each participant during the posttest, which would be used for still photos for
 4 newspaper and video footage for television news programs. To make it more believable, the
 5 participant was informed about the collaborative grant the researchers received for this study and
 6 it was explained the video footage would be shared among the researchers for maximum
 7 international media coverage. The participant was also told that group-specific routines should
 8 be followed and accuracy measurements would be the focus of this test to emphasize the
 9 importance of the situation. During the posttest, participants in the intervention groups were
 10 monitored closely by the researcher (and video-recording) to ensure that they completed the
 11 group-specific routine accurately. In cases where the routine was not completed, the shot attempt
 12 was terminated and participants were asked to stop, reset, and complete the routine again. A total
 13 of 11 shots (i.e., 1 = PPR, 4 = dynamic handgrip, 6 = combined), out of all posttest shots for all
 14 participants were stopped, reset, and completed again due to routine non-adherence during a shot
 15 attempt.

16 To investigate in-game performance changes, the 12 competition (i.e., league-based)
 17 games prior to, and immediately following, the accuracy testing were obtained from the league
 18 secretary (similar to Mesagno et al., 2015). Internal consistencies (Cronbach's alpha) for the 12
 19 competition game scores before and after the accuracy testing were .84 and .86, respectively.
 20 Finally, after the 12 games of league play following the accuracy testing, the routine use question
 21 was sent via sms (i.e., short message service) to each participant in the intervention groups to
 22 determine the amount they used their group-specific routine.

23 **Results**

24 **Homogeneity of Groups.** A one-way ANOVA on league average (see Table 2 for
 25 descriptive statistics) indicated no significant Group differences, $F(3, 36) = .55, p = .65, \eta_p^2 =$

1 .04. Thus, equal group-based bowling ability was found. Similarly, there were no significant
 2 Group differences, $F(3, 36) = .06, p = .98, \eta_p^2 = .01$, for total number of leagues bowled per
 3 week (ranging from one to three leagues), indicating that the amount of leagues bowled in per
 4 week should not affect performance.

5 **Task Performance.** We conducted a 4×2 (Group $\times$ Phase) repeated measures ANOVA to
 6 examine the accuracy scores (see Table 2). The ANOVA indicated a non-significant Phase main
 7 effect, $F(1, 36) = .31, p = .58, \eta_p^2 = .01$, a non-significant Group main effect, $F(3, 36) = 1.96, p =$
 8 $.14, \eta_p^2 = .14$, but a significant interaction, $F(3, 36) = 3.75, p = .02, \eta_p^2 = .24$. Subsequent simple
 9 main effects analysis indicated no group differences pretest, $F(3, 36) = 1.20, p = .33, \eta_p^2 = .09$,
 10 but a significant group difference posttest, $F(3, 36) = 2.91, p = .048, \eta_p^2 = .20$. Contrast-coded
 11 analysis ($-1, -1, -1, +3$, for the three intervention groups and the control group, respectively)
 12 was significant, $t(36) = 2.87, p = .01$, indicating that participants in the intervention groups
 13 outperformed control participants in the posttest. A contrast-coded test $+1, +1, -2$, for the
 14 dynamic handgrip, extensive PPR, and combined groups, respectively, was not significant, $t(36)$
 15 $= -.13, p = .90$, indicating that the benefits of dynamic handgrip and extensive PPR used in
 16 combination were not significantly higher than interventions used in isolation.

17 **State Anxiety.** We conducted a 4×2 (Group $\times$ Phase) repeated measures ANOVA to
 18 examine whether the anxiety changed across the four groups from pretest to posttest (Table 3).
 19 The ANOVA revealed no Phase main effect and no interaction ($ps > .23$), indicating that
 20 participants exhibited the same anxiety levels pretest and posttest. There was only a main effect
 21 for group in somatic anxiety, $F(3, 36) = 3.55, p = .02, \eta_p^2 = .23$, which was due to significant
 22 group differences pretest, $F(3, 36) = 3.34, p = .03, \eta_p^2 = .22$.

23 **Bowling League Performance.** A 4×2 (Group $\times$ Phase) repeated measures ANOVA for
 24 in-game performance (see Table 2) indicated no significant Group, $F(3, 36) = .81, p = .49, \eta_p^2 =$
 25 $.06$ or Phase main effect, $F(1, 36) = .34, p = .56, \eta_p^2 = .01$, but a marginal interaction, $F(3, 36) =$

1 2.34, $p = .090$, $\eta_p^2 = .16$. However, subsequent simple main effects analysis did not reveal group
 2 differences either pretest or posttest ($ps > .41$).

3 **Routine Use.** Four participants (i.e., three from the dynamic handgrip and one from the
 4 PPR groups) did not reply to the SMS request about routine use, thus they were excluded from
 5 this analysis. Participants indicated regular use of their routines during league ($M = 6.81$, $SD =$
 6 2.51). No significant Group differences, $F(2, 23) = 1.70$, $p = .21$, $\eta_p^2 = .13$, were found, which
 7 indicates that groups were equivalent on the amount they used the intervention during league.

8 **Discussion**

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

16 **Study 2 Limitations**

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

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

11 **General Discussion**

12 The purpose of this multi-study research paper was to ascertain whether left-hand dynamic
 13 handgrip has effects comparable to other evidence-based PPR (i.e., the extensive PPR; Mesagno
 14 & Mullane-Grant, 2010) in improving accuracy in closed, self-paced motor performance both in
 15 a simulated and sport-specific task. We also investigated whether combining dynamic handgrip
 16 with an extensive PPR may have an additive performance effect. This was the first known
 17 research paper to compare dynamic handgrip with other PPR interventions to improve
 18 performance or examine additive performance effects.

19 **Performance Accuracy**

20 In both studies, the intervention groups were more accurate than the control group. This
 21 result supports other general performance (e.g., Boutcher & Crews, 1987; Cohn et al., 1990;
 22 Marlow et al., 1998) and performance under pressure (e.g., Gröpel & Mesagno, 2017;
 23 Lautenbach et al., 2015; Mesagno et al., 2015; Mesagno et al., 2008; Mesagno & Mullane-Grant,
 24 2010) intervention research, which indicated that a PPR generally helps to improve performance
 25 accuracy. The general performance improvement effect was mainly exhibited in less experienced

1 students without anxiety present (Study 1, the first posttest) and on a sport-specific task where
 2 the posttest (pressure) phase was not effective in increasing anxiety in experienced bowlers
 3 (Study 2). This also supports researchers' (e.g., Kingston & Hardy, 2001; Cotterill, 2010; Czech
 4 et al., 2004; Lidor & Mayan, 2005; Mesagno et al., 2015) views that a PPR can generally (i.e.,
 5 not under increased anxiety) help athletes of all skill levels perform more accurately. This is the
 6 first study to show that the dynamic handgrip preparatory strategy is also effective in situations
 7 where no perceived anxiety increase occurs since researchers (Beckmann et al., 2013; Gröpel &
 8 Beckmann, 2017) have, to date, reported that the dynamic handgrip strategy improved
 9 performance accuracy under pressure. This positive result may indicate that dynamic handgrip
 10 could be used for performance accuracy irrespective of how much (or little) anxiety the
 11 participants' experience.

12 Using a combined (i.e., dynamic handgrip and extensive) PPR, however, may not have
 13 accumulative performance effects as one might assume. That is, the combined dynamic handgrip
 14 and PPR group in the current paper did not equate to better accuracy based on using both
 15 interventions together. Yet, in both studies, the combined PPR was still a better intervention for
 16 performance accuracy than having no PPR at all (i.e., control group). These results refute other
 17 researchers' results (e.g., Mesagno et al., 2015; Mesagno & Mullane-Grant, 2010) who found
 18 that using different components in a combined routine had a greater accuracy performance effect
 19 than the respective components in isolation. These differences are likely inherently design
 20 related. First, when reflecting on the comparison between studies that had similar short (i.e., 15
 21 minutes) learning period intervention development (i.e., the current paper and Mesagno &
 22 Mullane-Grant, 2010), the Mesagno and Mullane-Grant study was a combination of behavior
 23 routines that seemed to fit well to help the athletes maintain focused attention. The current study,
 24 however, provided a preparation strategy to a routine that was not directly related to improving
 25 concentration (i.e., dynamic handgrip) and was relatively unfamiliar to participants. Secondly,

1 the Mesagno et al. (2015) study was different to the current paper because the time allotted to
 2 learn the intervention was extended (i.e., 4-weeks). That is, in the current paper, there was likely
 3 not enough time (i.e., approximately 15 min) to learn the routine in a way that allowed them to
 4 become comfortable with the extra cognitive load. Perhaps participants were overwhelmed by an
 5 abundance of routine steps while combining the dynamic handgrip and extensive PPR during the
 6 accuracy test. These concerns were likely a difference in the results between Mesagno et al. and
 7 this paper, considering Mesagno et al. found, qualitatively, that participants reported that using
 8 both routines was initially distracting. Furthermore, it appears that participants in the Mesagno et
 9 al. study favoured the PPR over the post-performance routine in the combined group, which is
 10 expected since the PPR was to help with concentration before each shot. Since the post-
 11 performance routine intervention was cognitive (i.e., bowlers asked themselves evaluation
 12 questions about previous attempts) rather than behavioural in the Mesagno et al. study, there was
 13 no way of determining that it was followed precisely. This selective processing may have been
 14 the reason for the equal improvements in performance accuracy of participants in the combined
 15 and PPR groups in the Mesagno et al. study, but in the current paper, the steps of the dynamic
 16 handgrip and extensive PPR groups were mainly behavioural, overt, monitored closely, and
 17 could not be avoided.

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

1 **In-Game Performance (Study 2 only)**

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

15 **Overall Limitations**

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

1 researchers would benefit to control for coping ability in PPR research settings (under pressure)
 2 or determine if PPR education directly effects coping ability.

3 **Future Research**

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

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

19 **Applied Implications**

20 The dynamic handgrip is effective in preventing motor skill failure (choking under
 21 pressure; Beckmann, et al., 2013; Gröpel & Beckmann, 2017). In this series of studies, dynamic
 22 handgrip has been effectively integrated as a preparation strategy into a PPR and is applicable to
 23 moderate to highly skill athletes. Based on Reinvestment theory (Masters, 1992) that underlies
 24 the elimination of choking under pressure, the dynamic handgrip should be effective only if
 25 (complex) motor skills have already become automated. Since dynamic handgrip does not

1 require extensive motor learning and is easy to include into practice especially for skilled
 2 athletes, it could constitute a simple and valuable tool for coaches and athletes to implement for
 3 enhanced performance in general, or under pressure, even if they have not worked alongside a
 4 sport psychologist developing this strategy. Experienced sport psychologists could further
 5 develop PPRs with athletes and potentially combine those individually developed PPRs with the
 6 dynamic handgrip. Based on the current study and other PPR results (Mesagno et al., 2015), it
 7 may be beneficial to provide a longer education period when combining the extensive PPR and
 8 dynamic handgrip to ensure reduced cognitive load so that the execution of the PPR does not
 9 consume cognitive capacity. Furthermore, the current research used adults in both studies, yet
 10 PPRs and preparation strategies that include dynamic handgrip could be systematically
 11 developed in experienced, youth athletes. Incorporating preparation strategies, such as the ones
 12 investigated in these studies, into training and competition can help youth athletes understand to
 13 better concentrate and potentially a method of cortical relaxation at a young age, which may add
 14 to their ability to deal with the pressure of competition.

15 **Conclusions**

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

- 1 which is important for performance generally (and under pressure) in any target-based (i.e.,
- 2 focusing on an external cue for aiming) sports.
- 3

Acknowledgements

This research was supported by a grant from the Federal Institute of Sport Sciences in Germany (#072006/16-17) and a grant from Universities Australia and the German Academic Exchange Service (#57215072) as a part of the Australia-Germany research cooperation scheme. We would like to thank the employees and participants at Oz Tenpin Bowling Ballarat, WynCity Bowling and Entertainment Center, AMF Bowling Dandenong, and AMF Bowling Frankston for helping with data collection and participation in the study. We would also like to thank Tom Kossak, Anna-Maria Schoberer, and Emily Svanosio for helping with data collection and entry.

9

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1 Table 1.
2 *Mean and Standard Deviation (SD) for cognitive anxiety and somatic anxiety before (Pre) and*
3 *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)

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

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

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1 Table 3.
2 *Mean and Standard Deviation (SD) for cognitive anxiety and somatic anxiety pretest and*
3 *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)

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2 *Figure 1.* Mean performance score (Inverse Efficiency Score) in the acquisition and test phases

3 for the different groups (Study 1).

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