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Capio, Catherine M, Uiga, Liis , Lee, Man Hong and Masters, Rich SW (2019) Application of analogy learning in softball batting: Comparing novice and intermediate players. *Sport, Exercise, and Performance Psychology*, 9 (3). pp. 357-370. ISSN 2157-3905

DOI: <https://doi.org/10.1037/spy0000181>

Publisher: American Psychological Association (APA)

Version: Accepted Version

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1 **Application of analogy learning in softball batting: Comparing novice and intermediate**
2 **players**

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21 Word count (main text): 5,861

1 **Application of analogy learning in softball batting: Comparing novice and intermediate**
2 **players**

3 This field-based study developed and implemented analogy instructions for softball
4 batting, and examined batting performance outcomes. A focus-group discussion
5 involving a coach and a number of team captains of a collegiate-level softball team
6 identified the typical instructions used for batting (i.e. explicit) and developed an analogy
7 instruction that combined these rules in one biomechanical metaphor (i.e. swing your bat
8 like you are breaking a tree in front of you with an axe). Forty collegiate-level club
9 players (20 novice, 20 intermediate) were assigned to either an analogy learning or an
10 explicit learning group and took part in six training sessions. Batting performance was
11 assessed using a standardised criteria-based rating scale in single-task conditions before
12 and after training, and a dual-task condition after training. The findings show that the
13 novice, but not the intermediate players, displayed significant improvements in batting
14 performance after training. Novices who received the analogy instruction displayed
15 stable batting performance in a dual-task condition, but novices who received explicit
16 instructions, and intermediate players who received the analogy instruction, displayed
17 batting performance decrements. The findings suggest that the benefits of analogy
18 instructions are evident only in novices; learners' previous experiences must, therefore,
19 be carefully considered when developing coaching and instruction programmes.

20
21 Keywords: analogy learning, coaching, instruction, softball, batting

1 **Introduction**

2 The process of acquiring movement skills has been traditionally described to begin with a
3 cognitive stage during which individuals utilize and accumulate rule-based knowledge to
4 monitor and control actions (Fitts & Posner, 1967). As one progresses to an autonomous stage,
5 performance is carried out with little reliance on rules to facilitate movement performance.
6 Based upon this classic definition, substantial sports research has examined skill learning
7 through a cognitive lens. With an intention to promote the most efficient progression to an
8 autonomous stage, researchers have developed various approaches to training movement skills.
9 A number of paradigms are based on the dichotomy of implicit and explicit motor learning.
10 While explicit motor learning is a process that is consistent with traditional rule-based
11 approaches to skill learning, implicit motor learning avoids a rule-based approach in order to
12 promote skill learning with minimal accumulation of declarative knowledge (Masters, 1992).

13 It has been argued that implicit motor learning results in more efficient movement
14 performance, because fewer attention resources are used to process the technical elements of
15 the skill. Implicitly learnt motor skills have also been shown to be robust when performers are
16 subjected to dual-task demands (e.g. Liao & Masters, 2001), high-pressure situations (e.g.
17 Hardy, Mullen, & Martin, 2001), or physiologically fatiguing activities (e.g. Poolton, Masters,
18 & Maxwell, 2007a). For instance, Liao and Masters (2001) showed that a biomechanical
19 metaphor promoted implicit learning of a table tennis forehand topspin and that skill
20 performance tended to be robust when a concurrent secondary task was included. This apparent
21 advantage has been linked to the theory of reinvestment, which posits that performance
22 breakdown can occur when attempts to gain optimal control of movements lead to conscious
23 task processing through the use of previously acquired explicit knowledge (Masters, 1992;
24 Masters & Maxwell, 2008). As a means to counter reinvestment, implicit motor learning
25 paradigms have been designed to prevent accumulation of rule-based knowledge about the

1 motor skill, thereby reducing the likelihood of consciously monitoring and controlling
2 movement.

3 There has been great interest in applying implicit motor learning approaches to real-
4 world conditions, primarily in sports and physical education (van der Kamp et al., 2015), but
5 also in rehabilitation (e.g. Capiro, Poolton, Sit, Holmstrom, & Masters, 2013; Kleynten et al.,
6 2015) and surgical training (e.g. Malhotra et al., 2015; Winning, Malhotra, & Masters, 2018).
7 It is important to note, however, that implicit motor learning is not always advantageous across
8 conditions. Liao and Masters (2001), for example, reported that implicit and explicit learners
9 acquired skills at similar rates, while Poolton and colleagues (2007a) found comparable
10 retention of skills by explicit and implicit learners.

11 Some implicit motor learning approaches seek to deliberately limit accrual of
12 declarative knowledge by interfering with working memory. For example, the first attempts to
13 cause implicit motor learning used a simultaneously performed secondary task to occupy
14 working memory, thus disrupting active hypothesis testing (Masters, 1992; MacMahon &
15 Masters, 2002). Hypothesis testing is also unlikely to occur if fewer practice errors are
16 experienced (i.e. errorless learning; see Capiro et al., 2013; Maxwell, Masters, Kerr, & Weedon,
17 2001). However, these techniques can be difficult to use effectively in practical coaching
18 settings (Bobrownicki, MacPherson, Coleman, Collins, & Sproule, 2015). An alternative
19 approach, analogy learning, might be more feasible when coaches wish to facilitate implicit
20 motor learning.

21 *Analogy learning*

22 Motor analogies provide a powerful tool with which to influence the way people move (see
23 Masters & Poolton, 2012, for a review). An analogy is delivered as an instruction; however,
24 the complex rules that would normally be provided explicitly by the coach are concealed within

1 the analogy as a biomechanical metaphor (Masters, 2000). For example, a person learning a
2 basketball free throw can be instructed with a number of rules about how to throw correctly,
3 which requires working memory involvement and conscious information processing;
4 alternatively, a person can be told to ‘shoot as if you are trying to put cookies into a cookie jar
5 on a high shelf’ (e.g. Krause, Meyer, & Meyer, 2008). This simple analogy has been shown to
6 effectively convey the fundamentals of the free throw movement without the need for
7 additional verbal guidance (Lam, Maxwell, & Masters, 2009).

8 Besides the basketball free throw, sport-specific analogy instructions have been
9 designed and tested in a number of sports, including the forehand topspin shot in table tennis –
10 ‘move the bat as though it is travelling up the side of a mountain’ (Koedijker et al., 2011; Liao
11 & Masters, 2001; Poolton, Masters, & Maxwell, 2006); breaststroke in swimming – ‘glide two
12 seconds with your arms outstretched’ (Komar, Chow, Chollet, & Seifert, 2014; Komar,
13 Potdevin, Chollet, & Seifert, 2018); and the push pass in hockey – ‘move the stick as if you are
14 sloshing a bucket of water over the floor’ (van Duijn, Hoskens, & Masters, 2019). Most of the
15 studies, however, have been laboratory-based, leaving the question of practical utility when
16 coaching generally unanswered. An exception is a study by Schücker and colleagues (2010),
17 which used analogy instructions to train a full golf swing over a six-week training period, with
18 the aim to obtain official permission to play golf.¹ In this study, however, a number of analogy
19 instructions were used instead of a single metaphor as has been typically used in other work.
20 The authors believed that a single metaphor would not encapsulate all of the aspects of a golf
21 swing. Effectively, this means that the volume of instructions (and thereby the corresponding
22 cognitive requirements) was not lower for the analogy approach.

¹ Official permission to play golf is required in Germany and is obtained by passing standard tests that are designed separately for indoor and outdoor conditions.

1 The range of sports in which analogy instructions have been tested suggests great
2 potential for analogy learning as an approach that can be applied in different contexts. This
3 current study contributes to this growing base of applications by testing analogy learning in
4 softball batting. Besides the new sports context, this study contributes to field-based evidence,
5 which is currently lacking, as the study is situated in the training programme of a collegiate
6 level softball club. Such evidence is crucial for transforming research findings to useful insights
7 that can be applied in coaching and teaching.

8 The evidence supporting analogy learning has been largely relevant to novices (e.g.
9 Lam, et al., 2009; Liao & Masters, 2001; Poolton, et al., 2006). However, the reality on the
10 field, particularly at collegiate club levels, is that players will often have some experience prior
11 to embarking on further training. Consequently, they are not novices, yet they need further
12 instruction to improve their skills. We have yet to verify whether a bout of analogy learning
13 would be useful for those who might already have declarative knowledge associated with the
14 skill. To contribute to a better understanding of suitable approaches for players with different
15 levels of experience, this study compares novices and relatively experienced players.

16 An important factor in players' acquisition of skills is self-efficacy, which refers to
17 "beliefs in one's capabilities to organize and execute the course of action required to produce
18 given attainments" (Bandura, 1997, p.3). Implicit motor learning approaches have been
19 suggested to promote learners' self-efficacy (van der Kamp, Duivenvoorde, Kok, & Hilvoorde,
20 2015); however, there has been limited empirical evidence of this, especially in relation to
21 motor performance following bouts of implicit learning. Liao and Masters (2001) determined
22 that confidence was associated with motor performance for explicit learners but not for implicit
23 learners. They interpreted this as evidence that implicit learners acquired less metaknowledge
24 of the acquired movement skills compared to explicit learners. Despite such lack of knowledge
25 amongst implicit learners, self-efficacy could be enhanced as performance accomplishments

1 have been identified as the most important contributing factor (Bandura, 1997). Change in self-
2 efficacy, however, has been largely unexamined in the context of implicit motor learning. With
3 the knowledge that higher self-efficacy has consistently been associated with better sports
4 performance and greater task engagement (McAuley & Blissmer, 2002), it is of value to verify
5 the impact of motor learning approaches on self-efficacy. Whilst self-efficacy has been
6 examined in different skills acquisition contexts (e.g. Stevens, Anderson, Dwyer, & Williams,
7 2012), it has yet to be examined alongside motor performance following an analogy approach.

8 ***Softball batting***

9 There has been relatively limited skills acquisition research into softball batting compared to
10 sports like golf or baseball (Flyger, Button, & Rishiraj, 2006). To the best of our knowledge,
11 this is the first application of analogy learning in softball batting. Biomechanically, softball
12 batting requires weight shifting, hip rotation, shoulder rotation, arm rotation, and elbow
13 extension (Welch, Banks, Cook, & Draovitch, 1995). The nature of the task also includes
14 recognition, reaction, and adjustment to the oncoming ball, adding to the complexity.
15 Moreover, softball batting takes place in an open loop such that adjustments may be limited
16 once the stimulus is released (Rose & Christina, 2006). Instructions are therefore critical for
17 batters to manage the relatively complex task demands. Explicit instructions are likely to be
18 effective in promoting biomechanically correct movements, but cognitive processing of the
19 rules for movement is likely to compete with the information processing demands related to
20 the pitched ball. We therefore suggest that analogy learning is a viable alternative form of
21 instruction, because the movement instructions can be delivered as a single biomechanical
22 metaphor (Liao & Masters, 2001). When movement instructions are processed as a single
23 analogy, cognitive resources should be free to manage the perceptual demands of the skill (i.e.
24 recognition, reaction and adjustment to the pitched ball).

1 This current study applied analogy learning to softball batting, and examined skill
2 performance as the outcome. Because self-efficacy is believed to interact with cognitive and
3 training factors (Feltz & Lirgg, 2001), this study also examined its relationship with skill
4 performance. The main aims of this study were to (a) develop an analogy relevant for softball
5 batting and (b) compare batting performance following analogy learning by novice and
6 intermediate players.

7 Typical coaching instructions (i.e. explicit) were identified, and analogy instructions
8 were developed through a focus-group discussion with previous and present team captains, and
9 a team coach of a collegiate-level softball club. The instructions were used to train novice and
10 intermediate players. We expected improved batting performance from pre- to post-training in
11 both analogy and explicit training conditions. Improvement was expected to be greater for the
12 novices compared to the intermediate players, because they had more room for improvement
13 and there is a potential “ceiling” effect for intermediate players. In the presence of a secondary
14 cognitive task, which was expected to reduce the amount of cognitive resources available to
15 support execution of batting, we expected analogy learners to display robust skill performance
16 while explicit learners were expected to display performance decrements. We also expected
17 that self-efficacy would be positively associated with change in skill performance regardless
18 of level of experience or instructions received.

19 **Materials and methods**

20 *Participants*

21 A priori power analysis using G*Power 3.1 for repeated measures analysis of variance
22 (ANOVA; within-between interactions, four groups, three measurements) determined that to
23 achieve 85% power, alpha of 0.05, with expected effect size of 0.28 (Liao & Masters, 2001),
24 the required sample size was 36. Participants consisted of members of a collegiate softball

1 team, and the sample size ($n = 40$, 14 males and 26 females) was ultimately determined by the
2 number of players who were interested and committed to an actual training programme that
3 consisted of six sessions over three weeks. The participants' ages ranged from 18 to 25 years
4 (mean 21.00, $s = 1.40$). Recruited participants were categorised as either (a) intermediate
5 players ($n = 20$) who had one to two years of experience playing collegiate-level softball, or
6 (b) novice players ($n = 20$) who had less than 10 hours of batting experience. Within each
7 subgroup (i.e. intermediate, novice), participants were allocated to either an analogy or an
8 explicit instruction condition according to the sequence of recruitment (i.e. participants were
9 assigned to the analogy or explicit condition alternately as they signed up for the study). Hence,
10 four training groups were formed ($n = 10$ per group): analogy-intermediate, explicit-
11 intermediate, analogy-novice, and explicit-novice. While the sex distribution across the groups
12 was not equal, the difference was not statistically significant ($\chi^2 = 0.44$, $p = 0.930$). All
13 procedures were reviewed and approved by the institutional ethics review committee, and all
14 participants provided informed consent to join the study.

15 ***Instructions***

16 To develop content-valid instructions for softball batting, a focus-group discussion was
17 conducted. The focus-group participants consisted of one coach, two past team captains and
18 one current team captain of a collegiate-level softball team. The coach had 20 years of
19 experience in coaching softball; the previous team captains had three years of experience in
20 playing softball; and the current team captain had two years of experience. Drawing from their
21 experiences in training and practicing softball batting, the participants came to a consensus that
22 an eight-point set of explicit instructions was representative of the typical instructions given on
23 the field (see Table 1).

24 An independent researcher, experienced in developing analogy instructions for motor
25 learning contexts, provided background knowledge on analogy learning for the focus-group

1 participants. Using examples of other analogies for sports-related tasks as a starting point (e.g.
2 forehand topspin analogy; Poolton, Masters, & Maxwell, 2007b), a discussion was facilitated
3 to develop the analogy instruction. Each participant proposed an analogy instruction for softball
4 batting. The suitability and merits of the instructions, including points of relevance and
5 understanding by the softball club players, were discussed at length until a final analogy
6 instruction was agreed upon. The following analogy instruction was identified: “swing your
7 bat like you are breaking a tree in front of you with an axe”. The analogy instruction and the
8 process through which it was developed, were then reviewed by a team of two independent
9 skills acquisition researchers and the first author of this study.

10 ***Insert Table 1 about here***

11 *Training*

12 The study was implemented within the context of an actual training programme of a collegiate-
13 level softball team. Besides the softball batting training conducted in the study, participants
14 received the same amount of fitness and endurance training as other members of the team (i.e.
15 90 minutes training, twice/week).

16 Softball batting training consisted of six sessions over a period of three weeks (i.e.
17 twice/week). In each training session, participants hit a total of 150 balls (25 balls/set x 6 sets),
18 totalling 900 balls over the six-session training period. The interval between two consecutive
19 balls in each set was five seconds, and the rest interval between two consecutive sets was two
20 minutes, which allowed sufficient recovery to avoid fatigue. Instructions (analogy or explicit)
21 were provided verbally, and presented visually as printed text, to each participant before the
22 start of each set. They were also reminded that they were not to share the instructions that they
23 received with their team mates.

1 In the first session, balls were placed on a tee stand and participants had to bat the ball
2 towards a practice net located at a two-meter distance to the front of his or her position. In the
3 second session, the senior pitcher of the collegiate team was designated to pitch the balls at
4 constant conditions for all participants. The designated pitcher stood 2.5 meters away and at 45
5 degrees diagonal to the participant, and pitched balls towards the participant's strike zone. The
6 strike zone is defined as the volume of space between the top of the participant's knees and the
7 midpoint of his or her torso (International Softball Federation, 2014). The pitcher aimed to
8 pitch the balls at a relatively constant speed across trials and participants. In the third session,
9 a pitching machine was positioned at a distance of 13.10 m (43 feet) from the participant. This
10 is the standard distance between the pitcher and the batter for international women's softball
11 (International Softball Federation, 2014). Plastic balls of the same size as a standard softball
12 were pitched by the machine at a speed of 72.42 kph (45 mph) towards the participant's strike
13 zone. These conditions were maintained across the remaining training sessions (i.e. fourth,
14 fifth, and sixth sessions).

15 ***Testing***

16 Pre-test and post-test conditions were similar to those of the last training session, wherein a
17 machine pitched balls from a standard distance (13.10 m), and at standard speed (72.42 kph)
18 towards the participant's strike zone. The test consisted of 30 balls, pitched at five-second
19 intervals. Participants were instructed to try their best to bat the balls. Batting performance was
20 rated using the Softball Batting Performance Rating Scale, which had been adapted by Krane
21 and colleagues (1994) from the original scale developed by Lowe (1973), and used in a study
22 that examined batting performance in relation to anxiety and situation criticality. The rating
23 scale categorises each hit as one of nine types (see Table 2 for operational definitions), with
24 ratings ranging from one to eight - higher scores represent better performance. From 30 trials,
25 a participant may therefore have a minimum score of 30, and a maximum score of 240.

1 Strikeout definitions were modified because each pitch was rated, whereas three pitches per
2 rating had been used in a previous study that used the scale (Krane, et al., 1994). Ratings were
3 performed by a collegiate level team captain from a different league who was unfamiliar with
4 the study participants, and naive to the study aims and training conditions. Prior to testing, the
5 rater was trained on using the scale, and scored ten collegiate softball players (non-participants)
6 concurrently with the third author of this study. Inter-rater agreement was above 90% prior to
7 testing. No performance feedback was given to participants following the pre-test and post-test
8 sessions.

9 After each of the testing sessions, participants were asked to evaluate their batting self-
10 efficacy using a visual analogue scale, which provided a continuum for participants to mark
11 their response. Visual analogue scales have been found to be valid measures of a range of
12 psychological constructs, such as visual experience of movement (Rausch & Zehetleitner,
13 2014), anxiety (Davey, Barratt, Butow, & Deeks, 2007), and mood (Kontou, Thomas, &
14 Lincoln, 2012). A visual analogue scale is particularly suitable when the question is along a
15 single dimension (Rausch & Zehetleimer, 2014). In this study, participants were asked a single
16 question – how well they could perform softball batting – to which they responded by marking
17 a line on a standard sized line (i.e. 10cm) without scale markings. Labels were provided on the
18 scale only for the extremes (i.e. ‘lowest performance’ corresponded to 0 cm, ‘highest
19 performance’ corresponded to 10cm). Participants’ marks on the visual analogue scale were
20 measured in cm and were converted to percentage, such that 100% represented the highest
21 rating, marked at the 10 cm point on the visual analogue scale.

22 After a 5-minute rest following the post-test, a dual-task testing condition was
23 additionally performed. Because attentional capacity is limited, batting performance that is
24 reliant on conscious processing of instructions may be compromised by a secondary task that
25 also requires conscious processing (e.g. Abernethy, Masters, Maxwell, van der Kamp, &

1 Jackson, 2007). In the dual-task condition, participants were asked to perform a tone counting
2 task while simultaneously batting in the same conditions as the post-test. The tone-counting
3 task has been successfully used to occupy cognitive resources in previous motor learning
4 studies (e.g. Maxwell, Masters, & Eves, 2000; Zhu, Yeung, Poolton, Lee, Leung, & Masters,
5 2015). High-pitched (1000 Hz) and low-pitched (500 Hz) tones were presented in a randomized
6 order at intervals of 1000ms through headphones. Participants were instructed to count the
7 number of high-pitched tones throughout the 30 test trials. Secondary task performance was
8 calculated as percentage accuracy (number of high-pitched tones reported against actual
9 number of high-pitched tones presented).

10 ***Insert Table 2 about here***

11 *Data Analysis*

12 Normality of data was tested using the Shapiro-Wilk test, which showed that batting
13 performance scores and self-efficacy ratings were normally distributed (all p 's > 0.05). To
14 examine the effect of the instructions on skill performance of novice and intermediate players,
15 a mixed-model 3 (test: pre-test, post-test, dual-task) x 4 (group: analogy-novice, explicit-
16 novice, analogy-intermediate, explicit-intermediate) analysis of variance (ANOVA) was
17 performed on batting scores. Mauchly's test confirmed that the sphericity assumption was not
18 violated ($p = 0.216$). To examine change in self-efficacy following training, a mixed-model 2
19 (test: pre-test, post-test) x 4 (group) ANOVA was performed on self-efficacy scores.
20 Significant main effects and interactions were followed up by group-level repeated measures
21 ANOVAs and paired samples t-tests with Bonferroni corrections. One-way ANOVAs were
22 used to compare the secondary task performance of the four groups. Statistical significance
23 was set at $p < 0.05$. All tests were performed using SPSS 25.0.

1 **Results**

2 ***Batting performance***

3 Figure 1 illustrates batting performance of the instruction groups during the pre-test, post-test,
4 and dual-task condition. Within-subjects, a significant main effect of test was found ($F(2, 72)$
5 $= 12.768, p < 0.001, \eta^2 = 0.262$), indicating that the batting performance of participants changed
6 across the three tests (i.e. pre-test, post-test, dual-task). A significant interaction was found
7 between test and group ($F(6, 72) = 8.684, p < 0.001, \eta^2 = 0.420$). Follow-up tests showed
8 significant main effects of test for the analogy-novice ($F(8, 2) = 7.61, p = 0.010, \eta^2 = 0.86$),
9 explicit-novice ($F(8, 2) = 13.30, p = 0.003, \eta^2 = 0.77$) and analogy-intermediate groups ($F(8,$
10 $2) = 10.64, p = 0.006, \eta^2 = 0.73$), but not for the explicit-intermediate group ($F(8, 2) = 0.84, p$
11 $= 0.550, \eta^2 = 0.14$).

12 Paired comparisons showed that batting performance of the analogy-novice group
13 improved from pre-test to post-test ($t(9) = -3.49, p = 0.007$), and did not change from post-test
14 to dual-task ($t(9) = -0.47, p = 0.650$). Batting performance of the explicit-novice group
15 improved from pre-test to post-test ($t(9) = -5.17, p = 0.001$), but deteriorated from post-test to
16 dual-task ($t(9) = 3.61, p = 0.006$). There was no change in the batting performance of the
17 analogy-intermediate group from pre-test to post-test ($t(9) = 0.02, p = 0.990$), but there was a
18 deterioration in performance from post-test to dual-task ($t(9) = 3.09, p = 0.010$). There were no
19 significant changes in the batting performance of the explicit intermediate group (p 's > 0.05).

20 Between-subjects, a significant main effect of group was found ($F(3, 36) = 7.142, p =$
21 $0.001, \eta^2 = 0.373$). Pairwise comparisons of estimated marginal means showed significant
22 differences when the analogy-novice group was compared to the analogy-intermediate ($p =$
23 0.006) and the explicit-intermediate ($p = 0.033$) groups. Significant differences were also found

1 between the explicit-novice and analogy-intermediate groups ($p = 0.007$), and the explicit-
2 novice and explicit-intermediate groups ($p = 0.041$).

3 ***Insert Figure 1 about here***

4 ***Secondary task performance***

5 One-way ANOVA showed no significant between group differences for the tone-counting task
6 ($F(3, 36) = 1.40, p = 0.26$), with mean percentage accuracy across all participants 91.60% ($s =$
7 9.4).

8 ***Self-efficacy***

9 A significant within-subjects effect of test was found ($F(1, 36) = 11.170, p = 0.002, \eta^2 = 0.237$);
10 self-efficacy improved from pre-test to post-test (see Figure 2). An interaction was not evident
11 between test and group ($F(3, 36) = 1.378, p = 0.265, \eta^2 = 0.103$), indicating no effect of the
12 group on the changes in participants' self-efficacy. Between subjects, the main effect of group
13 was not significant ($F(3, 36) = 2.489, p = 0.076, \eta^2 = 0.172$).

14 ***Insert Figure 2 about here***

15 **Discussion**

16 This study aimed to apply analogy learning to softball batting and examine skill performance
17 outcomes, comparing novices and intermediate players. Performance was measured using an
18 established criteria-based rating scale, which has been developed specifically for softball
19 batting (Krane, et al., 1994; Lowe, 1973). As expected, novices displayed improvements in
20 performance regardless of the instructions that they received. While the trends suggest some
21 improvement in performance of intermediate players, changes from pre-test to post-test were
22 not significant in the analogy or the explicit learning groups despite completing 900 trials over
23 six training sessions. Task difficulty needs to be optimal for skill levels of learners in order to
24 promote improved performance (Guadagnoli & Lee, 2004); in this case, it is possible that the

1 practice conditions were not optimal for intermediate players. It may also be the case that the
2 practice dosage was not sufficient to promote further improvement for non-novices. On the
3 other hand, novice players presumably had greater room for improvement, so practice –
4 regardless of instructions – improved performance.

5 *Underlying mechanisms*

6 The advantage of implicit motor learning approaches, such as analogy instruction,
7 manifests in circumstances during which there are competing demands for cognitive resources
8 (Lam, et al., 2009; Poolton, et al., 2006). We expected that analogy learners would display
9 robust performance during the dual-task condition in this study, whereas explicit learners
10 would display disrupted performance. Our findings confirm this for novices, as those in the
11 analogy learning condition displayed stable batting performance, while those who learnt
12 explicitly showed worse batting performance, in the dual-task compared to the single-task post-
13 test condition. Similar to studies of basketball free throwing (Lam et al., 2009) and table tennis
14 (Koedijker et al., 2008), no differences were found in performance of the secondary task across
15 analogy and explicit learners. Participants displayed high accuracy at the tone-counting task,
16 so it appears that they conscientiously and effectively engaged in the secondary task, but with
17 differing impacts on performance of the batting task. Novice analogy learners did not display
18 an advantage over novice explicit learners at post-test and, as expected, the benefits only
19 became evident when competing cognitive demands were present. As the theory of
20 reinvestment posits, the availability of explicit knowledge enables conscious processing of skill
21 performance, which ultimately leads to breakdown (Maxwell, Masters, & Poolton, 2006).
22 Considering this, the explicit learners were provided explicit knowledge to reinvest whereas
23 the analogy learners were not, which may explain the greater tendency for performance
24 breakdown. We note, however, that the novice learners may not have reached an autonomous

1 stage of performance, in which case, alternative explanations would account for the advantage
2 demonstrated by novice analogy learners.

3 Masters and Liao (2003) proposed that the underlying mechanism of analogy learning
4 is a process in which relevant and discrete pieces of information are integrated into a single
5 representation (i.e. referred to as ‘chunking’). If such were the case, the novices would have
6 had adequate cognitive resources to manage the demands generated by the secondary task
7 without an impact on their batting performance, presumably because the relevant information
8 for batting was ‘chunked’ in the analogy instruction. This advantage is particularly useful for
9 baseball coaches, who need to train novices to display robust batting skills, and at the same
10 time, process information related to recognition, reaction, and adjustment to the oncoming ball.

11 It is also possible that the apparent benefits of analogy instruction for novices in this
12 study are a function of the volume of instructions. This being a field-based study, we
13 endeavoured to compare the analogy instruction to the typical coaching instructions being
14 deployed in the softball club. Consequently, this meant that the single analogy instruction was
15 compared to a set of eight explicit instructions. We therefore acknowledge that the differences
16 in training outcomes could be due to variations in cognitive requirements caused by the volume
17 of instructions. Related to this, Schucker et al. (2010) used multiple analogy instructions for a
18 golf swing, equivalent in volume to explicit instructions, and found no differences in
19 performance by learners following a six-week training period. Nevertheless, we note that
20 Bobrownicki and colleagues (2015) have argued that the strength of analogies in applied
21 contexts is that they potentially deliver relevant movement instructions in a concise package.
22 From this perspective, the value of analogy learning in coaching and instruction is probably
23 linked to cognitive efficiency. While we do not have empirical evidence of cognitive efficiency
24 in this current study, recent work by van Duijn et al. (2019) offers evidence from
25 electroencephalography (EEG) suggesting that analogy instructions promote cognitive, rather

1 than psychomotor, efficiency among novices. Future work could explore methodologies that
2 measure cognitive efficiency in field-based research, as EEG is generally more suitable for
3 laboratory-based experiments.

4 Whilst we set out to verify whether a bout of analogy learning would be useful for non-
5 novice learners, our findings make it difficult to draw conclusions on this. We did not find
6 improvements following training amongst intermediate players, but we found that they
7 displayed a different pattern of performance in relation to the dual-task condition – the
8 intermediate explicit learners were stable and the intermediate analogy learners got worse. The
9 intermediate players had previously received instructions that were comparable to the eight-
10 point instructions used in the explicit training group. Analogy learning is thought to have the
11 potential to enable learners to simplify previously established concepts related to the movement
12 (Masters, 2000; Bobrownicki, Collins, Sproule, & MacPherson, 2018). However, the
13 intermediate players in this study appear to have processed the analogy instruction as new
14 information, and failed to make connections with their existing knowledge base. This was not
15 apparent from pre-test to post-test as all intermediate players maintained their batting
16 performance levels. The cognitive cost of introducing the analogy instruction to intermediate
17 learners, who presumably have an existing knowledge established through previous
18 instructions, became apparent in the dual-task condition. This suggests that the use of analogy
19 instructions in coaching needs careful consideration, especially with reference to players’
20 previous learning experiences and existing knowledge base. However, more research is needed
21 to further examine the utility of analogy instructions for non-novice players, considering both
22 cognitive efficiency (e.g. measured by EEG or alternative methods) and processing of
23 instructions (i.e. controlling the volume of instructions).

24 The patterns displayed by intermediate learners also brings into focus the relevance of
25 considering implicit and explicit learning approaches not in isolation. Poolton, Masters, and

1 Maxwell (2005) showed that the benefits afforded by an initial bout of implicit motor learning
2 tend to be retained even when this is followed by a bout of explicit learning. Based on evidence
3 from an errorless learning paradigm, they suggested that the initial stages of learning should be
4 implicit so that skills are robust in the face of competing cognitive demands. Whether the same
5 holds true in the case of an analogy learning paradigm has yet to be tested. In this study, a
6 reverse sequence occurred, with intermediate players having prior explicit training. It appears
7 that an initial explicit stage followed by analogy learning could lead to disadvantages that may
8 be caused by additional cognitive processing requirements. Given that field conditions are such
9 that collegiate club players may have varying learning experiences prior to training, future
10 research needs to examine the effects of combinations and sequences of explicit and analogy
11 learning approaches.

12 *Self-efficacy*

13 Cognisant that self-efficacy is an important factor to consider when developing coaching and
14 physical education programmes (van der Kamp et al., 2015), we examined the effects of
15 instruction on batting self-efficacy. The findings show that participants' self-efficacy improved
16 following training, across novice and intermediate players and regardless of the instructions
17 they received. It has been established that information about performance accomplishments
18 forms the basis for self-efficacy levels (Bandura, 1997). In this study, no feedback about
19 performance was provided to the participants. Nevertheless, they are likely to have gathered
20 information from intrinsic feedback that was available in each practice trial (Magill &
21 Anderson 2017). It is worth noting that self-efficacy increased even for intermediate players
22 who actually did not show significant improvements in performance following training. We
23 know that self-efficacy is a significant contributor to motivation and performance levels across
24 a wide range of contexts (Bandura & Locke, 2003) and therefore sought to verify the suggestion
25 that implicit motor learning could promote better self-efficacy (van der Kamp et al., 2015). The

1 current study findings do not provide evidence for this, as it appears that the opportunity for
2 practice, whether in explicit or implicit conditions, was sufficient to cause improvements in
3 self-efficacy. It would be worth examining this further, using alternative implicit motor
4 learning paradigms (e.g. errorless learning).

5 ***Limitations***

6 In interpreting the findings of this study, it is also important to acknowledge a number of
7 limitations. Batting performance was measured using a criteria-based qualitative scale. While
8 the methodology ensured internal validity through standardised assessment, external validity
9 may be limited and further research that uses objective measures (i.e. three-dimensional motion
10 analysis) could add value. One of the training sessions employed a senior pitcher who
11 attempted, as much as possible, to pitch balls at a constant speed towards participants. We
12 acknowledge that this was subject to human limits, and would not have been as consistent as
13 the pitching machine employed in the subsequent sessions.

14 Unlike most motor learning studies, we did not check for verbal declarative knowledge,
15 because the constraints associated with the actual training context did not allow time for verbal
16 reports to be collected. We acknowledge that this prevents us from definitively ruling out the
17 possibility that participants in the explicit training conditions might have used significantly
18 fewer than the eight explicit instructions provided. Nevertheless, we believe that the available
19 evidence (e.g. Lam, et al., 2009; Masters, Poolton, Maxwell, & Raab, 2008; Poolton, et al.,
20 2006) clearly shows a difference in accrued declarative knowledge as a consequence of analogy
21 learning or explicit learning. Finally, analogies are known to be subject to nuances associated
22 with the language and culture of the population for which it was designed (see Poolton,
23 Masters, & Maxwell, 2007b). Hence, the analogy developed in this study needs to be re-
24 examined in other population groups, and possibly modified as appropriate.

1 *Conclusions*

2 The application of motor learning research across sports, education, and rehabilitation
3 continues to grow, as does evidence of the need for careful consideration of approaches and
4 their suitability for learners. Analogy learning is one of many approaches – explicit and implicit
5 – that could inform sport and physical education pedagogy, and could be used as a constraint
6 to facilitate movement exploration by novices (Komar et al., 2018). By demonstrating an
7 application of analogy learning in softball batting, this current study contributes to the evidence
8 supporting the use of analogy learning, adding to the range of sports to which the approach has
9 been applied to (Koedijker, et al., 2011; Komar, et al., 2014; Lam, et al., 2009). Furthermore,
10 by comparing novice and intermediate players, the findings of this study suggest that analogy
11 learning is not universally superior to typical explicit coaching approaches. It appears to be
12 beneficial for novices, and further research is needed to examine the underlying mechanisms,
13 particularly to understand the apparently different outcomes in those who have received
14 previous instruction. At the outset, we asked whether a bout of analogy instruction would be
15 beneficial for non-novices; our findings suggest otherwise. Based on current evidence, the
16 decision to adopt one specific instruction approach needs to be informed by the characteristics
17 of the learners. In other research, the suitability of explicit or implicit approaches appears to be
18 influenced by learners’ motor ability (Maxwell, Capio, & Masters, 2017), cognitive ability (van
19 Abswoude, Santos-Vieira, van der Kamp, & Steenbergen, 2015) or personality (van Ginneken
20 et al., 2017).

21 To conclude, this study tested an analogy for softball batting. The findings show that
22 the benefits associated with implicit motor learning were apparent in novice learners, but not
23 in intermediate learners with prior explicit training. Further research is recommended to gain a
24 better understanding of analogy instructions in field conditions, where explicit and implicit
25 learning might not occur in isolation. Ultimately, in the complex real world, coaching and

1 instruction has to be designed to meet the needs of players whose knowledge, skills,
2 dispositions and experience vary greatly.

3 **Declaration of interest statement**

4 The authors declare no conflict of interest.

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1 **Tables**

2 Table 1. Comparison of the analogy and explicit instructions.

Analogy	Explicit
Swing your bat like you are breaking a tree in front of you with an axe.	<ol style="list-style-type: none"> 1. Initiate the movement by rotating your trunk. 2. Lead with your front arm for the bat to contact the ball. 3. Push the bat forward with your back arm. 4. Rotate your wrists to push the ball further. 5. Keep your elbows down. 6. Keep your trunk perpendicular to the ground. 7. Keep most of your weight at the back leg up until the bat makes contact with the ball. 8. Keep looking forward after batting.

3

4

5 Table 2. Operational definition and scores using the adapted softball batting performance

6 rating scale (Krane, Douglas, & Rafeld, 1994).

Type of hit	Operational definition	Score
Strike-out looking	Participant calls a strike without swinging the bat.	1
Strike-out swinging	Participant swings and misses.	2
Hit by pitch	Participant is hit by the pitch.	4
Infield fly ball	Batted ball rises above the plane of the bat and travels into the infield.	5
Ground ball	Batted ball lands in the infield and bounces more than 4 times and rolls toward the outfield	5
Easy outfield fly ball	Batted ball rises above the plane of the bat and slowly travels to the outfield.	6
Hard ground ball	Batted ball lands in the infield and bounces no more than 3 times before it reaches the outfield; ball travels at high speed.	7
Hard fly ball	Batted ball rises above the plane of the bat and travels quickly into the air; ball lands in the outfield.	8
Hard line drive	Batted ball moves in the trajectory of a straight line; ball lands not more than once in the infield or first lands in the outfield.	8

1 **Figure Legend**

2 Figure 1 Batting performance of participants during the pretest, posttest, and dual-task
3 condition.

4 Figure 2 Self-efficacy of participants at pretest and posttest.