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3   The effect of consistent and varied follow-through practice schedules on learning a table
4   tennis backhand

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1 **Abstract**

2 In table tennis the follow-through action after a shot is an important part of skill execution. In

3 this experiment, we aimed to extend literature around the contextual interference effect by

4 investigating whether the way the follow-through is organised in practice affects learning of

5 the backhand shot in table tennis. Thirty unskilled participants were allocated to blocked-

6 variable practice, random-variable practice or a control-constant group and aimed backhand

7 shots towards a target following ball projection from a machine. Each group completed these

8 shots in a pre-test, a training phase with follow-through manipulations, a post-test, and a

9 retention test. The random-variable group improved their shot accuracy from pre-test to post-

10 test and from pre-test to retention test (both $P < 0.01$, $d = 1.03$), whereas neither the blocked-

11 variable nor the control-constant group displayed any change in shot accuracy. Practising the

12 follow-through in a random-variable fashion enhanced learning of the preceding shot

13 compared with blocked-variable practice or no follow-through instructions. The benefits of

14 learning motor skills under conditions of high contextual interference also apply to how

15 follow-through actions are organised. The findings are of value to coaches and suggest that

16 instructions related to the follow-through action should be considered as well as the primary

17 skill itself.

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1   **Introduction**

2   In table tennis, players must vary their shot selection and tactical play to cope with

3   complex, ever-changing, and relatively unpredictable performance constraints. However,

4   training these shots often occurs in a blocked and predictable fashion. The degree of

5   consistency or unpredictability with which skills are practised and how this affects motor

6   learning has received considerable attention in the broad field of human performance (see

7   Goode & Magill, 1986; Hall, Domingues, & Cavazos, 1994; Pyle, 1919; Rendell, Masters,

8   Farrow, & Morris, 2010; Shea & Kohl, 1990; Shea, Kohl, & Indermill, 1990; Shea &

9   Morgan, 1979; Shoenfelt, Snyder, Maue, McDowell, & Woolard, 2002; Wright et al., 2016).

10   Although researchers initially concluded that practising different skills in a blocked or

11   consistent fashion resulted in superior motor learning relative to performing these skills in a

12   more varied and unpredictable fashion (see Pyle, 1919), these early studies failed to include

13   retention tests and so were unable to distinguish between short-term performance effects and

14   more permanent long-term changes that would indicate learning.

15   The way in which practice is organised, namely whether it is in a blocked and

16   consistent fashion or in a varied and unpredictable manner, is thought to promote differing

17   levels of contextual interference which refers to the degree of interference between the

18   performance of one task or skill and the next in the context of practice (Battig, 1979). Skills

19   which are practised in a blocked and consistent fashion result in low levels of contextual

20   interference, whilst skills practised in a varied and unpredictable fashion produce high levels

21   of contextual interference. The common pattern of findings, referred to as the contextual

22   interference effect, is that blocked and consistent practice conditions promote rapid

23   improvements in performance but retard learning, as evidenced by performance at delayed

24   retention tests, whereas the opposite is true for practice conditions that produce high levels of

25   contextual interference (see Broadbent, Causer, Ford, & Williams, 2015; Ollis, Button, &

1 Fairweather, 2005; Pauwels, Swinnen, & Beets, 2014; Shea & Kohl, 1990; Shea & Morgan,

2 1979; Shea et al., 1990; Wright, Magnuson, & Black, 2005).

3   To date, studies which have investigated the structure and organisation of practice

4 have almost exclusively focused on the primary skill itself. In many sports, however, the

5 follow-through after the primary skill is an important feature of technique and is frequently

6 included in biomechanical analyses (e.g., Bezodis, Trewartha, Wilson, & Irwin, 2007; Cerrah

7 et al., 2011; Elliott, Marsh, & Overheu, 1989; Fleisig et al., 1996), yet how this follow-

8 through action is instructed or organised in practice and how this influences the motor

9 learning process has received very little attention. The importance of the follow-through is

10 evident in table tennis where it can noticeably vary depending on the direction, spin or speed

11 imparted on the ball. The high ball speed and the small court size in table tennis mean the

12 spatial-temporal demands placed on performers are extreme as they must quickly and

13 accurately switch between different technical skills and combinations of these skills which

14 exhibit different follow-through actions. These perceptual-motor skills and the ability to

15 combine shot and spin variations are key characteristics of successful performance in table

16 tennis (Limoochi, 2006; Munivrana, Furjan-Mandic, & Kondric, 2015; Toriola, Toriola, &

17 Igbokwe, 2004).

18   Howard, Wolpert, and Franklin (2015) provided a rare example of research which has

19 investigated how follow-through actions contribute to learning motor skills. Using a

20 laboratory-based lever-positioning task, they reported, contrary to the contextual interference

21 effect, that more consistent follow-through actions enhanced motor learning whilst varied

22 follow-through actions impaired the learning process. When interpreting their findings,

23 Howard et al. (2015) argued that a consistent follow-through action activates a single motor

24 memory and results in superior learning, whereas a varied follow-through results in

25 interference and prevents consolidation of the motor memory. However, when explaining the

1 contextual interference effect, it is precisely this interference which results from

2 unpredictable learning conditions that is considered responsible for the superior long-term

3 motor learning. Although this contextual interference makes learning conditions more

4 difficult and has been shown to slow the rate of performance change, increasing the degree of

5 cognitive challenge by being required to continually reconstruct (Lee & Magill, 1983, 1985)

6 or contrast between movement patterns in working memory so that each are made elaborate

7 and distinct (Shea, Hunt, & Zimny, 1985; Shea & Morgan, 1979; Shea & Zimny, 1983) is

8 thought to promote stronger memory representations which ultimately enhances long-term

9 learning. Critically in this regard, Howard et al. (2015) did not include a retention test in their

10 design. Given that learning is recognised as a *relatively permanent* change in performance,

11 including delayed retention tests after the initial training period is fundamental when looking

12 to draw conclusions about motor learning. Indeed, the pattern of findings that Howard et al.

13 (2015) present replicates what is seen during training periods in much research investigating

14 contextual interference (e.g., Broadbent, Causer, Williams, & Ford, 2017; Gane &

15 Catrombone, 2011; Shea & Kohl, 1990; Shea & Morgan, 1979; Shea et al., 1990). It is

16 therefore important to further investigate how a consistent or varied follow-through action

17 affects motor learning through a research design including a delayed retention test.

18 It is also important to examine if the conclusions drawn by Howard et al. (2015) using

19 a simple and artificial laboratory task also apply to learning more complex and sport-specific

20 skills. In table tennis, players are forced to play shots in response to an opponent and operate

21 under strict spatial and temporal constraints. These dynamic interactions are likely to

22 necessitate that table tennis players will be required to make quick perceptual-cognitive

23 decisions; different follow-through actions will, therefore, likely be exhibited as they adapt to

24 the technical demands of the situation. Given the different performance constraints which

25 operate in table tennis relative to the simple, closed, and self-paced task that was used by

1   Howard et al. (2015), along with their failure to include a retention test, we argue that their

2   results must be treated with caution when considering how follow-through actions might

3   affect motor learning for complex sport skills.

4   The aim in this experiment was therefore to examine how the organisation of follow-

5   through actions affected motor learning of a backhand shot in table tennis. Participants

6   learned to play a backhand shot with the aim always being to play the ball to a designated

7   target on the table which remained the same throughout. Participants were therefore always

8   presented with the same to-be-learned primary skill, however we manipulated the instructions

9   that we provided to participants regarding their follow-through action; some participants were

10   instructed to follow-through in a blocked fashion (i.e., consistent and predictable from one

11   trial to the next), whilst others were instructed to follow-through in a varied fashion (i.e.,

12   inconsistent and unpredictable from one trial to the next). We also used a control group who

13   were given no instructions related to the follow-through action. Given the strong theoretical

14   underpinnings and extensive body of literature which has demonstrated the contextual

15   interference effect when investigating how the primary skill is organised, along with our

16   critiques of the methods employed by Howard et al. (2015), we only expected to see changes

17   in performance in certain groups between specific time points and so made a series of a priori

18   hypotheses in relation to these. We predicted that the group practising with a blocked follow-

19   through would significantly improve their shot accuracy from pre-test to post-test. In the

20   absence of any instructions related to the follow-through action, we expected the control

21   group to follow-through in a consistent manner and so we also hypothesised that they would

22   show a significant improvement in accuracy from pre- to post-test. However, from pre-test to

23   retention test we predicted that the contextual interference and cognitive challenge caused by

24   organising the follow-through in a varied fashion during the training period would result in

25   the development of enhanced memory representations and so we predicted that the varied

1   follow-through group would be the only group to show a significant improvement in shot

2   accuracy from pre- to retention test.

3   **Method**

4   *Participants*

5   Thirty unskilled individuals (18 males, 12 females; mean ± SD age = 27.63 ± 5.58 years)

6   volunteered to participate in the study and were assigned to one of three groups; blocked-

7   variable practice group (n = 10), control-constant group (n = 10), or random-variable practice

8   group (n = 10). Participants were classed as unskilled if they reported not currently playing

9   table tennis recreationally or having ever played for a competitive table tennis club. Three of

10   the participants were left hand dominant and were evenly assigned across the three groups;

11   the remaining 27 participants were right hand dominant. To ensure the appropriateness of

12   sample size, we conducted a power analysis using G* power (Faul, Erdfelder, Lang, &

13   Buchner, 2007). The calculation was based on the effect size reported for a Group × Test

14   Type interaction in a study investigating blocked and random practice for learning golf chip

15   shots (Aiken & Genter, 2018; $\eta_p^2 = 0.25$). We set a moderate correlation ($r = 0.3$), power at

16   0.8, and alpha level at 0.05. The total sample size required for the 6 testing phases by 3

17   groups ANOVA used in the current study was n = 9.

18   Ethical approval was obtained from, and research was conducted within the guidelines

19   of, the lead author's University's research ethics committee (ethics approval reference:

20   SMEC_2016-17_11). The research was conducted following the principles of the Declaration

21   of Helsinki. All participants provided written informed consent.

22   *Apparatus*

1   The study was performed on a standard size (2.7×1.5 m) table tennis table (Butterfly,

2   Krefeld, Germany). The scoring system was adapted from Poolton, Masters, and Maxwell

3   (2006) as follows. Six 50 cm wide squares were marked on the opposing side of the table and

4   a 25 cm wide square was marked within the middle square furthest from the participant; three

5   points were awarded for hitting into this area, two points for the large square surrounding it,

6   and one point for the other five squares (see Figure 1). No points were awarded if the ball

7   was not hit to any of the six squares. Dunlop Club training balls (40 mm diameter) were

8   delivered to the participants from a ball projection machine (Table Tennis Buddy V200,

9   Joola, Germany) which was positioned behind the right-hand corner of the table opposite the

10 participant (Figure 1). The ball projection machine was set at a frequency of 30 balls/minute

11 and balls were projected at a speed of 6.5 m/s. All participants completed the study using the

12 same Dunlop Max All Round table tennis bat. A high definition camera (Panasonic HC-V720

13 HD Camcorder, Berkshire, UK) sampling at 50 Hz was mounted above the participants' end

14 of the table to record the follow-through of the bat.

15   FIGURE 1 NEAR HERE

16 *Procedure and Manipulations*

17 The experiment was divided into two sessions; the first comprised a pre-test and training

18 period and was followed by a retention test in the second session. Prior to the pre-test,

19 participants were informed that table tennis balls would be delivered from a ball projection

20 machine and that they were required to play a backhand shot. The ball had to bounce once

21 before being struck and the subsequent bounce should be on the other side of the net and

22 aimed for the central three-point target. No further instruction was given on how to play the

23 shot. Following a familiarisation period (10 shots), participants completed a pre-test of 50

24 shots aimed at the central three-point target with no further instruction.

1   Following the pre-test, participants were allocated to groups based on their pre-test

2   score to ensure there were no differences in performance levels between groups prior to the

3   intervention. After this, participants completed a training period consisting of three blocks of

4   50 trials in which backhand shots continued to be aimed at the central three-point square. The

5   control-constant group received no further instruction. The blocked-variable and random-

6   variable groups were instructed to aim the ball at the centre square but to guide the follow-

7   through of the shot to the right, left or middle. To follow-through to the right, participants

8   were instructed to complete their shot in such a way that the bat finished pointing towards the

9   far right-hand corner of the table. The same instruction was given regarding the left-hand

10   corner for the left follow-through. For the middle follow-through, participants were instructed

11   that the bat should follow the central line of the table. No further instructions were provided.

12   The blocked-variable group completed blocks of 50 trials with the same follow-through (50

13   left, 50 middle, and 50 right) and the order was counter-balanced between participants. The

14   random-variable group performed shots with the same number of follow-throughs to the left,

15   middle, and right as the blocked-variable group. However, for the random-variable group,

16   instructions as to which follow-through to perform were provided verbally by the investigator

17   prior to ball projection on each shot. Follow-throughs were performed in a random order with

18   no two consecutive trials the same. Following the training period, all groups completed a

19   post-test following the same procedure as the pre-test with no follow-through instruction. A

20   retention test was completed 24 to 48 hours later, in the same fashion as the pre- and post-

21   tests.

22   *Measures and Data Analysis*

23   The maximum score available was 150 points. Two observers live recorded shot accuracy

24   with agreement on 90% of the trials. Video images from the camera directly above the

25   participants were viewed frame-by-frame in Windows Media Player 12 to quantify the

1   follow-through execution by the blocked-variable and random-variable groups during the

2   training period. For shot numbers 20-30 in each block, the location of the centre of the bat

3   was marked at the point of contact with the ball and again at the end of the follow-through

4   (i.e., cessation of forwards movement of the bat). The average follow-through angle of the bat

5   relative to the centre line of the table was then identified for each participant in each of the

6   follow-through conditions (see Figure 2 for an example). The average follow-through angle

7   for each participant in the control-constant group for shot numbers 20-30 in the second block

8   of the training period was also identified.

9   FIGURE 2 NEAR HERE

10   A repeated measures ANOVA was conducted to verify that there were differences in

11 follow-through angles depending on whether participants were instructed to follow-through

12 to the left, middle, or right. A further one-way between participants ANOVA was run on pre-

13 test accuracy scores to ensure there was no initial difference in task performance prior to the

14 follow-through manipulation. A 3 (Group [blocked-variable, random-variable, control-

15 constant]) × 6 (Phase [pre-test, training 1, training 2, training 3, post-test, retention test])

16 mixed-design ANOVA with repeated measures on the last factor was conducted with

17 performance score acting as the dependent variable. To test our a-priori hypotheses that only

18 the blocked-variable and control-constant groups would increase their performance accuracy

19 from pre- to post-test and that only the random-variable group would improve their

20 performance accuracy from pre-test to retention test, paired samples t-tests were conducted to

21 compare mean accuracy scores in the pre-test with mean accuracy scores in the post and

22 retention test for each group.

23   Although our primary interest was to examine shot accuracy at retention- and transfer-

24 tests relative to pre-test as a function of follow-through instruction, we also analysed data to

1   check if follow-through instruction affected the direction of errors made during acquisition.

2   To do this, we analysed a sample of 900 acquisition trials (300 with the follow-through

3   movement to the right, 300 to the left, and 300 to the middle). We ran three separate 1-way

4   repeated measures ANOVAs to test if errors to the left, errors to the right, and errors down

5   the middle were affected by follow-instruction.

6   All data was checked to ensure it satisfied parametric assumption of normality and

7   homogeneity of variance. Violations of sphericity were corrected using Greenhouse-Geisser

8   procedures. Effect sizes are reported using partial eta squared (η_p^2) in all instances and

9   Cohen's *d* for comparisons between two means. In the case of significant main effects or

10   interactions, Bonferroni-corrected pairwise comparisons were used as post-hoc tests. The

11   alpha level was set at 0.05, but in the case of multiple *t*-tests, the sequential Bonferroni

12   correction was applied to control for family-wise error.

13   **Results**

14   First, the repeated measures ANOVA revealed a significant main effect of follow-

15   through instruction on the follow-through angle exhibited by the participants, F (1.33, 25.26)

16   = 40.789, $P < 0.001$, $\eta_p^2 = 0.68$. Post-hoc tests revealed that when instructed to follow-

17   through to the left ($M = -19.3$, $SE = 4.3°$), the follow-through was directed significantly

18   further to the left than when instructed to follow-through to the middle ($M = -1.5$, $SE = 3.0°$,

19   $P = 0.001$) which was in turn significantly further to the left than when instructed to follow-

20   through to the right ($M = 26.4$, $SE = 4.0°$, $P = 0.001$). The instructions for participants to

21   adopt different follow-through actions were therefore successful. The control-constant group

22   exhibited a mean follow through angle of $6.4 \pm 4.5°$ ($M \pm SE$).

23   Mean and standard error values of performance scores for the blocked-variable,

24   random-variable, and control-constant group are presented in Figure 3. A one-way ANOVA

1 revealed no significant differences in performance levels in the pre-test between blocked-

2 variable ($M = 72.30$, $SE = 4.85$), random-variable ($M = 72.50$, $SE = 5.42$) and control-

3 constant ($M = 72.70$, $SE = 9.71$) groups, $F(2, 27) = 0.001$. $P = 0.999$, $\eta_p^2 = 0.00$, meaning all

4 groups showed the same level of performance outcome in playing the backhand shot prior to

5 any experimental manipulation.

6   The 3 (Group [blocked-variable, random-variable, control-constant]) × 6 (Phase [pre-

7 test, training 1, training 2, training 3, post-test, retention test]) mixed-design ANOVA

8 revealed a significant Group × Phase interaction, $F(10, 135) = 3.55$, $P < 0.001$, $\eta_p^2 = 0.21$. A

9 main effect of Phase was also observed, $F(10, 135) = 14.38$, $P < 0.001$, $\eta_p^2 = 0.35$.

10 Bonferroni-corrected pairwise comparisons revealed that participants' performance levels

11 were significantly higher in the post-test ($M = 83.60$, $SE = 3.78$, $P = 0.009$, $d = 0.53$) and

12 retention test ($M = 82.80$, $SE = 3.51$, $P = 0.031$, $d = 0.51$) than in the pre-test ($M = 72.50$, SE

13 $= 3.90$).

14   To test our a priori predictions, we conducted planned comparisons between

15 performance scores from pre- to post-test and pre- to retention test for each of the three

16 groups. From pre- to post-test, a significant increase in performance level was observed for

17 the random-variable group ($M_{diff} = 17.70$, $SE = 5.03$, $P = 0.007$, $d = 1.03$) but not for the

18 blocked-variable ($M_{diff} = 7.60$, $SE = 5.52$, $P = 0.202$, $d = 0.42$) or control-constant group

19 ($M_{diff} = 13.23$, $SE = 4.18$, $P = 0.088$, $d = 0.29$). From the pre-test to the retention test, a

20 significant increase in performance level was observed for the random-variable group ($M_{diff} =$

21 13.70, $SE = 3.87$, $P = 0.006$, $d = 0.89$) but not for the blocked-variable ($M_{diff} = 7.40$, $SE =$

22 5.84, $P = 0.237$, $d = 0.37$) or control-constant group ($M_{diff} = 9.80$, $SE = 5.77$, $P = 0.124$, $d =$

23 0.38). Finally, the main effect of Group was not significant, $F(2, 27) = 0.65$, $P = 0.529$, $\eta_p^2 =$

24 0.05.

1   FIGURE 3 NEAR HERE

2   The follow-through condition had no effect on the number of misses to the left ($F =$

3   2.086, $p = 0.175$, $\eta_p^2 = 0.294$) or to the right ($F = 2.389$, $p = 0.142$, $\eta_p^2 = 0.323$). ANOVA

4   showed misses in the middle third were affected by follow-through instruction ($F = 4.520$, $p =$

5   0.040, $\eta_p^2 = 0.475$), however no significant pairwise effects were evident when post-hoc

6   Bonferroni corrections were applied. Being instructed to follow-through to the right or left

7   did not bias errors to these directions.

8   **Discussion**

9   We aimed to examine how different follow-through practice schedules affect learning

10   of the backhand shot in table tennis. Given the extensive body of research which has reported

11   the contextual interference effect when investigating how the primary skill is practised, we

12   made two main predictions. First, we predicted that the blocked-variable and control-constant

13   groups would significantly improve their shot accuracy from pre- to post-test as we expected

14   participants in both of these groups to adopt a consistent follow-through within training

15   phases, which would reduce interference and disruption from one shot to the next and enable

16   them to acquire greater shot accuracy over the training period. Second, we predicted that

17   participants in the random-variable follow-through group would be forced to contend with

18   greater interference from one trial to the next, which would slow the initial rate of

19   performance change, but lead to better long-term learning. Consequently, we hypothesised

20   that only the random-variable group would improve their shot accuracy from pre- to retention

21   test. Our findings partially supported these hypotheses. As we predicted, participants in the

22   random-variable group significantly improved their shot accuracy from pre- to retention test.

23   However, contrary to our hypotheses the random-variable group also significantly improved

1   their shot accuracy from pre- to post-test whereas both the blocked-variable and control-

2   constant groups did not.

3   The finding that a more random and varied practice schedule results in superior motor

4   skill learning (as inferred through performance at delayed retention tests) has been well

5   reported (see Brady, 1998; Green & Sherwood, 2000; Hall, Domingues, & Cavazos, 1994;

6   Lee & Simon, 2004; Shea & Morgan, 1979; Shea et al., 1990). However, this is the first study

7   to demonstrate that the benefits of a random-varied practice schedule also apply to the

8   organisation and structure of the follow-through action. Being forced to continually vary and

9   adapt the follow-through is likely to have been challenging for participants and demanded

10   high levels of concentration on the skill. In line with the forgetting-reconstruction (Lee &

11   Magill, 1985) and elaboration-distinctiveness (Shea & Zimny, 1983) theories, we argue this

12   heightened concentration and cognitive engagement will have resulted in the development of

13   more robust memories and long-term learning that was evidenced through superior

14   performance in the retention test. These theories, which have been used to interpret results

15   related to how the primary skill is organised, can also explain why a random-variable follow-

16   through results in superior motor skill learning relative to blocked-variable and control-

17   constant conditions.

18   In addition to performance at post- and retention-tests, it is important to consider

19   performance curves (illustrated in Figure 3) to gain a more complete picture of the skill

20   acquisition process. Both experimental groups show degradation in performance after pre-

21   test, which contrasts the typical pattern of performance curves that show rapid rates of

22   improvement in the early stages of skill learning (e.g., see Gane & Catrambone, 2011; Lohse,

23   Sherwood, & Healy, 2010; McNevin, Shea, & Wulf, 2003; Menayo, Sabido, Fuentes,

24   Moreno, & Garcia, 2010). However, in the acquisition phase of this study, participants

25   completed the task in a different way than they had done in the pre-test (i.e., they were

1   required to direct their follow through toward a particular location). This is likely to have

2   made the task more difficult, explaining this initial degradation for both experimental groups.

3   It could also explain the distinct trends of the two experimental groups over the course of

4   acquisition. Whereas the blocked-variable group showed minimal improvement through

5   training, the random-variable group improved shot accuracy over time. Having to follow

6   through to a different location in each block appears to have prevented the blocked-variable

7   group from improving performance over time as they were forced to "start from scratch"

8   every fifty trials. Conversely, whilst the random-variable group faced greater variability from

9   one trial to the next, the instructions and task for each training block remained the same, thus

10 facilitating adaptation to the task demands and performance improvements over time. The

11 constant-control group, in contrast, who were not constrained to satisfy any particular follow-

12 through instruction, showed a performance curve that more closely resembles that typically

13 associated with acquisition of motor skills.

14   Although we did not measure constructs related to intrinsic motivation, recent

15 theoretical accounts and empirical investigations highlight their importance in motor learning

16 and offer a useful perspective to interpret the distinct between-group trends. The random-

17 variable group - the only group to significantly improve shot accuracy from pre- to post- and

18 retention-tests - was also the group which showed the largest improvements from each

19 training block to the next. These improvements through the intervention period may enhance

20 perceptions of competence (Saemi, Wulf, Varzaneh, & Zarghami, 2011), interest/engagement

21 in the task (Sheldon & Filak, 2008), and result in greater effort being expended during

22 practice (Abbas & North, 2018). These effects have also resulted in participants

23 demonstrating superior motor learning relative to those who were exposed to conditions that

24 led to lower perceptions of competence, interest or effort ratings. Perceived competence,

25 which is conceptually similar to self-efficacy (Bandura, 1997), is considered a basic

1   psychological need (cognitive evaluation theory; Deci, 1975; Deci & Ryan, 1985) and so any

2   variables positively impacting such measures are likely to improve intrinsic motivation,

3   which itself is now identified as a key theoretical construct in aiding motor learning

4   (OPTIMAL theory of motor learning; Wulf & Lewthwaite, 2016). Whilst caution must be

5   applied to this interpretation, as measures of intrinsic motivation were not recorded in the

6   current study, it appears worthwhile for future research to investigate whether these findings

7   from investigations into feedback and motor learning (e.g., Abbas & North, 2018) and

8   attentional focus and motor learning (e.g., Wulf & Lewthwaite, 2016) from a motivational

9   perspective also transfer to contextual interference.

10   To date, only one other study has investigated how organisation of the follow-through

11   action affects learning of the preceding skill (see Howard et al., 2015). Our finding that a

12   random-variable follow-through action results in superior motor learning of the primary skill

13   directly contrasts with the conclusions of Howard et al. (2015). The failure of Howard et al.

14   (2015) to include a retention test, which makes it difficult to distinguish between transient

15   performance effects and more permanent learning, is one potential explanation for this.

16   Another important variable which could explain the contrasting findings concerns the nature

17   of the task. In contrast to the self-paced lever moving task employed by Howard et al. (2015),

18   which has little transferability to sport-specific or other 'real-world' tasks, the table tennis

19   backhand shot we used is a complex task that represents a skill that is used in game

20   situations. Such a skill necessitates controlling multiple degrees of freedom, is externally

21   paced, and requires participants to intercept a fast-moving projectile that must be struck in to

22   a narrow target area. In table tennis, where performers operate under strict temporal pressures

23   and may play shots to the same location but impart different spins on the ball which may

24   require different follow-through actions, we have presented evidence that practising with a

25   more varied follow-through action leads to superior learning. A particular advantage in

1   practising with a random-variable follow-through action is likely to be in the ability to adapt

2   to different task constraints and show variation in the shots played. Although we employed a

3   retention test to distinguish between performance and learning effects, we did not include

4   transfer tests. This is something that researchers should look to investigate in future studies.

5   Given the need to adapt to different types and speed of shots from table tennis opponents, as

6   well as being required to direct shots to various locations on the table, it would be reasonable

7   to expect that the advantages of being forced to continually adapt the follow-through action

8   during acquisition would lead to even greater learning advantages being evident in transfer

9   tests.

10   A surprising finding, and one that is contrary to the pattern of results observed in the

11   contextual interference effect and our hypotheses, was that the random-variable group also

12   made significant improvements in shot accuracy from pre- to post-test, outperforming both

13   blocked-variable and control-constant groups. However, most studies investigating the effects

14   of blocked and varied practice schedules have used a relatively small number of trials during

15   training periods (18 acquisition trials per task, Shea & Morgan, 1979; 30 trials per task,

16   Green & Sherwood, 2000), yet when more extended training periods are employed it is not

17   unusual by the end of practice for varied practice groups to progress to the same performance

18   levels as blocked groups (see Helsdingen, van Gog, & van Merrienboer, 2011; Pauwels et al.,

19   2014) or even exceed them (see Maslovat, Chua, Lee, & Franks, 2004). It is possible the

20   relatively high number of trials we employed in the training period meant that the learning

21   benefits of practising in cognitively challenging conditions were realised by the end of

22   training and thus our retention test reflected persistence of learning rather than indicating

23   learning in the first instance. Inspection of performance after the first training block (where

24   the number of trials is more in line with that typically employed throughout entire acquisition

25   periods) shows a pattern of results which more closely matches the contextual interference

effect. This pattern of findings matches those reported by Maslovat et al. (2004) and Pauwels

et al. (2014) who also employed longer training periods and suggests the initial detrimental

effects of practising in difficult conditions can be overcome if the training period is extended.

However, it is worth highlighting the findings of Shea et al. (1990) who reported that,

regardless of whether participants practised for 50, 200, or 400 acquisition trials, the random

group always showed inferior performance through the acquisition period when compared to

the blocked group.

Conclusions

In conclusion, we have presented evidence that practising a skill with a random-varied

follow-through action results in superior motor learning of that skill compared with blocked-

variable practice of different follow-through actions or no specific follow-through action

instructions. We have demonstrated that contextual interference effects related to practice

organisation of the primary skill also transfer to the practice structure and organisation of the

follow-through action. However, this is the first study to demonstrate the contextual

interference effect in follow-through movements and so it is important for future researchers

to replicate these findings before they can be confidently applied to practice. The temporal

and spatial constraints of table tennis, along with the importance of the follow-through in

table tennis when varying shot type, mean that practising the follow-through in a varied and

unpredictable fashion enhances learning and the ability to adapt externally-paced skills. The

findings are potentially of practical value to table tennis coaches and suggest that when trying

to learn a backhand shot, their athletes should follow-through after the shot in a varied

fashion. These novel findings have important implications for practice design in table tennis,

and future research should ascertain their generalisability to different table tennis shots and

other racquet sports, as well as to other sporting movements where a follow-through is

employed.

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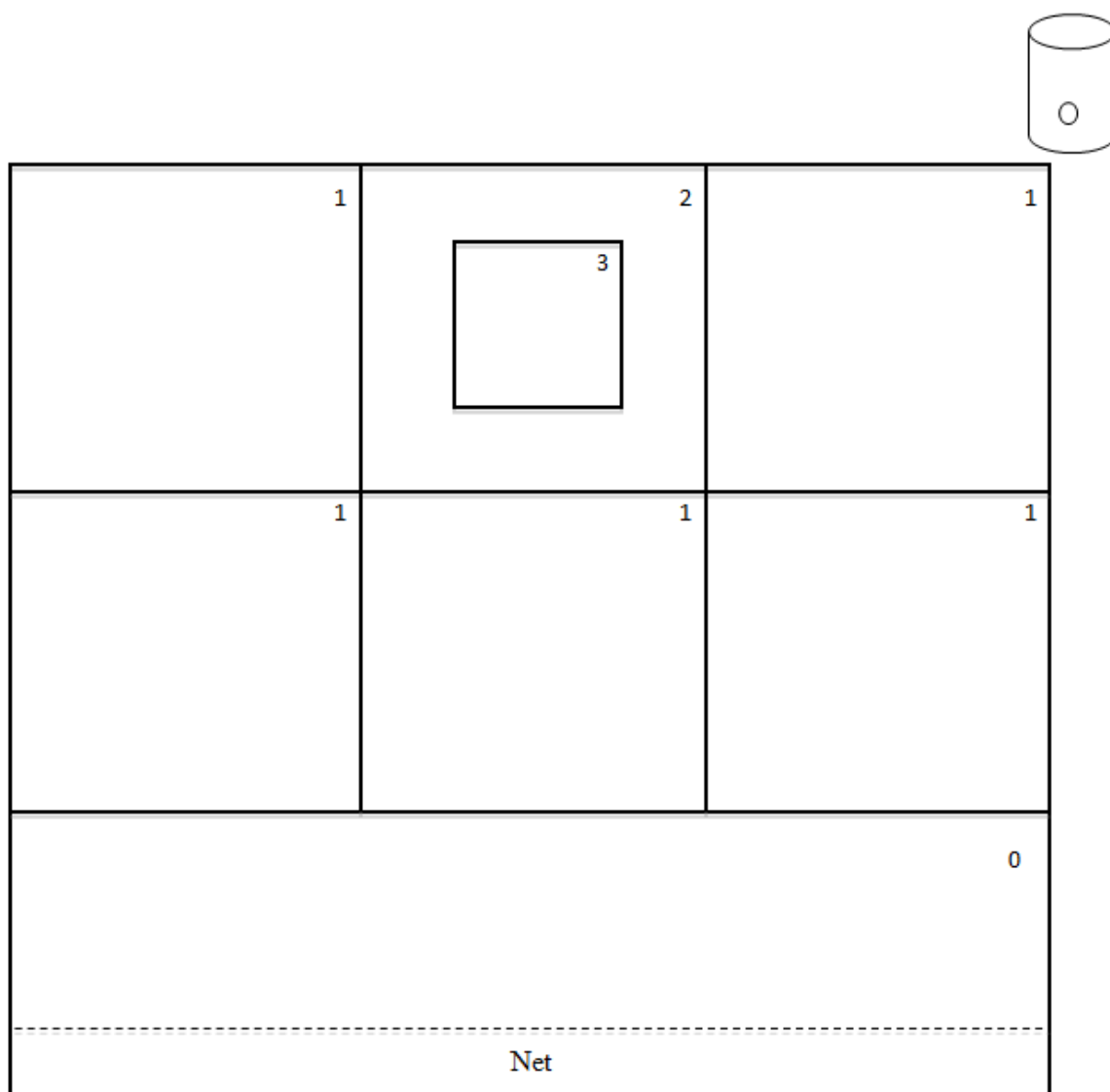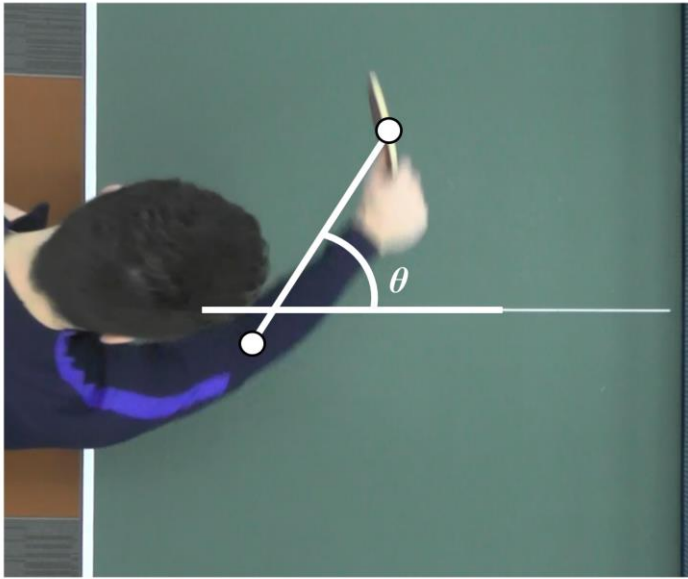
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1 **Figures**

2

3 Figure 1. Position of ball projection machine (top-right corner) and scoring system, adapted

4 from Poolton et al. (2006), with numbers representing the point score awarded for a shot

5 landing in that area.

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2   Figure 2. Example of a participant executing a left follow-through and how angles were

3   quantified. An angle of zero represented a follow-through (from ball contact to the most

4   forward point of the follow-through) parallel to the line down the centre of the table, a

5   negative angle represented a follow-through to the left and a positive angle represented a
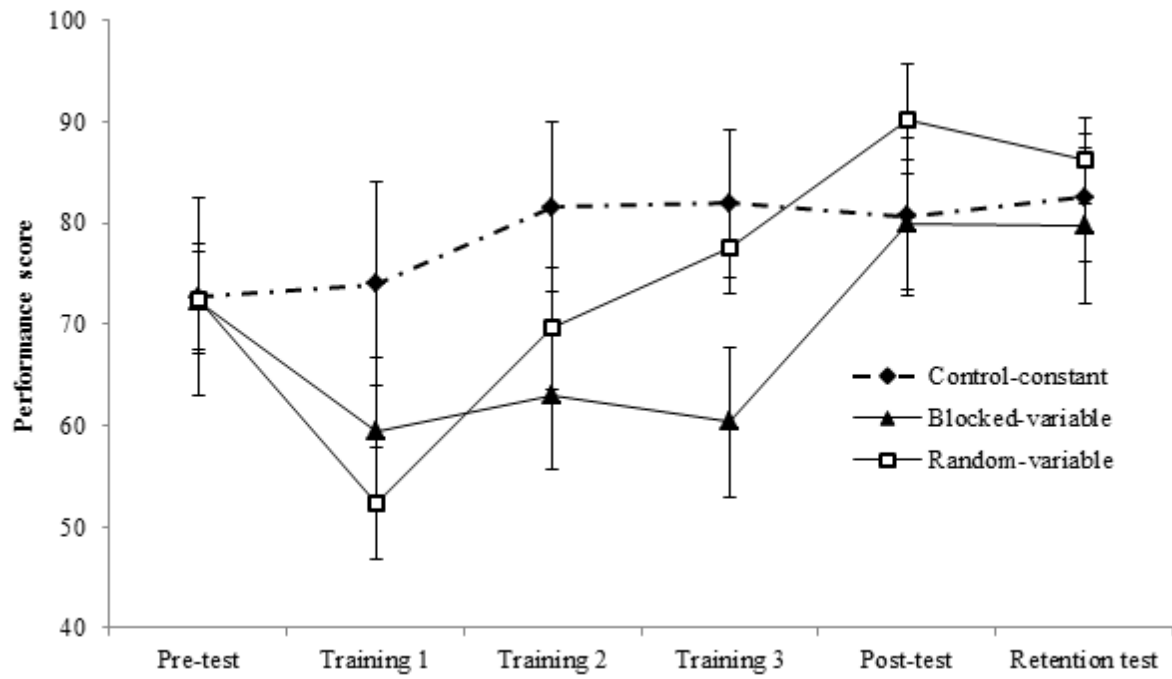
6   follow-through to the right.

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Figure 3. Mean ± SE performance scores in pre-test, training blocks 1–3, post-test, and retention test for the control-constant, blocked-variable, and random-variable groups.

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3   The authors report no conflicts of interest.