Distinguishing the effects of verbalizing a skill on performance and learning in novice and skilled populations

by

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Abstract

This dissertation is a synthesis of two interdependent studies examining the impact of verbalization on motor learning and performance. In the first study, Rhoads et al. (in press) investigated the effects of expecting to teach and teaching on motor learning. Results revealed no impact of teaching on a 24-h delayed retention test, suggesting verbalizing a motor skill via teaching does not influence motor learning. The second study examined the impact of verbalization on motor performance and learning. Results revealed no impact of verbalization on immediate retention test or delayed retention test. These studies add to previous literature investigating the verbal overshadowing effect in the motor domain. Verbal overshadowing is "the idea that verbalization creates a language-based representation that overshadows difficult-to-verbalize aspects of perceptual memory" (Flegal & Anderson, 2008, p. 927). This literature suggests verbalizing a motor skill affects motor performance assessed by way of an immediate retention test (Flegal & Anderson, 2008; Chauvel et al., 2013). Importantly, this effect may only be present if participants possess a certain level of declarative knowledge. Skilled participants may revert back to declarative mechanisms after verbalization to control their movements causing a decline in motor performance (Flegal & Anderson, 2008). Likewise, novice participants may experience performance decrement due to verbalization when declarative knowledge is used for task execution (Chauvel et al., 2013). The second study revealed no impact of verbalization on immediate motor performance, thus, superficially contradicting the previous literature. However, the novice and skilled participants exhibited relatively low levels of declarative knowledge (observed via scored verbalization task and free recall assessment). Perhaps, these participants lacked the appropriate amount of declarative knowledge in order to experience a verbal overshadowing effect on immediate motor performance. Taken together, verbalization may only influence motor performance when declarative knowledge is possessed and utilized by participants. Conversely, verbalization may not impact motor learning (regardless of the amount of declarative knowledge present). The second study aligns with Rhoads et al. (in press) suggesting verbalizing a motor skill does not influence performance on a delayed retention test. Future research should investigate a potential "wash-out" period of verbalization, as well as the amount of declarative knowledge necessary to observe a verbal overshadowing effect. Ultimately, verbalizing a motor skill may affect immediate motor performance if an appropriate amount of declarative knowledge is possessed by participants, but presumably does not impact delayed motor performance.

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List of Abbreviations

BVE	Bivariate variable error
EEG	Electroencephalography
EMG	Electromyography
IMI	Intrinsic Motivation Inventory
MLP	Motor learning and performance
MPT	Motor preparation time
RE	Radial error

Chapter 1: The effects of expecting to teach and actually teaching on motor learning

1. Introduction

Peer-tutorial programs are common across the United States. These programs are designed for one student (the tutor) to assist another (the tutee) in an academic subject. Interestingly, the tutee is not the only person who exhibits academic gains, as several reports provide evidence for the tutor also achieving academic gains, sometimes even to a greater extent than the tutee (e.g., Allen & Feldman, 1973; Johnson, Sulzer-Azaroff, & Maass, 1977). Similarly, graduate students are traditionally required to teach classes in order to supplement their progression toward subject-matter expertise (McKeachie & Kulik, 1975). The notion that teaching facilitates the teacher's learning has been a long accepted assumption in education.

Bargh and Schul (1980) sought to investigate the cognitive benefits of teaching for the teacher. They proposed three stages of the teaching process: (1) preparation for teaching (e.g., organizing material in one's mind), (2) initial presentation of material to students (e.g., explaining material in a coherent manner while indicating key concepts), and (3) responding to the students' questions (e.g., interacting with students about material). Recently, several studies have investigated the relationship between the first two phases on learning in academic settings. This research found that preparing (expecting) to teach and explaining to others (actually teaching) provided cognitive benefits (e.g., Fiorella & Mayer, 2013; Fiorella & Mayer, 2014; Hoogerheide, Loyens, & van Gog, 2014). Specifically, Fiorella and Mayer (2013) found that studying while expecting to teach and then teaching enhanced performance on an immediate retention test of academic information relative to a group that simply studied the information. Similarly, Fiorella and Mayer (2014) observed that studying while expecting to teach and teaching enhanced performance on an immediate retention test of academic information relative to a group that studied with the expectation of being tested. Additionally, the authors' results suggested teaching provided an advantage over simply expecting to teach on a delayed retention test. Hoogerheide and colleagues (2014) examined the effects of expecting to teach and teaching through creation of a webcam video on a college-aged population and secondary school-aged population. The college-aged population performed better on retention and transfer tests of academic information after teaching, while this effect was only evident on the transfer test for the secondary school-aged youth. In a college-aged population, Hoogerheide and colleagues (2016) found that explaining to a fictitious partner via webcam video was more beneficial than restudying information, while explaining to a fictitious partner by way of writing was not. However, there was no significant difference between the explanation by video and the explanation by writing conditions.

In sum, the extant literature suggests expecting to teach and teaching may benefit learning academic information. However, less is known about how expecting to teach and teaching affect learning motor skills. It cannot be taken for granted that expecting to teach and teaching will benefit learning motor skills as it does academic skills, as the former relies heavily on the accrual of procedural knowledge, whereas the latter relies entirely on the accrual of declarative knowledge (Rosenbaum, Carlson, & Gilmore, 2001). The accumulation of procedural knowledge is thought to occur implicitly, and is often measured by assessing how accurately and precisely a skill is executed. Conversely, the amassing of declarative knowledge is thought to occur explicitly, and is frequently indexed by determining how many facts can be recalled; in the case of motor learning, these facts are about the skill being learned. Interestingly, declarative knowledge may cause motor learning to occur in an inefficient manner, whereby the learned skill is susceptible to breakdown under high cognitive workload (Masters, 1992; Masters & Maxwell, 2008; see Stanley &

Krakauer, 2013 for an alternative perspective). Therefore, it is important to determine whether expecting to teach and teaching enhances motor learning.

Some research has examined the effects of expecting to teach on motor learning. Specifically, Daou, Buchanan, Lindsey, Lohse, and Miller (2016), Daou, Lohse, and Miller (2016), and Daou, Lohse and Miller (2018) had half of their participants practice a motor skill with the expectation of teaching the skill to another participant, while the other participants practiced with the expectation of being tested on the skill. A day later (and, in the case of Daou, Lohse, et al., a week later), all participants were tested on the motor skill. Results revealed expecting to teach enhanced skill accuracy and precision as well as recall of skill facts on the delayed posttests, relative to expecting to test. This evidence suggests expecting to teach enhances motor learning. However, this paradigm does not consider the influence of actually teaching on learning a motor skill. The effect of actually teaching is important to consider, as it may have an additive effect in learning (Fiorella & Mayer, 2014).

The reasons why expecting to teach and teaching a motor skill enhance skill learning are also important to consider. Increases in motivation are a potential cause, as motivation has been associated with expecting to teach (Benware & Deci, 1984; Fiorella & Mayer, 2014, Experiment 1) and motor learning (Wulf & Lewthwaite, 2016). Expecting to teach and teaching should increase motivation by way of responsibility or pressure, such that the learner realizes someone else's learning depends upon the learner. However, the evidence is equivocal. Specifically, expecting to teach has been shown to enhance motivation in some studies (Benware & Deci, 1984; Fiorella & Mayer, 2014, Experiment 1), but not in others (Daou, Buchanan et al., 2016; Daou, Lohse et al., 2016; Daou, Lohse et al., 2018). Similarly, motivation should enhance motor learning through modulations in dopaminergic activity (Wulf & Lewthwaite, 2016). However, research reveals inconsistent results with respect to the relationship between motivation and motor learning. Specifically, past experiments suggest a positive relationship between motivation and motor learning at the group level (Grand et al., 2015), but not the individual level (Grand, Daou, Lohse, & Miller, 2017; Ste-Marie, Carter, Law, Vertes, & Smith, 2016). That is, participants in a treatment group may exhibit higher motivation than participants in a control group concomitant with superior motor learning, however individual participants' motivation does not predict their motor learning when controlling for their group assignment.

Additionally, motor learning and performance research has recently considered engagement, which reflects the experience of focused attention and task involvement (Leiker, Bruzi et al., 2016; Leiker, Miller et al., 2016). Engagement should be enhanced by expecting to teach and teaching because individuals who are expecting to teach may be more focused and involved in what they are practicing, since they know they will have to teach another person. To this point, Daou, Lohse et al. (2016) reported that expecting to teach enhanced information processing, which is associated with engagement (Leiker, Miller et al., 2016). Importantly, as with motivation, engagement has been linked to motor learning (hypothetically through dopaminergic mechanisms) at the group level, but not the individual level (Lohse, Boyd, & Hodges, 2016).

Engagement and motivation share similar qualities. For example, intrinsically motivated individuals are interested in the task they are performing, similar to how engaged individuals experience involvement in the task they are performing. However, the two constructs are distinct. Specifically, motivation encourages action toward a goal, whereas engagement reflects the experience of a person while acting toward the goal (Lohse et al., 2016). As such, motivation and engagement may impact performance and learning cooperatively or separately and, thus, were both considered in the present experiment.

To the best of our knowledge, there has been no investigation regarding the effects of actually teaching a motor skill on learning the respective motor skill. The purpose of this study is to examine the effects of expecting to teach and actually teaching a motor skill on learning that respective motor skill (both procedural learning in terms of skill accuracy and precision as well as declarative learning in terms of recall of facts about the skill). Based on previous research in the academic domain, we believe expecting to teach will enhance learning, and teaching will interact with expecting to teach, by increasing learning significantly more than expectation alone. That is, participants who expect to teach will exhibit superior learning relative to those who do not, and participants who expect to teach and teach will demonstrate greater learning than participants who only expect to teach. We also investigated whether motivation and engagement could explain any effects of expecting to teach and actually teaching on learning. Specifically, we examined whether expecting to teach and actually teaching modulated motivation and engagement, and whether motivation and engagement predicted learning independent of expecting to teach and actually teaching (i.e., whether motivation and engagement predicted learning at the individual level). As past research has reported inconsistent effects of expecting to teach on motivation, and equivocal effects of motivation and engagement on motor learning, we considered our investigation into these effects to be exploratory and made no specific hypotheses.

2. Methods

Prior to beginning data collection, the experimental design and analyses were registered and made public on AsPredicted.org: https://aspredicted.org/kh86b.pdf. We designed the current experiment in a more ecologically-valid way than prior expecting to teach paradigms by allowing participants intrinsic visual feedback at pretesting and posttesting (cf. Daou, Buchanan et al., 2016; Daou, Lohse et al., 2016). However, we still maintained some experimental constraints used in previous paradigms such as only allowing participants 1-min breaks after each block of putts during acquisition.

2.1. Participants

One hundred and twenty-one right-handed young adults with limited golf experience (N = 121, M_{age} = 21.7, *SD* = ±2.85 years) provided written consent to an institution-approved research protocol. Sample size was determined with an a priori power calculation providing 80% power ($\alpha \leq .05$) to detect a moderate-sized effect ($f^2 = .15$) of the interaction between expecting to teach and teaching on motor learning in a multiple linear regression model (Faul, Erdfelder, Lang, & Buchner, 2007). The model controlled for the following variables: the main-effects of expecting and teaching, time spent studying during the acquisition phase of the experiment, number of putts taken during the acquisition phase, and pretest motor skill performance. The power calculation yielded $N = 81$, but 3 additional participants were initially recruited to create equal n/group. Further, an additional 37 participants were recruited after data had been collected from the initial 84 participants, due to significant group differences in pretest accuracy in the initial sample. These additional participants were quasi-randomly assigned to groups based on pretest accuracy[1]. The participants were recruited through kinesiology and physical education classes, university research participation system (SONA), and word-of-mouth. Participants were compensated with course credit when possible and entered to win one of four $20 VISA gift cards.

2.2. Task

Participants used a right-handed golf putter (Bionik RL Series 207) to putt a golf ball (Top Flite XL) toward a target on an artificial grass surface (660 cm x 190 cm) in a laboratory setting.

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[1] Specifically, each new participant's pretest accuracy was associated with a quartile derived from the initial 84 participants. The new participant was then assigned to the group with the fewest *n* from that participant's quartile, thus creating equal *n*s from each quartile in each group.

The target was a 12 cm x 12 cm painted cross (+) approximately 120 cm away from the participants. The objective of the task was to putt the ball as close to the center of the target as possible. Golf putting was chosen because putting is a motor skill that can be taught through verbal instruction and physical demonstration (which was important for the experimental paradigm—see Procedure section). Further, the task (i.e., putting 120 cm) has been employed in previous expecting to teach studies (Daou, Buchanan et al., 2016; Daou, Lohse et al., 2016).

2.3. Demographic measures

A golf experience and handedness (hand used most often for motor tasks) questionnaire was administered at the beginning of data collection. This questionnaire inquired about participants' lifetime golf experience, as well as experience within the past year. Additionally, participants were asked to report their dominant hand while performing physical tasks.

2.4. Performance measures

A metric tape measure was used to measure the distance the ball stopped from the center of the target in two dimensions, vertically (i.e., ball stops short or long of target) and horizontally (i.e., ball stops left or right of target). Radial error (RE) served as the measure for putting accuracy and bivariate variable error (BVE) indexed putting precision as recommended by Hancock, Butler, and Fischman (1995). RE and BVE were calculated for each putt in the pretests and posttests and averaged within each pretest and posttest (blind pretest, un-blind pretest, etc.). RE and BVE were calculated for each putt in the odd-numbered acquisition sets and averaged within each set. Learning was assessed by accuracy and precision measures on the posttests, controlling for performance at pretest. These measures were also recorded during acquisition blocks to measure changes in performance.

2.5. Self-reported measures

The Intrinsic Motivation Inventory (IMI) was used to assess motivation during the acquisition phase of the experiment (McAuley, Duncan, & Tammen, 1989). The IMI has been frequently utilized as a measure of motivation in motor learning and performance research. Specifically, McAuley et al. (1989) established the IMI's validity and reliability in a competitive sport setting, and numerous motor learning studies continue to use the IMI and report good reliability (Abbas & North, 2017; Post, Aiken, Laughlin, & Fairbrother, 2016). Moreover, this questionnaire is an appropriate measure for the current experiment because of the questionnaire's capability to index several types of motivation. All subscales of the IMI were included in the questionnaire, but specific subscales of interest were interest/enjoyment (intrinsic motivation), value/usefulness (internalized motivation), effort/importance (general motivation), and pressure/tension (pressure). Examples of each subscale of interest are as follows: interest/enjoyment item, "I enjoyed doing this activity very much"; value/usefulness item, "I think this is an important activity"; effort/importance item, "I put a lot of effort into this activity"; pressure/tension item, "I was anxious while working on this activity". The questionnaire was scored on a seven-point Likert scale with "not true at all" and "very true" as the anchors. According to recommended scoring protocols (selfdeterminationtheory.org), items were averaged within each subscale of concern: interest/enjoyment, value/usefulness, effort/importance, and pressure/tension.

Additionally, a language-adapted version of the User Engagement Scale was utilized to assess overall engagement in the activity during the acquisition phase (O'Brien & Toms, 2010). This scale has previously been used in motor learning research, and good reliability has been reported (Leiker, Bruzi et al., 2016; Leiker, Miller et al., 2016). The modified version included the following subscales: focused attention, endurability, novelty, and involvement (for full language-adapted scale, see Leiker, Bruzi et al., 2016). Examples of each subscale of interest are as follows: focused attention item, “I was absorbed in my task”; endurability item, “I would recommend this task to my friends and family”; novelty item, “I felt interested in my task”; involvement item, “This task was fun”. The questionnaire was scored on a five-point Likert scale with “strongly disagree” and “strongly agree” as the anchors. According to recommended scoring protocols (O’Brien & Toms, 2010), items were averaged within each subscale of concern: focused attention, endurability, novelty, and involvement.

2.6. Declarative knowledge measure

A free recall test was used to measure the declarative knowledge retained from the acquisition phase. The participants were asked to report (in as much detail as possible) any methods, rules, or techniques they may have used to putt the golf ball during the acquisition phase of the experiment (Daou, Buchanan et al., 2016; Daou, Lohse et al., 2016; Daou, Lohse et al., 2018; Maxwell, Masters, & Eve, 2000). The number of key concepts from an instruction booklet used during acquisition that a participant correctly recalled served as their free recall score (Daou, Buchanan et al., 2016) (see Procedure section for details about instruction booklet). The key concepts were: (1) establish proper grip, (2) place the putter head behind the ball and take a hip-width stance, (3) place the eyes directly over the ball by hinging from the hips, and (4) stroke the ball without breaking the wrists. Each key concept was worth 1 point for a maximum score of 4 points on the test.

2.7. Study time and physical practice measures

The researcher recorded the amount of time a participant spent looking at the golf instruction booklet in order to quantify the time spent studying the skill. Specifically, the researcher recorded the initial study time (≥ 2 min). Also, the researcher recorded the time spent looking at the booklet during 1-min rests between sets. (Participants were limited to 1-min rests.) A sum of these recorded times served as the total study time variable for this experiment. Additionally, the total number of acquisition putts was recorded during acquisition phase to index number of physical practice repetitions.

2.8. Procedure

2.8.1. Day 1

The participants reported to the laboratory at their scheduled time. After providing consent, participants were asked to complete the golf experience and handedness questionnaire. Next, the pretest portion of the experiment included two phases: blind (10 putts) and un-blind (10 putts). Previous expecting to teach paradigms employed only blind pretests (i.e., participants were blind-folded and ear-plugged) in the protocols (Daou, Buchanan et al., 2016; Daou, Lohse et al., 2016). These blind pretests were conducted in order to isolate performance and minimize on-line learning of the skill (Dyke et al., 2014). However, un-blind pretests offer greater ecological validity. Therefore, it is important to determine whether these tests cause experimental results to differ from experiments employing blind tests. That is, whether the expecting to teach/teaching effect is robust enough to withstand a more ecologically valid protocol. For phase 1 of pretest (blind), participants wore earplugs and were permitted to view the ball and target before vision was occluded. The researcher placed the ball on the starting line; participants placed the putter in line with the ball, pulled the blindfold down over their eyes with one hand, which they then returned to the putter, and hit the ball toward the target. The participants were asked to keep the blindfold over their eyes until the researcher instructed them to look at the ball when preparing the next putt. This procedure prevented the participant from obtaining information about the outcome of the putt, reducing on-line learning in phase 1 of the pretest. After phase 1 of the pretest, the participant was asked to complete phase 2, which consisted of 10 putts toward the target without blindfold or earplugs (un-blind).

After the pretest, the participant was asked to sit and received further instructions based on their experimental group. There were four groups in this experiment and these instructions set up the participant's expectation for the end of acquisition and the following day (i.e., retention). Participants in the Expect-Teach and Expect-No Teach groups were told, "Tomorrow you will be tested on your putting. Today, you have 1 hour to learn how to putt. You do not need to use the entire hour. You will start learning by studying this golf putting instruction booklet for at least 2 min. But, you may study it for as long as you like; and you may return to study it whenever you like during practice. After the hour of practice and studying, you will have to teach the skill for future participants. We will record a video of you teaching the skill. This video will be used for future participants, so they can learn how to putt a golf ball." The No Expect-Teach and No Expect-No Teach groups were told, "Tomorrow you will be tested on your putting. Today, you have 1 hour to learn how to putt. You do not need to use the entire hour. You will start learning by studying this golf putting instruction booklet for at least 2 min, but you may study it for as long as you like; and you may return to study it whenever you like during practice." It is important to note that all participants expected to be tested the following day unlike in Daou, Buchanan et al. (2016), Daou, Lohse et al. (2016), and Daou, Lohse et al. (2018), where only the expect to test group was given this expectation. After the instructions were given, participants studied the golf instruction booklet, which contained visual and written, step-by-step instructions for proper putting and were provided by an expert golfer (for further details, see Daou, Buchanan et al., 2016). The participants studied the booklet for at least 2 min, but were able to study as long as they deemed necessary. Next, the participants were informed about the acquisition phase. All groups were told the following: "Now you will continue learning by performing at least 5 sets of 10 putts. You will have a 1-min break after each set. During these breaks, you may study the booklet. You may stop putting whenever you like, as long as you have performed at least 5 sets of 10 putts. When you are done putting, please let us know. If you decide you are done, you must remain in the lab for the duration of the hour. During this time, you can browse the Internet, do homework, etc., but you may not study the booklet or resume putting". Following these instructions, the participant proceeded to the acquisition-putting phase. The researchers measured and recorded all putts of the odd sets (i.e., Set 1, 3, 5, etc.), as well as study time between all sets. This process was repeated until the participant announced they were finished putting or the 1 h time limit was complete.

Once the acquisition phase concluded, the teach or no teach scenario was set up depending on the participant's designated group. The No Expect-No Teach group was told, "You must practice and study for an additional 2 min to finish up for today". The No Expect-Teach group was told, "Okay, one final thing in our protocol today: We are going to record you teaching how to putt a golf ball. It needs to be a short 2-min instructional video for teaching future participants how to putt. We are only going to record from your neck down, so you cannot be identified". The Expect-No Teach group was deceived; they were told, "The battery in the camera is dead and I don't have time to charge it... so, you can practice and study for an additional 2 min instead to finish up for today." Finally, the Expect-Teach group was told, "As discussed at the beginning of the experiment, we need you to record a 2-min instructional video on how to putt a golf ball. We need this video for teaching future participants how to putt. We are only going to record from your neck down, so you cannot be identified". All videos were recorded from the neck down in attempt to ensure participants' anonymity. Each group carried out their respective tasks, with the teaching groups providing verbal instructions and putting demonstrations. The tasks were timed for 2 min to ensure time consistency between all four groups. After the teach scenarios were completed, the participants filled out the two questionnaires: IMI and User Engagement Scale. Researchers scheduled Day 2 and participants were free to leave the laboratory.

2.8.2. Day 2

The participants returned approximately 24 h later for posttesting. The retention test was the exact same format as the pretest. The participant completed 10 blind putts, then 10 un-blind putts to the same target as the previous day. The participant was asked to complete these putts to the best of their ability. After the posttest, the participants completed the free recall test. Finally, the participants were thanked and debriefed about the experiment. The participants that taught were informed that their videos would be deleted and not used for future purposes.

3. Statistical analysis

To assess pretest performance, separate 2 (Expect: teach/no teach) x 2 (Teach: yes/no) x 2 Pretest (blind/un-blind) mixed-factorial ANOVAs were conducted for RE and BVE, with repeated-measures on the last factor. To assess acquisition performance, separate 2 (Expect) x 3 Acquisition Block (1/3/5) mixed-factorial ANCOVAs were conducted for RE and BVE, with repeated-measures on the second factor and average pretest RE/BVE (averaged across blind and un-blind tests) serving as the covariate. (Whether participants taught was not considered for the acquisition performance analysis since actual teaching occurred at the end of acquisition). The Greenhouse-Geisser correction was applied when sphericity was violated.

To assess learning, we conducted separate 2 (Expect) x 2 (Teach) x 2 Posttest (blind/un-blind) mixed-factorial ANCOVAs for RE and BVE, with repeated-measures on the last factor, and average pretest RE/BVE, study time, and acquisition putts serving as the covariates. The purpose of these ANCOVAs was to justify averaging across the blind and un-blind posttests for RE and

BVE in the multiple linear regression models (Lohse, Buchanan, & Miller, 2016). For both RE and BVE, posttest did not interact with expect, teach, or Expect x Teach (*p*s ≥ .562). Therefore, we averaged across posttest type in the multiple linear regression models.

Our primary analyses were linear regression models to assess motor learning. Specifically, separate regressions were conducted for RE and BVE (averaged across posttests). The first step of each regression model included pretest (RE or BVE), practice putts, and study time. The second step included the following variables: expect and teach. The third step was the interaction term Expect x Teach. An exploratory fourth step added IMI (averaged across motivation subscales) or User-Engagement Scale (averaged across subscales) to determine whether motivation or engagement predicted learning (irrespective of expectation or teaching).

To assess group differences in acquisition putts, study time, IMI subscales, and User-Engagement subscales, three MANOVAs were conducted. The first MANOVA included putts and study time as dependent variables; the second MANOVA included IMI subscales as dependent variables; the third MANOVA included User-Engagement subscales as dependent variables. For each MANOVA, expectation served as the independent variable because the dependent variables reflected measures based on the expectation portion of the acquisition phase, before participants were asked to teach/not teach.

The free recall test was analyzed with a 2 (Expect) x 2 (Teach) between-subjects ANOVA. Alpha levels were set to .05 and *CI*s = 95%.

4. Results

4.1. Descriptive data

Table 1 displays descriptive data for demographic variables, acquisition variables, and free recall. We removed two participants from analyses because they were univariate outliers on RE (z-score = 4.68) or BVE (z-score = 9.74) for average pretest, and they were influential data points in one or more regression analyses (Cook's distances ≥ 1.20). (No other data points were outliers in terms of their influence on the model (Cook's distances ≤ 0.63; Cohen, Cohen, West, & Aiken, 2003, p. 410). The results that change in statistical significance when these outliers are excluded are noted below.

Table 1. Descriptive data for each group. Confidence interval (*CI*) is 95%.

Descriptive Data by Group				
	Expect / Teach (*n* = 30)	Expect / No Teach (*n* =29) =2	No Expect / Teach (*n* =30)	No Expect / No Teach (*n* = 30)
	M *(CI)*	*M* *(CI)*	*M* *(CI)*	*M* *(CI)*
Age (Years)	22.7 (21.2-24.2)	21.1 (20.3-21.9)	21.7 (20.8-22.6)	21.2 (20.3-22.1)
Lifetime Experience[a]	2.43 (0.46-3.08)	1.86 (1.35-2.37)	1.87 (1.36-2.39)	2.37 (1.75-3.0)
Past year Experience[a]	0.67 (0.46-0.88)	0.52 (0.33-0.71)	0.77 (0.43-1.11)	0.70 (0.44-0.96)
Study Time	206.1 (166.1-246.1)	272.1 (218.4-325.8)	199.6 (158.7-240.5)	178.1 (135.6-220.6)
Practice Putts	73.3 (62.6-84.0)	84.5 (73.3-95.7)	69.7 (59.4-80.0)	67.7 (60.1-75.3)
Interest	5.31 (4.81-5.81)	5.64 (5.36-5.92)	5.37 (5.07-5.67)	5.67 (5.32-6.02)
Effort	5.66 (5.31-6.02)	6.33 (6.08-6.58)	5.35 (4.74-5.40)	5.85 (5.55-6.15)
Pressure	2.12 (1.71-2.53)	2.06 (1.74-2.38)	2.29 (1.95-2.63)	2.21 (1.82-2.60)
Value	5.63 5.23-6.03	5.58 (5.28-5.88)	5.46 (5.18-5.74)	5.62 (5.28-5.96)
Focused Attention	3.63 (3.38-3.88)	3.87 (3.66-4.08)	4.01 (3.86-4.16)	4.14 (3.92-4.35)
Novelty	3.87 (3.62-4.12)	3.98 (3.69-4.27)	4.08 (3.83-4.33)	4.19 (3.95-4.43)
Endurability	3.73 (3.50-3.96)	3.86 (3.76-4.05)	4.01 (3.86-4.16)	4.11 (3.94-4.28)
Involvement	3.88 (3.67-4.09)	4.01 (3.81-4.21)	4.23 (4.07-4.39)	4.39 (4.18-4.6)
Free Recall	1.87 (1.37-2.37)	2.21 (1.76-2.66)	1.43 (0.97-1.89)	1.83 (1.36-2.30)

[a] 0 = Never putted; 1= Putted 1 – 10 times; 2 = Putted 11 – 20 times; 3 = Putted 21 – 30 times; 4 = 31 – 40 times; 5 = 41 -50 times; 6 = 50 + times

4.2. Preliminary analyses

4.2.1. Pretest, acquisition accuracy, and precision

Figures 1 and 2 display RE and BVE for all phases of the experiment. Neither pretest RE nor BVE differed as a function of expectation, teach, Expectation x Teach, Expectation x Pretest, Teach x Pretest, nor Expectation x Teach x Pretest (*p*s ≥ .409). Acquisition RE and BVE revealed no effect of expect, block, or Expect x Block interaction (*p*s ≥ .252).

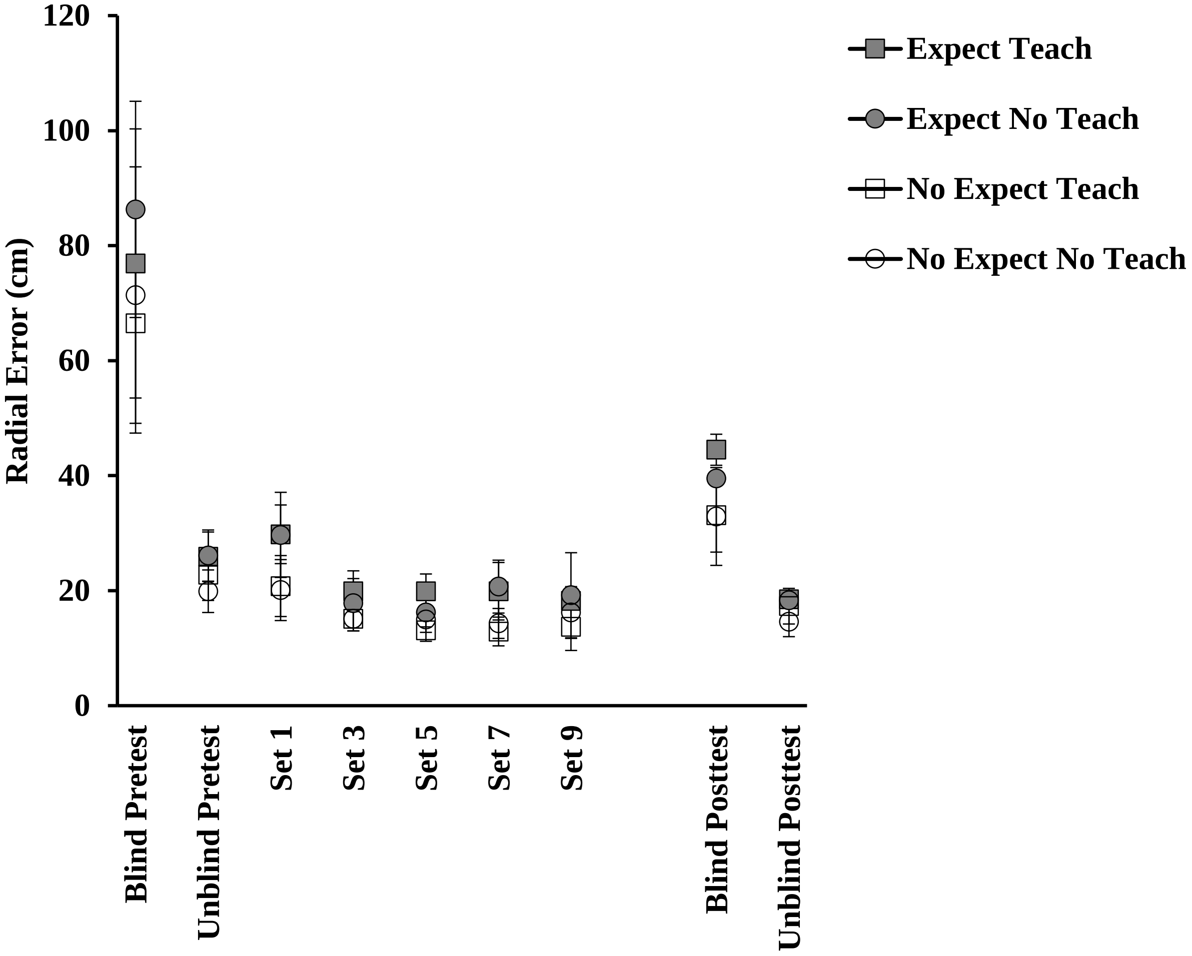

Figure 1. Radial error (lower scores indicate greater accuracy) as a function of experimental phase and group. Error bars represent 95% *CI*s.

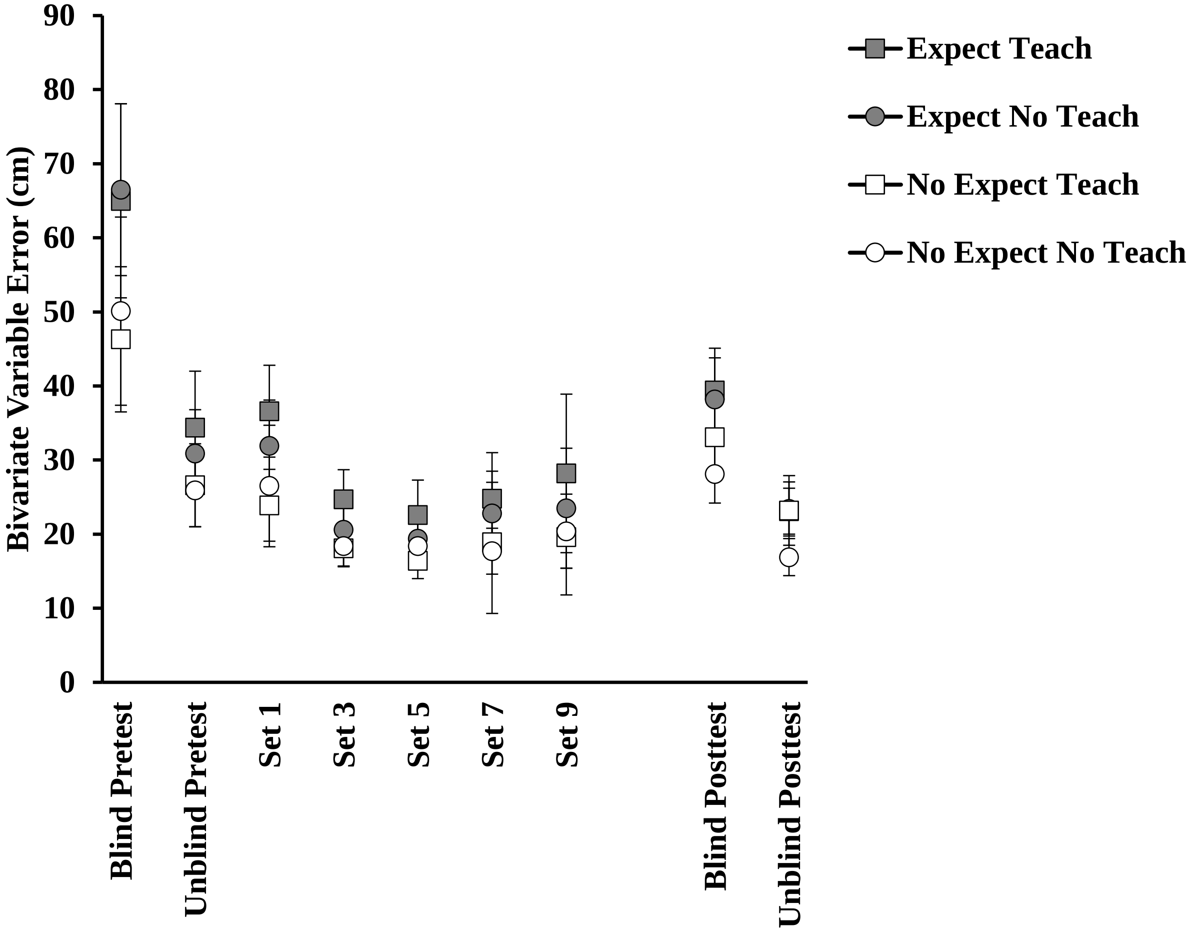

Figure 2. Bivariate variable error (lower scores indicate greater precision) as a function of experimental phase and group. Error bars represent 95% *CI*s.

4.2.2. Study time and putts

Expectation significantly affected study time and putts ($F(2, 116) = 4.09$, $p = .019$, Wilk's $\Lambda = 0.934$, $\eta^2_p = .066$). Follow-up univariate ANOVAs revealed participants who expected to teach spent more time studying ($M = 239$ s, $CI = 206 – 272$ s) relative to participants who were not expecting to teach ($M = 189$ s, $CI = 161 – 217$ s; $F(1, 117) = 5.09$, $p = .026$, $\eta^2_p = .042$). Additionally, participants expecting to teach took more practice putts ($M = 78.8$, $CI = 71.3 – 86.3$) relative to participants who were not expecting to teach ($M = 68.7$, $CI = 62.6 – 74.8$; $F(1, 117) = 4.28$, $p = .041$, $\eta^2_p = .035$).

4.2.3. Motivation, pressure, and engagement

Internal consistency of self-reported questionnaires was assessed using Cronbach's α statistic. The Cronbach's α of IMI items within subscales of interest were as follows: interest/enjoyment = .92, effort/importance = .82, value/usefulness = .85, and pressure/tension = .74. Thus, the IMI exhibited very good reliability (DeVellis, 2003). For exploratory analyses using motivation as a predictor variable, the interest/enjoyment, effort/importance, and value/usefulness subscales of the IMI were averaged together for a total motivation score (Grand et al., 2017) (these subscales were significantly correlated (*r*s ≥ .389, *p*s < .001) and exhibited respectable reliability [Cronbach's α = .748]). The Cronbach's α of User Engagement Scale items within subscales were as follows: focused attention = .76, novelty = .75, endurability = .68, and involvement = .78. Thus, the User Engagement Scale generally exhibited respectable internal consistency (DeVellis, 2003). For exploratory analyses using engagement as a predictor variable, the subscales were averaged together for a total engagement score (Leiker, Miller et al. (2016) (the subscales were significantly correlated (*r*s ≥ .422, *p*s < .001) and exhibited very good reliability [Cronbach's α = .839]). The correlation between total motivation and total engagement was strong (r = 0.81, p < .001). The reasons we averaged the IMI and User Engagement Scale across their respective subscales for the exploratory analyses were (a) to limit the number of statistical tests conducted, thus reducing the likelihood of producing a Type 1 error, and (b) because the various types of motivation and engagement are theorized to affect motor learning via the same underlying mechanism (modulations in dopamine; Lohse et al., 2016; Wulf & Lewthwaite, 2016).

A MANOVA with IMI subscales serving as the dependent variables revealed an effect of expectation ($F(4, 114) = 2.59$, $p = .040$, Wilk's $\Lambda = 0.917$, $\eta^2_p = .083$). Follow-up univariate ANOVAs revealed participants who expected to teach reported higher effort/importance subscale scores (M = 5.99, CI = 5.76 – 6.22) relative to participants who were not expecting to teach (M = 5.60, CI = 5.38 – 5.82); F(1, 117) = 5.98, p = .016, η^2_p = .049). The ANOVAs for the other subscales were not significant (ps ≥ .363). A MANOVA with User-Engagement Scale subscales serving as the dependent variables did not reveal an effect of expectation (p = .458).

4.3. Free recall

No significant effects of expect, teach, or Expect x Teach were observed for free recall scores (ps ≥ .081).

4.4. Primary analyses: posttest accuracy and precision

Table 2 displays the results of the multiple linear regression predicting posttest RE. Importantly, there were no significant effects of expect, teach, or Expect x Teach (ps ≥ .798 in the third model). However, total motivation predicted posttest RE ($\beta_{unstandardized}$ = -5.09 cm, CI = -8.32 — -1.86 cm, p = .002, see Figure 3). Similarly, total engagement predicted posttest RE ($\beta_{unstandardized}$ = -7.62 cm, CI = -12.2 — -3.04 cm, p = .001, see Figure 4).

Table 3 displays the results of the multiple linear regression predicting posttest BVE. No significant effects of expect, teach, Expect x Teach, total motivation, or total engagement were observed (ps ≥ .055). (Relationships between total motivation and acquisition performance as well as total engagement and acquisition performance are presented in supplementary online material.)

Table 2. Details of multiple linear regression model testing the hypothesis that learning (as indexed by posttest RE) occurs as a function of expecting to teach and teaching. The following predictors are included: pretest RE, study time, and practice putts (Model 1); expect (yes/no) and teach (yes/no) (Model 2); Expect x Teach interaction term (Model 3); Total Motivation (Model 4a); Total Engagement (Model 4b). Regression coefficients are not standardized and are thus interpretable in their natural units. For the group variables, expect = ‘1’ and no expect = ‘-1’; teach = ‘1’ and no teach = ‘-1’. *CI* is 95%.

Model 1: Avg. Blind and Un-Blind Posttest RE ~ Pretest RE + Studying + Putts					
	SS	*Df*	*MS*	*F*	R^2 Change
Regression	3,713	3	1,238	8.08	.174
Residual	17,620	115	153		
Coefficients	β	*CI*	*t*-value	*p*-value	

Intercept	18.8	10.8 – 26.8	4.66	< .001
Pretest RE	0.175	0.103 – 0.247	4.82	< .001
Studying	0.007	-0.12 – 0.026	0.712	.478
Putts	-0.21	-0.106 – 0.063	-0.501	.618

Model 2: Avg. Blind and Un-Blind Posttest RE ~ Pretest RE + Studying + Putts + Expect + Teach

	SS	*Df*	*MS*	*F*	R^2 *Change*
Regression	3,732	5	746	4.80	.001
Residual	17,601	113	156		

Coefficients	β	*CI*	*t*-value	*p*-value
Intercept	18.7	10.4 – 27.1	4.46	< .001
Pretest RE	0.175	0.102 – 0.247	4.77	< .001
Studying	0.007	-0.012 – 0.026	0.714	.477
Putts	-0.021	-0.107 – 0.066	-0.471	.639
Expect	-0.267	-2.61 – 2.08	-0.225	.822
Teach	-0.300	-2.58 – 1.98	-0.261	.795

Model 3: Avg. Blind and Un-Blind Posttest RE ~ Pretest RE + Studying + Putts + Expect + Teach + Expect x Teach

	SS	*Df*	*MS*	*F*	R^2 *Change*
Regression	3,733	6	622	3.96	.000
Residual	17,600	112	157		

Coefficients	β	*CI*	*t*-value	*p*-value
Intercept	18.7	10.3 – 27.1	4.39	< .001
Pretest RE	0.174	0.101 – 0.248	4.74	< .001
Studying	0.007	-0.013 – 0.027	0.713	.477
Putts	-0.020	-0.108 – 0.067	-0.459	.647
Expect	-0.272	-2.64 – 2.09	-0.228	.820
Teach	-0.298	-2.59 – 2.00	-0.257	.798
Expect x Teach	0.089	-2.25 – 2.42	0.075	.940

Model 4a: Avg. Blind and Un-Blind Posttest RE ~ Pretest RE + Studying + Putts + Expect + Teach + Expect x Teach + Total IMI

	SS	*Df*	*MS*	*F*	R^2 *Change*
Regression	5,154	7	736	5.05	.067
Residual	16,179	111	146		

Coefficients	β	*CI*	*t*-value	*p*-value
Intercept	46.0	26.9 – 65.2	4.76	< .001
Pretest RE	0.142	0.069 – 0.215	3.85	< .001
Studying	0.012	-0.007 – 0.031	1.26	.212
Putts	0.004	-0.082 – 0.089	0.082	.935
Expect	-0.155	-2.43 – 2.12	-0.135	.893
Teach	-1.05	-3.31 – 1.22	-0.916	.362
Expect x Teach	0.350	-1.90 – 2.60	0.308	.759
Total IMI	-5.09	-8.32 – -1.86	-3.123	.002

Model 4b: Avg. Blind and Un-Blind Posttest RE ~ Pretest RE + Studying + Putts + Expect + Teach + Expect x Teach + Total Engagement

	SS	*Df*	*MS*	*F*	*R^2 Change*
Regression	5,304	7	758	5.25	.074
Residual	16,030	111	144		
Coefficients	β	*CI*	*t*-value	*p*-value	
Intercept	47.8	28.5 – 67.0	4.92	< .001	
Pretest RE	0.155	0.084 – 0.226	4.33	< .001	
Studying	0.012	-0.007 – 0.032	1.28	.202	
Putts	-0.004	-0.088 – 0.081	-0.088	.930	
Expect	-0.392	-2.66 – 1.87	-0.343	.732	
Teach	-0.449	-2.65 – 1.75	-0.404	.687	
Expect x Teach	0.176	-2.06 – 2.41	0.156	.876	
Total Engagement	-7.62	-12.2 – -3.04	-3.30	.001	

Table 3. Details of multiple linear regression model testing the hypothesis that learning (as indexed by posttest BVE) occurs as a function of expecting to teach and teaching. The following predictors are included: pretest BVE, study time, and practice putts (Model 1); expect (yes/no) and teach (yes/no) (Model 2); Expect x Teach interaction term (Model 3); Total Motivation (Model 4a); Total Engagement (Model 4b). Regression coefficients are not standardized and are thus interpretable in their natural units. For the group variables, expect = ‘1’ and no expect = ‘-1’; teach = ‘1’ and no teach = ‘-1’. *CI* is 95%.

Model 1: Avg. Blind and Un-Blind Posttest BVE ~ Pretest BVE + Studying + Putts

	SS	*Df*	*MS*	*F*	*R^2* Change
Regression	3,285	3	1,095	12.2	.241
Residual	10,341	115	89.9		
Coefficients	β	*CI*	*t*-value	*p*-value	
Intercept	16.1	9.84 – 22.4	5.09	< .001	
Pretest BVE	0.224	0.140 – 0.308	5.27	< .001	
Studying[a]	0.015	0.001 – 0.030	2.08	.040	
Putts	-0.012	-0.076 – 0.053	-0.359	.720	

Model 2: Avg. Blind and Un-Blind Posttest BVE ~ Pretest BVE + Studying + Putts + Expect + Teach

	SS	*Df*	*MS*	*F*	*R^2 Change*
Regression	3,311	5	662	7.25	.002
Residual	10,315	113	91.3		
Coefficients	β	*CI*	*t*-value	*p*-value	
Intercept	15.9	9.39 – 22.4	4.84	< .001	
Pretest BVE	0.224	0.139 – 0.309	5.22	< .001	
Studying[a]	0.016	0.001 – 0.031	2.08	.040	
Putts	-0.010	-0.076 – 0.056	-0.299	.766	
Expect	-0.401	-2.20 – 1.40	-0.442	.659	
Teach	-0.242	-1.99 – 1.51	-0.274	.785	

Model 3: Avg. Blind and Un-Blind Posttest BVE ~ Pretest BVE + Studying + Putts + Expect + Teach + Expect x Teach

	SS	*Df*	*MS*	*F*	R^2 *Change*
Regression	3,328	6	555	6.03	.001
Residual	10,298	112	91.9		
Coefficients	β	*CI*	*t*-value	*p*-value	
Intercept	16.1	9.50 – 22.67	4.84	< .001	
Pretest BVE	0.225	0.140 – 0.310	5.22	< .001	
Studying	0.015	0.000 – 0.030	1.96	.052	
Putts	-0.012	-0.078 – 0.055	-0.342	.733	
Expect	-0.376	-2.18 – 1.43	-0.412	.681	
Teach	-0.254	-2.010 – 1.50	-0.286	.775	
Expect x Teach	-0.391	-2.18 – 1.40	-0.433	.665	

Model 4a: Avg. Blind and Un-Blind Posttest BVE ~ Pretest BVE + Studying + Putts + Expect + Teach + Expect x Teach + Total IMI

	SS	*Df*	*MS*	*F*	R^2 *Change*
Regression	3,578	7	511	5.65	.018
Residual	10,048	111	90.5		
Coefficients	β	*CI*	*t*-value	*p*-value	
Intercept	27.7	12.4 – 43.0	3.58	.001	
Pretest BVE	0.203	0.114 – 0.292	4.54	< .001	
Studying[a]	0.018	0.002 – 0.033	2.28	.025	
Putts	-0.001	-0.068 – 0.067	-0.020	.984	
Expect	-0.325	-2.12 – 1.47	-0.359	.721	
Teach	-0.570	-2.25 – 1.21	-0.634	.527	
Expect x Teach	-0.277	-2.05 – 1.50	-0.308	.758	
Total IMI	-2.14	-4.70 – 0.413	-1.66	.099	

Model 4b: Avg. Blind and Un-Blind Posttest BVE ~ Pretest BVE + Studying + Putts + Expect + Teach + Expect x Teach + Total Engagement

	SS	*Df*	*MS*	*F*	R^2 *Change*
Regression	3,665	7	524	5.84	.025
Residual	9,960	111	89.7		
Coefficients	β	*CI*	*t*-value	*p*-value	
Intercept	29.7	14.3 – 45.1	3.83	< .001	
Pretest BVE	0.209	0.123 – 0.295	4.83	< .001	
Studying	0.018	0.003 – 0.033	2.32	.022	
Putts	-0.003	-0.070 – 0.063	-0.098	.922	
Expect	-0.430	-2.22 – 1.36	-0.477	.634	
Teach	-0.326	-2.06 – 1.41	-0.372	.711	
Expect x Teach	-0.346	-2.11 – 1.42	-0.388	.699	
Total Engagement	-3.544	-7.17 – 0.078	-1.94	.055	

[a] Studying becomes nonsignificant when including outliers

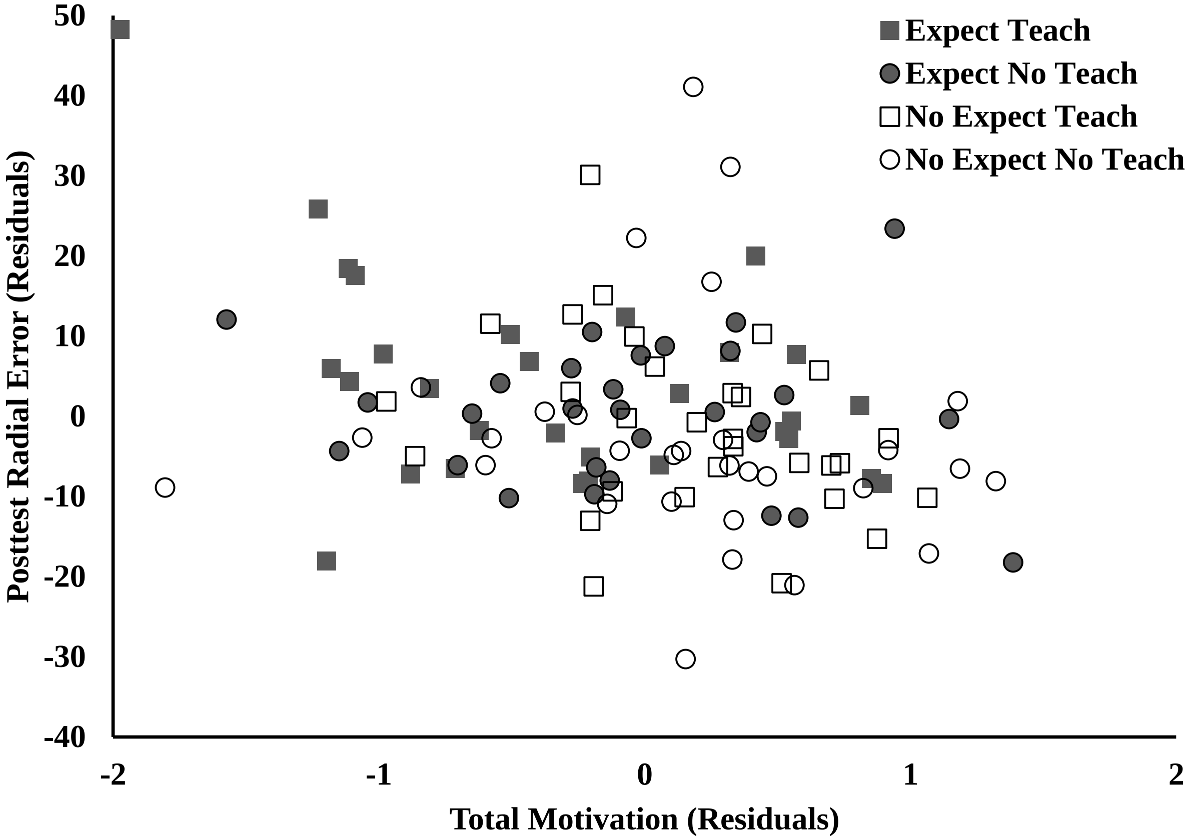

Figure 3. Posttest accuracy (RE) as a function of total motivation, controlling for pretest accuracy, studying, putts, and group assignment (expect, teach, and Expect x Teach). Higher values on the x-axis represent higher motivation and lower values on the y-axis represent greater accuracy.

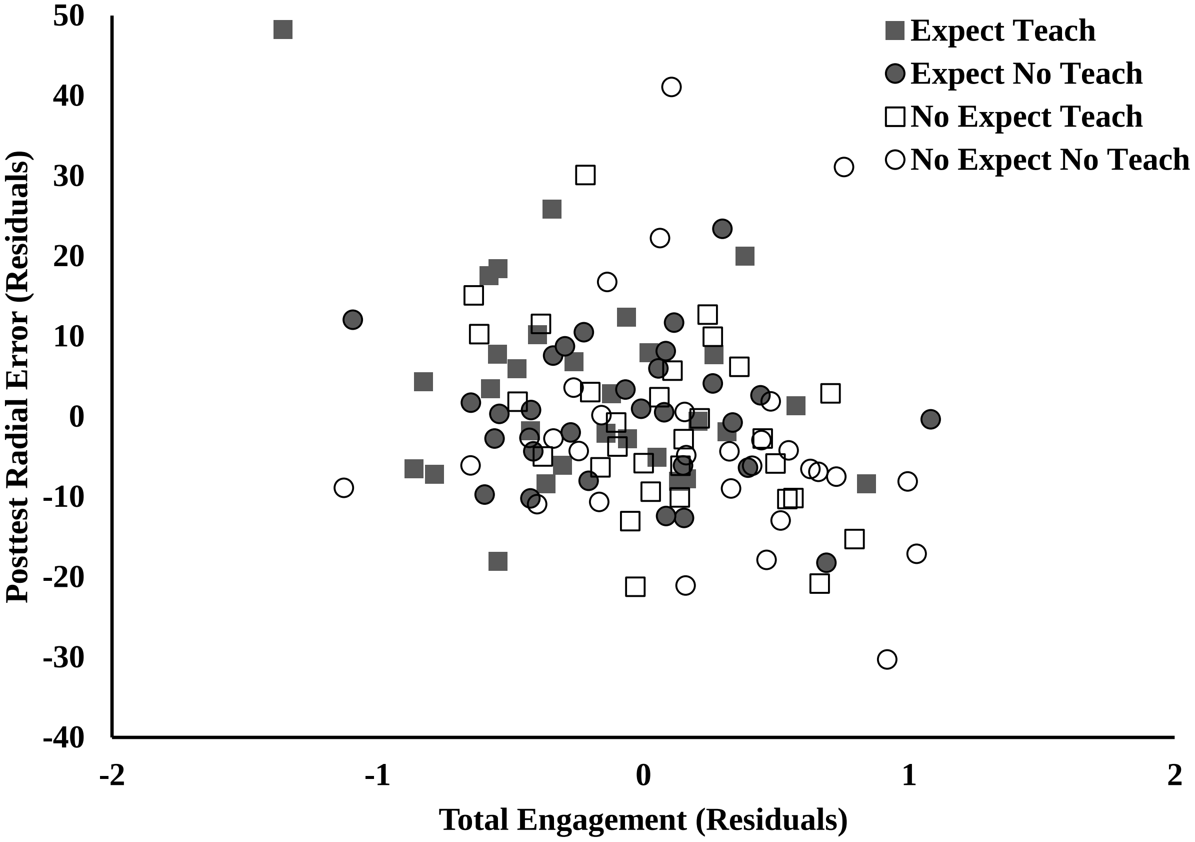

Figure 4. Posttest accuracy (RE) as a function of total engagement, controlling for pretest accuracy, studying, putts, and group assignment (expect, teach, and Expect x Teach). Higher values on the x-axis represent higher engagement and lower values on the y-axis represent greater accuracy.

5. Discussion

The current experiment sought to investigate the effects of expecting to teach and teaching a motor skill on learning that respective motor skill. It was predicted that expecting to teach would enhance learning, and the act of teaching would augment the effect of expecting to teach. Additionally, we explored motivation and engagement as potential mechanisms underlying any observed expecting to teach/teaching effect. Results revealed no significant effects of expecting, teach, or Expecting x Teach interaction when controlling for pretest scores, study time, and practice putts on posttest RE or BVE. Further, there were no effects of expecting, teach, or Expecting x Teach on free recall. Thus, results failed to support the hypothesis, as there were no effects on procedural or declarative motor learning components. Therefore, expecting to teach and teaching had no impact on the learning of a motor skill in the present experiment. There are several conceivable explanations for the incongruence with the predicted results.

An explanation for the absence of a main effect of expecting to teach may be a result of the timing of the expected teaching. Specifically, in the present experiment participants expected to fulfill their teaching obligation immediately after the acquisition phase, whereas in previous experiments participants expected to teach one day after acquisition (Daou, Buchanan et al., 2016; Daou, Lohse et al., 2016; Daou, Lohse et al., 2018). Thus, in the previous experiments expecting to teach may have facilitated offline consolidation to a greater extent, as participants had approximately 24 h to think about the skill they were expecting to teach. Future research should consider the potential impact of when the expectation of teaching is expected to be fulfilled.

Another important point to consider is the degree of social presence in the current experiment. The participants in the expect/teach and no expect/teach groups were asked to record a 2-min video to be used for teaching future participants how to putt a golf ball. The participants in these teach groups did not improve on the retention test beyond the no teach groups, therefore, no main effect of teaching was observed in the present experiment. A possible explanation for this null result may be that the teach group participants did not experience sufficient social presence in teaching via a video camera. Hoogerheide et al. (2016) revealed a benefit of teaching to fictitious others by way of a webcam video, but not by writing to them, compared to a control group. The authors attributed this difference to the higher degree of social presence felt with the webcam. Perhaps, a webcam video establishes a greater sense of social presence relative to the camcorder used in the present experiment. The webcam video may provide an enhanced feeling of social presence through its association with Internet media platforms (e.g., Skype, Facebook Live, Google Hangouts), while the camcorder may be more akin to writing due to the lack of social connection through the Internet. The heightened sense of social presence could be due to the webcam priming participants to think about social media and/or making participants actually think they are teaching someone in real time. Importantly, the degree of social presence may be positively associated with the reward of a social interaction. Thus, interacting with another person, even via Internet, may be more rewarding than interacting with a camcorder. Crucially, a more rewarding social interaction may increase the release of dopamine in the brain (Clark & Dumas, 2015), and dopamine is integral to learning (Wise, 2004).

Additionally, the low social presence in the present experiment may explain the absence of a main effect of expecting to teach. Specifically, past research has created the expectation of teaching an actual person (Daou, Buchanan et al., 2016; Daou, Lohse et al., 2016; Daou, Lohse et al., 2018), whereas the present study created an expectation of teaching an actual person via a video camera. The expectation in Daou, Buchanan et al. (2016), Daou, Lohse et al. (2016), and Daou, Lohse et al. (2018) likely elicited greater expectations for future social presence than the present paradigm. Thus, the participants who expected to teach in the present experiment may have done so with expectations for a moderately rewarding (or lower pressure) teaching experience, and these lower expectations may have precluded a learning benefit. Future research should consider the mode of teaching in order to account for the potential impact of social presence on expecting to teach and teaching.

Participants who expected to teach took significantly more practice putts and spent significantly more time studying than participants who did not expect to teach. Interestingly, these behavioral changes did not influence motor learning. The increased practicing and studying may reflect a behavioral measure of motivation, such that participants freely chose to practice and study more. Indeed, the number of putts practiced was positively correlated with effort/importance (*r* = .217, *p*s = .018), after controlling for whether participants were expecting to teach. Further, the amount of time studied was positively correlated with interest/enjoyment and effort/importance (*r*s = .187, *p*s = .043), after controlling for whether participants were expecting to teach. It is worth noting that Daou, Lohse et al. (2016) observed expecting to teach significantly enhanced studying (but not practicing), whereas Daou, Buchanan et al. (2016) observed expecting to teach did not significantly influence practicing or studying. Practicing and studying may be interesting variables to consider as behavioral measures of motivation in expecting to teach and other motor learning paradigms. Another way to improve the measurement of motivation and engagement would be to include baseline measures of these variables at pretest. This follows because participants may arrive at the experiment with different levels of motivation and engagement, and accounting for these baseline differences should allow for a more precise measure of experimental effects on the variables.

Although the primary hypothesis was not supported with the current results, exploratory analyses revealed significant results regarding the impact of motivation and engagement on motor learning. Specifically, self-reported motivation and engagement during acquisition predicted posttest RE. These results suggest that higher motivation and engagement during acquisition may be associated with learning of a motor skill, which is consistent with extant theory. Specifically, Wulf and Lewthwaite (2016) posit that motivation enhances motor learning. However, past experiments have generally failed to reveal this effect at the individual level (Grand, et al., 2017; Lohse et al., 2016; Ste-Marie et al., 2016). Similarly, Lohse et al. (2016) revealed concomitant increases in engagement and motor learning at the group level, but the authors did not observe a relationship between engagement and motor learning at the individual level. Thus, the present results are novel in terms of demonstrating relationships between motivation and engagement with motor learning at the individual level.

In conclusion, expecting to teach and teaching did not yield benefits for motor learning in the present experiment. However, there are several possibilities explaining why the results did not support the current hypothesis. Timing and social presence of the expectation may have influenced present results and, thus, should be considered in future expecting to teach experiments. Similarly, the exploratory results generate further questions regarding the relationships between motivation and engagement with acquisition improvement and learning.

Chapter 2: Distinguishing the effects of verbalization on performance and learning in novice and skilled populations

1. Introduction

1.1. Verbal language

Language is an essential aspect of everyday life; it represents our life experiences through communication and memory. Specifically, language may be utilized to share our experience with others and to consolidate memories for ourselves. Human performance is accompanied by language, particularly verbal language, in many realms of life (e.g., academia, athletics, medicine). From communication to education, language proficiency is necessary for success, particularly regarding the relationship between verbal language and memory. Generally speaking, verbal language benefits memory. Verbal rehearsal and elaboration have been documented to augment memory consolidation (e.g., Darley & Glass, 1975; Schooler & Engstler-Schooler, 1990). Similarly, verbalization has been shown to enhance performance on written tests of academic information (Fiorella & Mayer, 2013; Fiorella & Mayer, 2014). However, these tasks directly relate to declarative knowledge (i.e., verbal, rule-based knowledge), such that verbal language assists in declarative memory consolidation. Other types of knowledge may not benefit from aspects of verbal language, particularly perceptual and procedural knowledge.

1.2. Verbal overshadowing

1.2.1. Perceptual knowledge

Extensive research has investigated the impact of verbal language on perceptual memory. Specifically, research has explored the effect of verbalization on the recollection and utilization of perceptual memory and knowledge (e.g., Melcher & Schooler, 1996; Ait-Said, Maquestiaux, & Didierjean, 2014). Verbal language (i.e., verbalization) is often inadequate in describing perceptual knowledge, such that spoken words rarely capture all of the complex details of a perceptual memory. Stated otherwise, individuals lack the linguistic proficiency to describe a perceptual experience. This inadequacy may result in complications concerning the separate memory representations of an experience (i.e., verbal vs. perceptual knowledge). In fact, research suggests verbalization may interfere with subsequent recollection of perceptual knowledge (e.g., Melcher & Schooler, 2004; Ait-Said, Maquestiaux, & Didierjean, 2014). Schooler and Engstler-Schooler (1990) revealed impaired recognition of a difficult-to-verbalize stimulus (human face) for participants who described the stimulus in words compared to participants who did not describe the stimulus in words. Similarly, Melcher and Schooler (1996) observed compromised wine recognition for untrained wine drinkers following verbalization. Schooler and Engstler-Schooler (1990) termed this disruptive effect verbal overshadowing; "the idea that verbalization creates a language-based representation that overshadows difficult-to-verbalize aspects of perceptual memory" (Flegal & Anderson, 2008, p. 927). Verbal overshadowing has been investigated within many perceptual memory domains including: visual stimuli (Brandimonte, Hitch, & Bishop, 1992; Ait-Said et al., 2014), music (Timperman & Miksza, 2017), and taste (Melcher & Schooler, 1996). These perceptual experiences are difficult to describe in words; thus, after an attempted description, the verbal representation may interfere with the perceptual representation of the experience(s).

Several hypotheses exist explaining this interference between the verbal and perceptual memory representations. First, the recoding interference hypothesis suggests a verbal code is formed as a result of verbalization; this code is inadequate or inaccurate in describing the perceptual memory (Schooler, 2002). During memory retrieval, the verbal code interferes with or distorts the perceptual code causing the individual to rely on the verbal description rather than the perceptual experience (Flegal & Anderson, 2008; Ait-said et al., 2014). Next, the transfer-inappropriate processing theory suggests verbalization causes a shift in the processing of stimuli during memory encoding (Schooler, 2002). Specifically, the verbal overshadowing effect may engage a more feature-based or local mode of processing as opposed to the normal configural or global processing necessary for recognition (Flegal & Anderson, 2008; Ait-said et al., 2014). The shift in processing may limit recognition due to the focus on discrete features of the stimuli instead of holistic perceptual components (Flegal & Anderson, 2008). These hypotheses are specific to the perceptual domain, particularly concerning facial recognition (Schooler & Engstler-Schooler, 1990). Alternative hypotheses may be necessary to explain the verbal overshadowing effect on other types of knowledge. Perceptual knowledge has been comprehensively investigated concerning the verbal overshadowing effect, while other types of non-declarative knowledge have not received as much attention within this domain, specifically procedural knowledge.

1.2.2. Procedural knowledge

A majority of the verbal overshadowing literature describes perceptual and declarative knowledge. However, other types of knowledge may be impacted by the phenomenon, particularly procedural knowledge. As with perceptual knowledge, procedural knowledge consists of many difficult-to-verbalize characteristics. For example, an individual may know how to ride a bike, but oftentimes cannot verbally describe all of the components necessary to execute the task. Motor skills require some declarative knowledge, but rely more heavily on procedural knowledge for task execution (Rosenbaum, Carlson, & Gilmore, 2001). The procedural knowledge underlying the motor task is more difficult to verbalize than the declarative knowledge. Therefore, verbalization of procedural memory for a motor skill may pose impediments similar to those experienced after describing a perceptual memory (i.e., the verbal overshadowing effect). Previous research has investigated verbal overshadowing regarding procedural knowledge specific to motor skills.

Flegal and Anderson (2008) investigated the effects of verbalization on performance of a motor skill. Eighty participants with low to intermediate golf experience performed a golf putting task with the goal of completing three consecutive on-target putts. After completion, the verbalization group completed a 5-min writing task (i.e., providing a detailed description of how they performed the task); the non-verbalization group performed a 5-min verbal distractor task (i.e., providing the valence for words with no association to golf). Next, all participants completed a second golf putting task with identical criterion as the first. Results revealed a verbal overshadowing effect for the higher skilled golfers, such that the higher skilled participants in the verbalization group took twice as many putts to achieve the putting criterion compared to their higher skilled non-verbalization counterparts. Lower skilled golfers did not exhibit the same trend. Specifically, the lower skilled participants in the verbalization group tended to benefit from the writing task compared to their counterparts in the non-verbalization group, but this effect did not reach statistical significance. These results provide support for the presence of the verbal overshadowing effect in the motor domain, perhaps depending on skill level.

Chauvel and colleagues (2013) investigated the impact of verbalization on novice golfers utilizing an explicit/implicit motor learning paradigm. Eighty participants practiced a golf putting task in an explicit learning condition (i.e., relying on declarative knowledge) or an implicit learning condition (i.e., relying on procedural knowledge). After the practice phase, the verbalization group completed a 3-min writing task describing how they performed the task and the non-verbalization group performed a 3-min word search game. All participants completed a putting task at a novel distance immediately following the verbalization/non-verbalization task. Results revealed no benefit of the verbalization task for the novice golfers. In fact, putting was significantly impaired for the verbalization participants in the explicit learning condition. Participants in the implicit learning condition, however, were not impacted by the verbalization. The results of Chauvel et al. (2013) indicate the effects of verbalization may depend on how a skill is initially acquired, implicitly or explicitly.

Overall, the verbal overshadowing literature in the motor domain suggests verbalization may be detrimental to subsequent motor performance. However, other factors should be considered within these paradigms. Chauvel and colleagues (2013) provide evidence that is incompatible with the predictions provided by the verbal overshadowing literature in perceptual and procedural domains. Specifically, the implicit learning group should have been disrupted by the verbalization due to their reliance on procedural knowledge, but this was not the case; the explicit learning condition was negatively impacted, suggesting verbalization distorted the declarative knowledge representations while leaving the procedural representations intact (Chauvel et al., 2013). Similarly, the novice participants in Chauvel et al. (2013) did not benefit from the verbalization, while the lower skilled participants in Flegal and Anderson (2008) did perform better in verbalization condition (although, results were not significant). These observations demonstrate inconsistent effects of verbal overshadowing in the motor domain. However, skill level may explain these inconsistencies due to the different cognitive processes responsible for task execution for experts vs. novices.

1.3. Cognitive processes of motor skill level and verbal overshadowing

Skill level influences how a performer executes a motor task (e.g., Beilock, Carr, MacMahon, & Starkes, 2002; Beilock, Wierenga, & Carr, 2002). Specifically, the progression from novice to expert involves transitions in cognitive processing, focus of attention, and neural resources. Novice task execution is supported in a step-by-step fashion by discrete representations of the skill components that are held in working memory (Anderson, 1983). For successful performance, these discrete representations typically consist of declarative knowledge (i.e., verbal processes), which elicits the conscious processing of movement (Fitts & Posner, 1967). As a performer shifts into later stages of learning, successful task execution involves less attentional demand, more automatic control, and greater use of procedural knowledge (Fitts & Posner, 1967). That is, skilled performers rely on procedural knowledge (i.e., non-verbal processes) for task execution. The skill is represented as a single unit that does not require conscious processing for execution; instead, automatic processing is employed (Anderson, 1983). This transformation of cognitive processes throughout skill progression may influence an individual's susceptibility to the verbal overshadowing effect.

Flegal and Anderson (2008) revealed that skilled golfers took twice as long to return to baseline after a 5-min verbalization task, whereas the novice golfers benefited from the verbalization task (although not reliably). The authors suggest the verbalization disrupted the automatic processing and procedural knowledge associated with skilled task execution, thus, negatively impacting the performance of the higher skilled participants. Moreover, the novice participants may have benefited from the verbalization due to the conscious control and declarative knowledge incited by describing the motor task. These results may be explained with the concept of skill-focused attention presented by Beilock, Carr et al. (2002).

Beilock, Carr et al. (2002) investigated the impact of dual-task and skill-focused attention on motor skills. In Experiment 1, experienced golfers performed a putting task in two separate conditions: a dual-task condition and a skill-focused condition. The dual-task condition was designed to distract attention away from the task, while the skill-focused condition prompted attention to a specific component of the golf swing. Participants performed 20 practice trials before completing 20 trials in each condition; the order was counterbalanced and a short break was included between conditions. Results showed that experienced golfers performed better in the dual-task condition compared to the skill-focused condition. The skill-focused condition may have caused participants to attend to the step-by-step components of a presumably automated skill, thus compromising performance. These results provide evidence of a detrimental effect of skill-focused attention for skilled performers due to a shift to cognitive processing (i.e., non-verbal, automatic processing to verbal, conscious processing).

In Experiment 2, Beilock and colleagues (2002) sought to replicate Experiment 1 with a different type of task, whilst adding a variable of skill proficiency. Novice and experienced participants performed a soccer-dribbling task in dual-task and skill-focused conditions. The dual-task condition was a word-monitoring task and the skill-focused condition directed attention to a specific physical component of the task. Additionally, all participants were assessed in both conditions using their dominant and non-dominant foot. It is important to note the experienced participants' dominant and non-dominant feet may not have the same level of proficiency, thus altering the attentional mechanisms used to accomplish each task (Beilock, Carr et al., 2002). Specifically, the skilled participants likely used a skilled-focus attentional strategy to dribble the ball with their non-dominant foot, but not with their dominant foot. The participants completed four sets of two dribbling trials in a counterbalanced order and alternating feet (i.e., each participant completed every foot-attentional focus condition combination possible). In the dominant foot trials, the novice participants performed better in the skill-focused condition in comparison to the dual-task condition. In contrast, the experienced participants performed better in the dual-task condition compared to the skill-focused condition. However, in the non-dominant foot trials, the novice and experienced participants performed better in the skill-focused condition as opposed to the dual-task condition. Researchers inferred the attentional demands were different for each task based on skill proficiency (Beilock, Carr et al., 2002). The novices benefited from skill-focused attention in the dominant and non-dominant trials due to their inexperience and lack of automaticity in task performance; they required a step-by-step focus in order to adequately accomplish the task. Whereas the experienced performers were hindered by skill-focused attention when executing the task with their dominant foot, but benefited from skill-focused when performing the task with their non-dominant foot. The difference in performance may be due to a proceduralized or automated motor representation for the dominant foot that does not exist for the non-dominant foot. In sum, the skill-focused condition was beneficial for less proficient (or less automatic) task execution, while the dual-task condition was beneficial for higher levels of proficiency in the task.

The implications of Beilock, Carr, et al. (2002) may be associated with the results revealed in Flegal and Anderson (2008) due to the similarities between cognitive processing prompted by the respective experimental conditions. Beilock and colleagues (2002) provided an online manipulation of attention with their skill-focused paradigms in Experiment 1 and 2. Specifically, the participants' attention is directed to individual components of a task during execution in the skill-focused conditions. This attentional focus may elicit declarative mechanisms and conscious processing for task execution, which hindered higher levels of skill proficiency and benefited lower levels of skill proficiency. Flegal and Anderson (2008) provided an offline manipulation of attention with their verbalization task, which may have caused participants to adopt a skill-focused attention during task execution. The verbalization task utilized in Flegal and Anderson (2008) required participants to attend to individual components of the task through describing their movements in writing. This task may have caused participants to direct their attention to individual representations and declarative knowledge of the task during execution. That is, the verbalization task (although not performed during task execution) may have prompted skill-focused attention that effectively impacted subsequent task execution by directing attention to declarative knowledge and eliciting conscious processing (Flegal & Anderson, 2008). Therefore, the respective paradigms may have prompted similar cognitive processing that impacted task execution. These results provide evidence that skill-focused attention promotes the utilization of declarative knowledge that may disrupt the performance of skilled performers and enhance performance of novices (Beilock, Carr et al., 2002; Flegal & Anderson, 2008).

Skill-focused attention has been shown to alter relatively immediate motor performance through the manipulation of cognitive processing (Beilock, Carr et al., 2002; Flegal & Anderson, 2008). Perhaps, the change in cognitive processing impacts movement efficacy and efficiency through altered motor control, thus effecting motor performance. Attentional focus has been shown to impact neuromuscular coordination and motor unit recruitment patterns as indexed by electromyography (EMG) (Wulf, Dufek, Lozano, & Pettigrew, 2010; Lohse, Sherwood, & Healy, 2011). Specifically, a more internal focus of attention (i.e., focus on body movements during skill execution) increases co-contractions and EMG activity altering performance of motor task. An internal focus of attention may be similar to skill-focused attention in that each attentional focus directs attention to the body and/or the movement of the participant. For example, Lohse, Sherwood, and colleagues' (2011) internal focus of attention participants were provided with the following instructions: "Mentally focus on pushing with the muscle of your calf, because the platform is recording the force that you produce in this experiment. If you produce too much force, try to focus on contracting the muscle less. If you produce too little force, try to focus on pushing against the platform harder." (p. 176). In Beilock, Carr et al. (2002), participants in the skill-focused condition were asked, "to attend to the side of their foot that was in contact with the ball throughout the dribbling trial" (p. 11). Both of these experimental conditions direct attention to the body during movement. Due to these similarities, perhaps, a skill-focused attention elicits similar changes in motor control as an internal focus of attention. Thus, an alteration in muscular activity may have negatively impacted Beilock, Carr et al. (2002) skilled participants' performance through interference with previously automated skill execution. Increased EMG activity and/or co-contractions of effector muscles would presumably hinder skilled motor control and performance due to less efficient movement and deviation from automatic motor control.

Similarly, attentional focus has been revealed to impact kinematic variables of a movement, particularly movement variability and coordination of segments (Lohse et al., 2011; Lohse, Healy, & Sherwood, 2014). Focus on skill execution may prompt an individual to lock degrees of freedom. This reduced variability may impede adaptations to the environment and hinder coordination of segments resulting in a less fluid movement (Bernstein, 1967; Davids, Bennett, & Newell, 2006; Preatoni et al., 2013). Specifically, an internal focus of attention has been shown to alter movement variability (Lohse et al., 2011). As with EMG activity, skill-focused attention may elicit a similar effect on kinematic variables as internal focus of attention due to attention directed toward the body during movement. In Beilock, Carr et al. (2002), skill-focused attention may have caused the skilled participants to consciously control individual effector muscles or segments impacting their kinematic pattern and, thus, hindering their performance. This conscious control may have interfered with previously established automatic motor control associated with skilled performance (Fitts & Posner, 1967). It is important to consider the mechanisms behind the change in performance due to skill-focused attention, particularly the alteration of motor control. These mechanisms may be associated with the change in performance observed as a result of verbalization in Flegal and Anderson (2008).

Flegal and Anderson’s (2008) experimental manipulation may have altered motor control due to an emphasis on the individual components during verbalization. That is, the participants engaged in a 5-min verbalization task that may have prompted skill-focused attention, and thus conscious control/declarative mechanisms. This alteration in cognitive processing (prompted by verbalization) may have impacted muscular activity and kinematic properties of movement subsequently affecting putting performance. Specifically, the verbalization task may have promoted conscious control causing individuals to lock degrees of freedom due to focus on task components, ultimately impacting immediate motor performance. Moreover, skill-focused attention may have elicited greater EMG activity through attention to individual movement components, also potentially altering task execution and affecting performance. This impact on motor control would presumably benefit individuals in the early stages of learning and hinder those in the later stages (Fitts & Posner, 1967; Anderson, 1983), as observed with the novice and skilled performers in Flegal and Anderson (2008). In sum, skill-focused attention may influence the cognitive control of a movement, which impacts performance. However, this effect may depend on skill level; conscious control (and thus, skill-focused attention) may benefit novices, but not skilled performers.

Contrary to Flegal and Anderson's (2008) assessment, Chauvel and colleagues (2013) did not find a benefit of verbalization for novice golfers. These results generally contradict current hypotheses regarding cognitive processes of skill level and skill-focused attention. Perhaps verbalization does not incite appropriate cognitive processes, but interferes with them. Verbalizing a motor skill directly relates to declarative knowledge of the skill. This knowledge may interfere with the already present declarative mechanisms of task execution as Chauvel and colleagues (2013) demonstrated with the explicit learning condition. Specifically, the explicit learning group was hindered by the verbalization task, while the implicit learning group was unaffected. These results suggest performance may be disrupted when verbalization prompts the use of declarative mechanisms for task execution when declarative knowledge already exists for that skill. Performance disruption may occur when there is some reliance on declarative knowledge for task execution (as with the explicit learning condition in Chauvel et al. [2013]) or a reversion back to dependence on declarative knowledge (as with experts in Flegal & Anderson [2008]). Conversely, performance is not affected (or possibly enhanced) when little declarative knowledge previously exists about the skill (as with the implicit learning condition in Chauvel et al. [2013] and novices in Flegal & Anderson [2008]). This alternative perspective is an important aspect to consider given the possible implications of verbalizing a motor skill for a novice population.

Overall, the cognitive processes prompted by verbalization may impact various skill levels differently. Verbalization may be more beneficial for novices (compared to skilled performers) due to the declarative knowledge and skill-focused attention associated with verbalizing a motor skill. Notably, verbalization may only benefit novices if they do not have previously established verbal representations of the skill (i.e., preexistent declarative knowledge). It is important to consider this distinction moving forward in investigations. The level of experience may determine the effects of verbalization on memory processes of motor skill performance and learning. Specifically, it may impact the processes of memory in relation to the motor behavior – memory framework.

1.4. Motor behavior – memory framework

Memory is comprised of three distinct, yet interdependent processes: encoding, consolidation, and retrieval (Robertson & Cohen, 2006; Robertson, 2009). These processes apply to the creation and maintenance of all forms of memory, including procedural memory. Procedural memory underlies the decisions and movements of motor skill execution (Fuster, 1995). Motor skills are acquired through practice and experience; thus, memory is essential for execution and improvement. Kantak and Winstein (2012) introduce a theoretical framework to explain the processes of memory specific to motor skill performance and learning, the motor behavior – memory framework. This framework describes the relationship between the time course of memory processes and the phases of a motor learning paradigm. Specifically, Kantak and Winstein (2012) expound upon the particular memory processes influential during the phases of acquisition, immediate retention tests, and delayed retention tests. See Figure 1 for depiction of the motor behavior – memory framework.

The motor behavior – memory framework indicates encoding occurs throughout the acquisition phase, such that practice trials and/or experience are influential in the formation of the motor memory. During this memory process, the learner creates connections between goal, movement, and movement outcome (Robertson, 2009). Cognitive processes for stimulus identification, response selection, and task execution are evident for a motor response (Kantak & Winstein, 2012). Feedback mechanisms subsequently evaluate these processes for future motor response in order to improve performance. Experimental manipulations may impact the encoding process, effectively altering the observed motor behavior, positively or negatively (e.g., focus of attention [Wulf, Höß, & Prinz, 1998]; cognitive fatigue [Borragán, Slama, Destrebecqz, & Peigneux, 2016]; expectation of teaching [Daou, Buchanan et al., 2016]). Therefore, it is important to observe motor behavior throughout the entire encoding process. This process can be observed through the assessment of motor performance during acquisition and immediate retention tests. Performance curves are often utilized to investigate change in motor performance during acquisition as influenced by an experimental manipulation (Christina, 1997), whereas immediate retention tests reveal a change in motor performance after acquisition. Both acquisition and immediate retention test reflect changes in motor performance due to encoding. Skill acquisition can be inferred from a net change of performance during practice or training (Kantak & Winstein, 2012) as observed by performance curves or changes from pretest to immediate retention test. However, this net change may not reflect a relatively permanent change in skill level (i.e., motor learning).

Learning has been described as a relatively permanent change in behavior, such that an individual acquires an improved capability for motor skill execution through practice and experience (Salmoni, Schmidt, & Walter, 1984). It is critical to examine performance after a certain time interval for an appropriate assessment of motor learning (Salmoni et al., 1984). The motor behavior – memory framework suggests the memory process of consolidation needs to occur before learning can be assessed within a motor learning paradigm. Consolidation is an ‘off-line’ time-dependent process in which an encoded procedural memory representation may become more stable and robust (Krakauer & Shadmehr, 2006). It is the time period in which motor behavior is generally expected to change, improve, or stabilize as a result of acquisition or intentional training/practice. Research suggests a time period of 6 hours after acquisition is necessary for consolidation (Muellbacher et al., 2002; Walker & Stickgold, 2004). Additionally, research suggests that improvements continue to occur 24 hrs after acquisition indicating consolidation may be sleep-dependent (Walker & Stickgold, 2004; Siengsukon & Boyd, 2009). Considering these observations, motor memory may be more robust following acquisition depending on the amount of time provided for consolidation (Krakauer & Shadmehr, 2006). Kantak and Winstein (2012) propose consolidation occurs between the end of acquisition and a delayed retention test, preferably a 24-h retention assessment (see Figure 1). Therefore, performance on a delayed retention test may be more indicative of motor learning than performance during acquisition or on an immediate retention test. Research suggests immediate retention tests may not reveal the efficacy of consolidation processes occurring after acquisition; thus, such tests may be poor indicators of relatively permanent change in skill performance (Kantak & Winstein, 2012). Immediate and delayed retention tests offer separate insight into the memory representation formulated and constructed during the acquisition phase. However, delayed retention tests allow for a sufficient consolidation period, allowing one to assess the relative permanence of the originally encoded motor memory.

Following consolidation, retrieval is a critical component of memory profoundly impacting daily life. It is the day-to-day functioning aspect of memory, including processes of recall, recognition, relearning, and recollection (Kantak & Winstein, 2012). When one is retrieving a motor memory, they are performing a motor skill based on its encoded and consolidated representation. Research suggests retrieval can be effected by factors occurring during encoding (i.e., practice or training conditions) (Naveh-Benjamin, Kilb, & Fisher, 2006). Specifically, acquisition environments and conditions may promote or hinder later retrieval, particularly for immediate or delayed retention tests. Thus, Kantak and Winstein (2012) indicate the importance of retrieval in the motor behavior – memory framework. Delayed retention tests are intended to assess retrieval after a period of consolidation; thus, they are suggested to provide the most accurate representation of motor learning.

Overall, the processes of memory are essential for motor learning and performance. The motor behavior – memory framework provides a detailed description of the relationship between these processes and the sequence of motor learning and performance paradigms. It is important to consider this framework within existing literature and concepts in the motor learning and performance domain, specifically relating to verbal overshadowing.

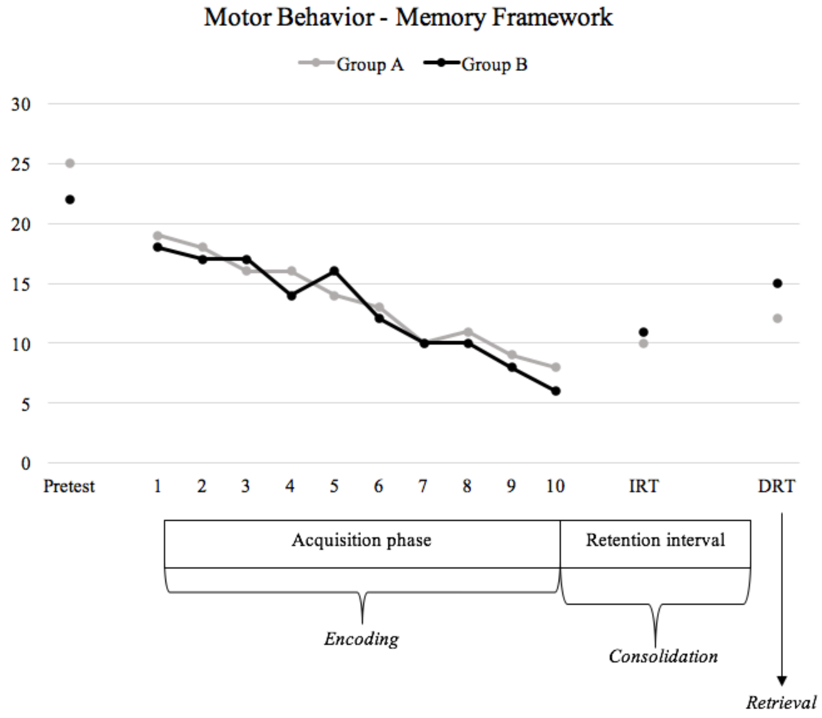

Figure 1. A fictional data set is used to depict the relationship between the motor behavior – memory framework and memory processes. The framework describes the memory processes (encoding, consolidation, and retrieval) that correspond with the phases of motor learning paradigms (acquisition, immediate retention - IRT, and delayed retention - DRT) (Kantak & Winstein, 2012). As depicted above, encoding occurs during the acquisition phase of the experiment. Consolidation is associated with the time between the last acquisition trial and delayed retention test. Retrieval is assessed during delayed retention test typically administered after a period of time.

1.5. Motor behavior – memory framework and verbal overshadowing

Along with the level of experience, an important concept to consider within the verbal overshadowing literature in the procedural knowledge domain is the difference between motor performance and motor learning (i.e., the learning-performance distinction). This distinction is essential to understanding the effects of motor learning and performance paradigms on the processes of memory. It distinguishes between observing a relatively permanent change in motor behavior due to consolidation versus a temporary change in motor behavior due to encoding (i.e., the difference between immediate retention and delayed retention tests). Evidence suggests various schedules, experiences, or paradigms may influence performance, but not learning (or vice versa). For example, within the contextual interference literature, a block-scheduled practice (e.g., practicing skill A, then skill B followed by skill C – AAA BBB CCC) is generally more advantageous for performance and limits learning; whereas, random-scheduled practice (e.g., practicing skills A, B, & C at random – ABC BCA CBA) augments learning, but is not beneficial for performance (Shea & Morgan, 1979; Brady 1998). Similarly, when participants are given feedback frequently during acquisition, they exhibit enhanced performance, but poor learning (Salmoni, Schmidt, & Walter, 1984). These examples demonstrate that changes in motor behavior due to an experimental manipulation during acquisition may cause temporary performance changes, and/or relatively permanent (learning) changes. Thus, it is imperative to design protocols that investigate performance and learning separately within the verbal overshadowing domain.

That said, previous research within the verbal overshadowing procedural domain has only examined temporary performance changes. Specifically, these studies (Flegal & Anderson, 2008; Chauvel et al., 2013) assessed motor performance via an immediate retention test. That is, participants were not allotted a sufficient consolidation period before undergoing a skill assessment (e.g., Robertson, Press, & Pascual-Leone, 2005; Siengsukon & Boyd, 2009). Neither investigation included a delayed retention test within the respective protocols, specifically an assessment 24 hrs after experimental manipulation (i.e., verbalization). Therefore, whether verbalization causes a relatively permanent change in the representation of a motor skill due to consolidation is unknown. Nonetheless, Flegal and Anderson (2008) make assertions regarding the "longer term impact of verbalizing procedural skills on later execution" (p. 927). However, considering the learning-performance distinction and motor behavior – memory framework, the results may not reflect the retrieval of a consolidated motor memory due to the assessment in the protocol (i.e., immediate retention test). Similarly, Chauvel and colleagues (2013) state verbalization may "change the course and structure of cognitive processes" for motor skill execution, yet the results reveal performance on an immediate retention test (p. 182). Memory retrieval was not assessed after a sufficient consolidation period.

Accordingly, these results may collectively demonstrate an effect on motor performance (but not necessarily learning) given the immediacy of the assessments, particularly for the novice participants. The verbalization task may impact the encoding of a new motor skill or merely alter the method of task execution. Foremost, the novice participants may exist in a state of encoding throughout the entire protocol because of the novelty of the skill. Regardless of the lack of practice trials, the experience of the pretest assessment and verbalization protocol may be enough to stimulate encoding of a motor memory (Flegal and Anderson experimental protocol: pretest, verbalization task, then immediate retention test) (Flegal & Anderson, 2008). Verbalization may prompt conscious processing and step-by-step control associated with successful novice performance due to the allocation of attention to declarative aspects of the motor skill (Fitts & Posner, 1967; Anderson, 1983). Thus, a declarative representation is encoded and utilized for task execution. Flegal and Anderson (2008) provide weak evidence for this suggestion in that the novice participants generally performed better after verbalization, perhaps utilizing declarative mechanisms (Beilock, Carr et al., 2002). Verbalizing declarative aspects of a motor skill may influence the process of encoding for novices, thus impacting motor performance as assessed by way of an immediate retention test. Alternatively, the verbalization task may not impact encoding of a motor memory for novices, but simply alter the way the participants are performing the skill by promoting the use of declarative knowledge. That is, the novice participants utilize declarative knowledge (e.g., a skill-focused attention) for task execution without encoding a new motor representation. This notion would also explain an improved performance on an immediate retention test in Flegal & Anderson (2008). Irrespective of whether verbalization affects how a memory is encoded or merely how it's executed, it is imperative to include a delayed retention test in order to determine whether a memory that may be encoded with verbalization is consolidated with the verbal information. If it is, then the effects of verbalization should be evident when the skill is retrieved at a delayed retention test.

Whereas verbalization may affect novices' encoding, it is possible that verbalization may recode experts' motor memory, impacting later retrieval (Meissner, Brigham, & Kelley, 2001; Flegal & Anderson, 2008). Motor memories are labile when retrieved and, subsequently, may be recoded and reconsolidated in a different form. Stated otherwise, each time a memory is retrieved it is susceptible to alteration before being reconsolidated and stored for later retrieval (Walker, Brakefield, Hobson, & Stickgold, 2003; Trempe & Proteau, 2012). This notion may apply to newly formed motor memories, as well as previously established motor memories (Alberini, 2005). Thus, novices and experts' memories may be susceptible to recoding if the paradigm or experience provides an appropriate stimulus to incite a modification of the memory representation.

Verbalization may be sufficient in inducing recoding due to the differences between declarative and procedural memory representations (Flegal & Anderson, 2008). Additionally, the cognitive processes of motor skill level may determine the recoding effects as a result of verbalization. However, as with encoding, the verbalization task may not stimulate an alteration in motor representation. Instead, verbalizing the aspects of the motor skill may simply change the method of task execution without modifying the memory representation.

Chauvel and colleagues (2013) provide evidence for a potential recoding effect in novices. A newly formed motor memory may be vulnerable to alterations through reactivation of memory representation (Walker et al., 2003). In Chauvel et al. (2013), the novice participants were subject to an explicit or implicit learning condition (i.e., an acquisition phase). After the respective learning condition, participants were asked to verbalize the task. This verbalization task may have prompted recoding of the newly formed motor memory because the memory was not yet stable (i.e., no consolidation time was provided). The recoding process subsequently impacted performance on immediate retention test. However, the verbalization may have only influenced representations directly associated with declarative knowledge. The verbalization task may have overshadowed previously established declarative representations for the explicit learning group, thus, hindering subsequent performance (Chauvel et al., 2013). Likewise, the declarative knowledge of the implicit learning group participants may have been distorted by the verbalization task, but the procedural representation encoded during acquisition was left intact allowing for successful task execution (Chauvel et al., 2013). Thus, verbalization may only affect relevant declarative representations of a motor memory as indexed by an immediate retention test. The lasting effects are unknown, such that these recoded memories may or may not be robust after an extended period of time (e.g., 24 h). Specifically, it is unknown whether the novice motor memory is consolidated in its newly recoded form and available for later retrieval. Conversely, the verbalization task may simply cause temporary performance effects, such that recoding does not occur as a result of verbalization. Instead, the verbalization task prompts declarative mechanisms for task execution, leaving the memory representation unaltered. These temporary performance effects may dissipate after a period of time. Thus, a delayed retention test should be implemented to observe if a lasting effect of verbalization is evident through recoding of a memory representation; or if the a verbalization task alters the method of performance execution without impacting the memory.

Similarly, Flegal and Anderson's (2008) skilled participants may have been subject to recoding due to verbalization. A previously existing proceduralized motor memory (associated with skilled performance) may have been susceptible to alteration due to potential offline skill-focused attention primed by verbalization (Flegal & Anderson, 2008). Alternatively, the offline skill-focused attention prompted by verbalization may only affect the subsequent task execution, leaving the existing proceduralized memory intact. That is, verbalizing the skill may have incited the utilization of declarative mechanisms for task execution hindering skilled performance (Beilock, Carr et al., 2002) without altering the memory representation. If verbalization only impacts the mechanisms of task execution, the procedural memory should remain intact and later retrieval should not be effected. Conversely, if verbalization recodes the memory (which is then consolidated in its recoded form), lasting effects may be evident during future retrieval. It is important to investigate the potential lasting effects of verbalization on procedural memory, specifically whether recoding of memory occurs because of verbalizing a motor skill.

Although not directly related to the verbal overshadowing literature, recent research has investigated the effect of teaching a motor skill on learning that respective motor skill. Specifically, Rhoads et al. (in press) investigated the effects of expecting to teach and actually teaching on motor learning. Two groups of novice participants studied and practiced with the expectation of teaching, while two groups studied and practiced without this expectation. After acquisition, one group who expected to teach and one who did not expect to teach taught the skill by providing a 2-min verbal and physical demonstration to a video camera, while the other two groups studied and practiced for an additional 2-min. The results of a 24-h retention test did not reveal an effect of expecting to teach, actually teaching, or an interaction between these variables. Therefore, the verbalization (2-min verbal and physical demonstration) presumably did not affect learning. While Rhoads et al. (in press) used a 24-h retention test, they did not use an immediate retention test. This difference in assessment may explain why Rhoads et al.'s results differ from those of verbal overshadowing experiments. Additionally, Rhoads et al. (in press) included an acquisition phase in which participants studied and practiced under an experimental manipulation (i.e., the expectation of teaching). This manipulation may have impacted the participants' behavior and learning processes beyond verbalization alone. Regardless, results suggest verbalization may not benefit learning in novice performers.

Overall, verbal overshadowing has been revealed to impact motor performance. Skilled performers' performance was impacted immediately after a verbalization task (Flegal & Anderson, 2008). Similarly, novice participants' motor performance was affected when they acquired the skill with a relatively large amount of declarative knowledge (Chauvel et al., 2013). Verbalization has prompted performance changes in skilled and novice participants (depending on how the skill was initially acquired [Chauvel et al., 2013]). This impact on performance has been observed by way of immediate retention tests; thus, it may not reflect the impact verbalization has on motor learning (relatively permanent changes in performance due to encoding and consolidation). The influence of verbalization on motor learning remains unexamined, particularly in light of the processes of memory. Specifically, verbalization may alter the encoding and/or provoke recoding of memory representations within these paradigms, ultimately affecting the consolidation and retrieval of the motor memory. A sufficient consolidation period needs to be included in the investigation of retrieval in order to assess the potential changes in the memory representations (e.g., Robertson, 2009; Siengsukon & Boyd, 2009). Considering the motor behavior – memory framework, a delayed retention test should be included to observe the enduring effects of verbalization on the memory processes, particularly how verbalizing may impact recoding of a memory representation for later retrieval. It is important to determine whether the performance changes induced by verbalization represent a recoding of the motor memory that is then consolidated in its recoded form and retrieved in this form (at a 24-h delayed retention test).

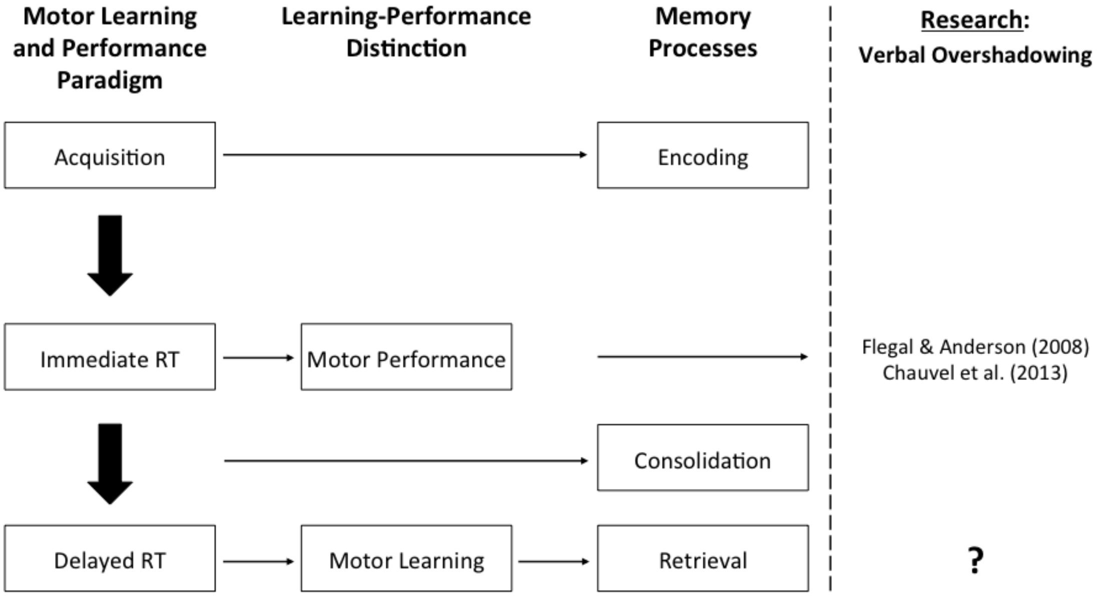

Figure 2. Relationship between the processes of memory, learning-performance distinction, and typical motor learning and performance paradigms. The figure indicates previous research investigating this relationship within the verbal overshadowing domain (i.e., Flegal & Anderson, 2008; Chauvel et al., 2013), as well as, the present gap in the literature regarding a delayed retention test and appropriate consolidation period.

1.6. Mechanisms of verbal overshadowing effect in procedural knowledge

A couple of studies have examined the verbal overshadowing of a motor skill, but the mechanisms behind the phenomenon remain relatively unknown. Manipulation of cognitive processes has been proposed as a potential mechanism within the paradigm. Specifically, Flegal and Anderson (2008) suggest verbalization may provoke delayed skill-focused attention potentially shifting the mode of task execution. Similarly, Chauvel and colleagues (2013) suggest the cognitive processes of task execution may be altered due to verbalization, particularly the utilization of declarative and/or procedural mechanisms. Therefore, it is important to provide insight into this shift of cognitive processes through the investigation of potential mechanisms, specifically cognitive processing during movement preparation.

Verbalization may introduce declarative knowledge into the memory representation. The addition of this knowledge may prompt declarative mechanisms or conscious control during motor memory retrieval, which may influence movement efficiency and cognitive effort. Notably, this shift in cognitive processes may be evident in the movement preparation time (Daou, Lohse et al., 2016) due to greater cognitive effort and less efficient movement execution (Lam, Masters, & Maxwell, 2010). Movement preparation has been shown to require greater attentional resources than movement execution (Holroyd, Yeung, Coles, & Cohen, 2005). Thus, the greater cognitive effort and less efficient movement execution potentially incited by verbalization may extend the motor preparation time. That is, individuals who have declarative knowledge associated with a motor memory may take longer to prepare the movement because they are applying explicit instructions and conscious control to task execution. For example, verbalization may prompt skill-focused attention due to the focus on declarative knowledge (i.e., verbal, rule-based knowledge). This attentional focus may impact the pre-movement cognitive processing by increasing cognitive effort and causing less efficient movement patterns, thus prolonging the motor preparation time. Importantly, an investigation of movement preparation time may shed light on the possibility that cognitive processing demands increase after verbalization.

2. Purpose

The primary purpose of the present study was to investigate the impact of verbalization on the memory processes associated with motor performance and motor learning in various skill levels. The experiment examined the impact of verbalizing a motor skill on the process of encoding for later retrieval in a skilled and novice population. The inclusion of a delayed retention test provided ample time for consolidation (i.e., 24 h), thus providing an appropriate observation of motor memory retrieval. Additionally, the mechanisms of verbal overshadowing remain unknown regarding the impact on procedural knowledge. Thus, this experiment also investigated potential mechanisms behind the verbal overshadowing effect in the motor domain, particularly cognitive processing during movement preparation. To our knowledge, these objectives have not been previously investigated within the field of motor learning and performance. The effect of verbalization has not been comprehensively researched within the verbal overshadowing and procedural knowledge domain. Therefore, this research extends the extant literature by investigating memory processes and potential mechanisms, while providing insight into a different motor task and novice/skilled populations.

3. Hypotheses

We predicted a 2 Skill (Novice/Skilled) x 2 Condition (Verbal/No Verbal) x 3 Test Type (Pretest/Immediate/Delayed) interaction. The skilled participants' performance was expected to decline from Pretest to Day 1 retention test (immediate retention test) in the verbalization condition, but not in the no verbalization condition. The novice participants' performance was predicted to increase from Pretest to Day 1 retention test (immediate retention test) in the verbalization condition, but not in the no verbalization condition. Due to the novelty of the paradigm, we were unable to make an informed prediction regarding performance for Day 2 retention test (delayed retention test). Thus, we performed the experiment without a specific prediction of Day 2 performance for the skilled and novice participants.

Additionally, verbalization paradigms may influence the cognitive processing that occurs during movement preparation (Daou, Lohse et al., 2016). Therefore, we predicted a Condition x Test Type interaction, such that participants in the verbalization groups would exhibit greater movement preparation times after verbalization (on immediate retention test) due to greater conscious processing and less automatic control, whereas no such increase in preparation time would be observed for participants in the non-verbalization condition. Again, we were unable to make an informed prediction regarding preparation time for Day 2 retention test.

4. Methods

4.1. Participants

One hundred and eighteen healthy adults (N = 118, M_{age} = 22.2, SD ±4.11 years) with no current musculoskeletal injuries provided informed-written consent to an institution-approved research protocol (Auburn University; 18-355-EP1809). Sample size was determined with an a priori power calculation providing 80% power ($\alpha \leq .05$) to detect a moderate-sized effect (f^2 = .15) of the interaction between verbalization, skill level, and test type in a mixed-factor ANOVA, with repeated measures on the last factor (Faul, Erdfelder, Lang, & Buchner, 2007). The power calculation yielded N = 76, but 14 additional participants were initially added to the sample. Within this sample, 22 participants (9 skilled and 13 novice) were removed from statistical analysis due to incorrect completion of the experimental manipulation. Twenty-eight participants (11 skilled and 17 novices) were recruited after data had been collected to replace the aforementioned participants. These additional participants were not randomly assigned to groups; they were added to novice and skilled experimental groups, respectively. Further, an additional three participants were removed for failure to complete the second day of the experimental protocol. Thus, 93 participants (N = 93, M_{age} = 22.2, SD ±4.06 years) were included in the statistical analysis and reported in the results. This sample size consisted of 42 skilled participants (22 experimental and 20 control) and 51 novice participants (26 experimental and 25 control). Skill level was determined prior to data collection by way of self-reported experience in basketball and free throw shooting percentage. Criteria for skilled classification included: must have played organized basketball for 4 years at the high school level or beyond and self-reported at least 60% free throw shooting percentage. Criteria for novice classification included: must have no previous experience playing organized basketball. All participants were recruited through kinesiology and physical education classes, the College of Education's Research Participation System, university basketball programs (e.g., collegiate, intramural), and word-of-mouth. Participants were compensated with class credit when feasible.

4.2. Independent and dependent variables

4.2.1. Demographics

Commencing data collection, participants were asked to complete a demographic questionnaire. This particular questionnaire inquired about participant's age, gender, handedness (hand used most often for motor tasks), (basketball) experience, and free throw shooting percentage (skilled performers only). (See *Appendix A* for detailed information.)

4.2.2. Motor learning and performance

Participants were asked to shoot a basketball from the free throw line (4.6 m). The objective of the task was to score as many points as possible. Points were based on a 6-point shooting assessment adapted from Hardy and Parfitt (1991); higher score was indicative of greater accuracy (see Table 1 for scoring criteria). This accuracy score served as the dependent measure of motor learning and performance. The variable was recorded throughout each testing phase (pretest, immediate retention test, delayed retention test). Each trial was captured with an iPad camera recording only the basketball hoop from the sagittal plane. Importantly, all video recordings were assessed and scored after data collection by two separate investigators for reliability purposes.

Points	**Shot performance**
5	"Swish" or clean shot
4	Hits rim and goes in
3	Hits backboard and goes in
2	Hits rim and misses
1	Hits backboard and misses
0	Complete miss

Table 1. Scoring criteria for basketball free throw shooting task (Hardy & Parfitt, 1991; Lam, Maxwell, & Masters, 2009)

4.2.3. Cognitive processing

Cognitive processing was indexed by way of movement preparation time (Daou, Lohse et al., 2016). Participants' pre-movement information processing may impact subsequent performance or learning (Cross, Schmitt, & Grafton, 2007). Importantly, a longer motor preparation time may be indicative of more cognitive processing for task execution. The investigation of movement preparation time may provide insight into the processing induced by the verbalization paradigm, whether beneficial or detrimental. Each trial was recorded with a video camera from the sagittal plane, which provides the most accurate representation of basketball shooting (Kirkpatrick, Wytch, Cole, & Helms, 1994; Whittle, 1996). Investigators assessed this variable after completion of data collection via the video recording. The time began when the ball was still before initial movement upward toward the basket (i.e., the first frame the ball was still in hands of the participant before movement upward) and ended when the participant initiated movement for the shot (i.e., the last frame before the ball was moved upward for the shot motion). This time frame was chosen to avoid shooting routines common when shooting a free throw. The movement preparation time was evaluated for every shot during all testing phases of the experiment.

4.2.4. Experience with verbalization

Participants were asked to report their experience with providing general and task-specific instruction to others. (See *Appendix D* for specific details of questionnaire.) General instruction included, but was not limited to, physical education, personal training, teaching, and coaching in any domain (i.e., not specific to basketball, athletics, or motor skills). Task-specific instruction included any teaching or coaching related to basketball (e.g., providing individual lessons, summer basketball camp counselor, youth league coach). Research suggests effects of verbalization may depend on experience with explaining to others (Hoogerheide et al., 2014), such that a certain level of experience with instruction (i.e., verbalization of skill) is required before a benefit can be observed. More experience with instruction may afford superior organization of task-relevant thoughts, allowing for greater individual cognitive representations of the steps required for task execution. As previously stated, novices rely on step-by-step representations for task execution (Anderson, 1983) and benefit from rule-based focus (Maxwell, Masters, & Eves, 2000). Thus, experience in instruction may provide an additive benefit to novices in a verbalization paradigm due to their ability to identify and organize task-relevant concepts. Skilled participants with experience in verbalization may be inoculated from the verbal overshadowing effect. They may be accustomed to verbalizing declarative knowledge and step-by-step instructions, while utilizing procedural knowledge for task execution. Importantly, this information was used in secondary analyses to determine whether experience moderates the effects of verbalization on skilled and novice participants.

4.2.5. Quantifying task-relevant verbal knowledge

The extant literature suggests the magnitude of the verbal-overshadowing phenomenon depends on an individual's level of verbal and perceptual expertise within a task domain (Melcher & Schooler, 1996). When the two levels of expertise are similar (i.e., either both strong or both weak), the verbal-overshadowing effect will be insignificant. However, when a discrepancy exists between verbal and perceptual expertise (i.e., one is strong and the other is weak), the verbal-overshadowing effect will be present. For example, Melcher and Schooler (1996) investigated the verbal overshadowing effect amongst non-wine drinkers, untrained wine drinkers, and trained wine drinkers. The untrained wine drinkers were the only group to suffer the verbal overshadowing effect due to the discrepancy between their verbal and perceptual skills. These results may be a manifestation of the recoding interference hypothesis, such that the verbal representation dominates the perceptual representation during memory retrieval (Brandimonte & Collina, 2008). Notably, these suggestions apply to verbal and perceptual expertise. This notion has not been investigated regarding procedural expertise. Therefore, a free recall assessment served as a measure of participants' task-relevant verbal knowledge. The tasks were scored considering the quantity of key concepts reported in the assessment (see Table 2 for key concepts and *Appendix E* for specific details of assessment). This information afforded a secondary investigation into whether varying levels of verbal and procedural expertise in basketball moderate the verbal overshadowing effect.

Key Concepts of Basketball Free Throw
(1) Square shoulders and torso to the basket
(2) Feet shoulder-width apart
(3) Slightly bend knees and waist
(4) Place dominant hand behind ball with fingers spread
(5) Non-dominant hand is used to stabilize ball on side
(6) Ball rests on pads of fingers, not palm of hand
(7) Shoot ball by extending knees and arms together and releasing non-dominant hand
(8) Follow through with the shot by extending elbow and flexing wrist

Table 2. Key concepts utilized to index participants' level of verbal expertise (adapted from Zachry, Wulf, Mercer, & Bezodis [2005]).

4.3. Procedure

4.3.1. Day 1

Participants were asked to report to the basketball court on their scheduled day. They provided written consent to an institution-approved research protocol and completed the demographic survey. A video camera was positioned on the dominant side of the participant in line with the free throw line (distance of approx. 4.7 m) to capture the entire body of the participant from the sagittal plane (Kirkpatrick, Wytch, Cole, & Helms, 1994; Whittle, 1996). Additionally, an iPad camera was positioned in line with the basketball hoop (distance of approximately 4 m) to record the entire hoop and backboard from sagittal plane. (See Figure 2 for depiction of entire experimental setup.) Participants were given a brief warm-up of three shots into the air (i.e., not towards the basketball hoop). This warm-up was chosen to limit a potential learning effect from extra shooting towards the basketball hoop, but to allow for preparation of the body and shooting mechanics. After warm-up, the participants proceeded to the pretest phase consisting of 10 shots from the free throw line. Next, skilled and novice participants were randomly assigned to a group and given instructions based on their experimental condition[2]. Participants assigned to the verbalization conditions (Verbal – Skill and Verbal – Novice) completed a 5-min verbalization task. They were told, "Please describe in as much detail as possible the free throw shooting task you just completed. You should attempt to describe the task such that someone else could execute the task based on your description" (Meissner et al., 2001)[3]. Participants assigned to the no verbalization conditions (No Verbal – Skill and No Verbal – Novice) completed a control task for an equivalent amount of time (5-min). They were told, "Please describe in as much detail as possible the weather outside today. You should attempt to describe the weather such that someone else could envision the weather based on your description" (Meissner et al., 2001). After their respective tasks, participants proceeded to the first retention test of the experiment. This immediate retention test consisted of 10 shots from the free throw line. After completion, participants were thanked and reminded of their scheduled time the following day.

4.3.2. Day 2

Participants returned approximately 24 h after their Day 1 scheduled time. Upon arrival, participants completed the same warm-up as Day 1 and a delayed retention test consisting of 10 shots from the free throw line. All variables collected during the Day 1 procedure were also assessed on Day 2 (i.e., accuracy score, movement preparation time). Participants completed the

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[2] Except for the additional 28 participants recruited after data had been collected. These participants were assigned to novice and skilled experimental groups, respectively (i.e., Verbal conditions).

[3] The additional 28 participants were provided with a supplementary instruction of "please focus your writing on shooting a free throw" to ensure an appropriate response to the experimental manipulation.

free recall assessment and verbal experience surveys. After completion, participants were debriefed and thanked for their participation.

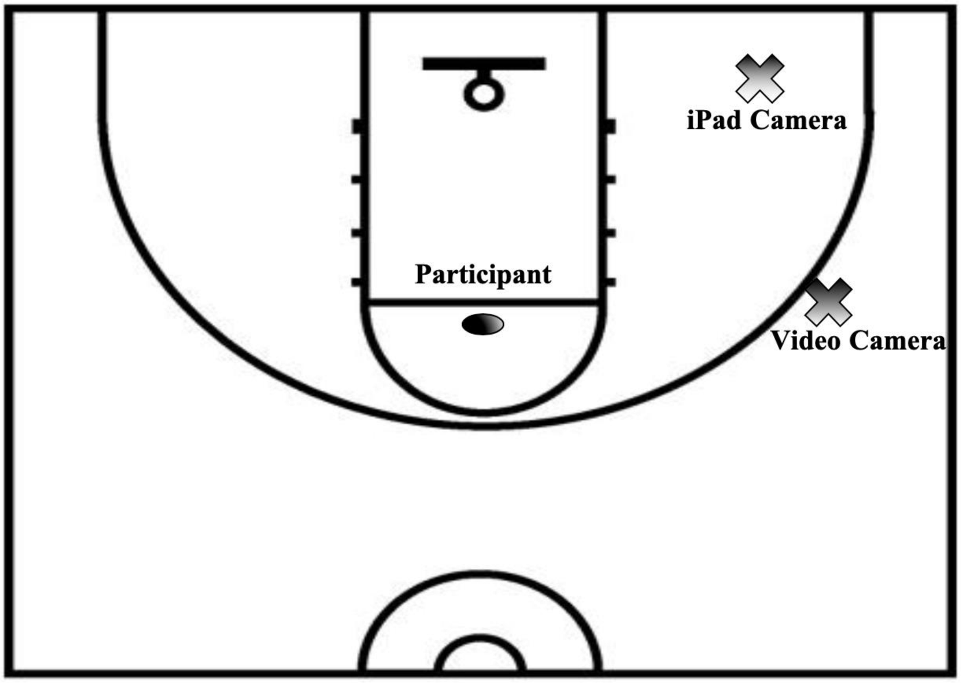

Figure 3. Depiction of experimental setup for a right-handed participant. Video camera and iPad camera were positioned to record the sagittal plane of participants' shooting motion and basketball hoop, respectively. The video camera was setup on a tripod for recording; the primary investigator held the iPad camera for all data collections. Importantly, the experimental setup is reversed for left-handed participants (i.e., the cameras are placed on left side of basketball hoop).

5. Statistical analysis

5.1. Motor learning and performance

To assess motor performance/learning, we conducted a 2 Condition (Verbal/No Verbal) x 2 Skill (Novice/Skilled) X 3 Test Type (Pretest/Immediate/Delayed) ANOVA with repeated-measures on the last factor for shooting performance.

5.2. Cognitive processing

To assess cognitive processing, a 2 Condition (Verbal/No Verbal) x 2 Skill (Novice/Skilled) x 3 Test Type (Pretest/Immediate/Delayed) ANOVA with repeated measures on the last factor was conducted for movement preparation time.

5.3. Secondary analyses

5.3.1. Experience with verbalization

To assess the impact of experience with verbalization, separate 2 Condition (Verbal/No Verbal) x 2 Skill (Novice/Skilled) x 2 Verbal Experience (Y/N) x 3 Test Type (Pretest/Immediate/Delayed) ANOVAs with repeated-measures on the last factor were conducted for shooting performance. General Verbal Experience and Task Specific Verbal Experience served as Verbal Experience in each respective model.

5.3.2. Task-relevant verbal knowledge

Free Recall served as an assessment of verbal knowledge. The scores were split into quartiles (Quartile 1: 0 key concepts; Quartile 2: 1 key concept; Quartile 3: 2 key concepts; Quartile 4: ≥ 3 key concepts) to be used as a between-subjects factor in a statistical model. A 2 Condition (Verbal/No Verbal) x 2 Skill (Novice/Skilled) x 4 Verbal Knowledge (Quartiles 1-4) x 3 Test Type (Pretest/Immediate/Delayed) ANOVA with repeated-measures on the last factor was conducted for shooting performance to assess whether task-relevant verbal knowledge moderated any verbal overshadowing effects.

6. Results

6.1 Demographics

Table 3 displays descriptive data for demographic, experimental, and assessment/survey variables. Table 4 includes frequency data for demographic and assessment/survey variables.

Table 3. Descriptive data for each group. Confidence interval (*CI*) is 95%.

Descriptive Data by Group				
	Skilled / Verbal (*n* = 22)	Skilled / No Verbal (*n* = 20)	Novice / Verbal (*n* = 26)	Novice / No Verbal (*n* = 25)
	M *(CI)*	*M* *(CI)*	*M* *(CI)*	*M* *(CI)*
Age (Years)	23.0 (20.9-25.1)	22.9 (20.8-25)	21.6 (20.3-23)	21.5 (20.5-22.5)
Estimated FT Shooting %	71.9 (68.4-75.4)	68.9 (63.5-73.5)		
MLP[a] Pretest	2.99 (2.70 – 3.28)	3.06 (2.74 – 3.38)	1.59 (1.20 – 1.98)	1.85 (1.47 – 2.23)
MLP Immediate Posttest	3.34 (3.07 - 3.61)	3.23 (2.90 – 3.56)	1.85 (1.12 – 2.58)	2.12 (1.80 – 2.44)
MLP Delayed Posttest	3.14 (2.86 – 3.42)	2.97 (2.69 – 3.25)	1.82 (1.52 – 2.12)	2.09 (1.78 – 2.4)
MPT[bc] Pretest	0.42 (0.28 – 0.56)	0.37 (0.26 – 0.48)	0.24 (0.14 – 0.34)	0.14 (0.10 – 0.18)
MPT[c] Immediate Posttest	0.44 (0.32 – 0.56)	0.37 (0.27 – 0.47)	0.25 (0.13 – 0.37)	0.13 (0.09 – 0.17)
MPT[c] Delayed Posttest	0.44 (0.30 – 0.59)	0.37 (0.27 – 0.48)	0.25 (0.14 – 0.36)	0.13 (0.09 – 0.17)
Free Recall	3.00 (1.98-4.02)	2.15 (1.34-2.96)	2.27 (1.51-3.03)	1.76 (1.19-2.33)

[a] MLP = Motor Learning and Performance – Shooting Performance

[b] MPT = Motor Preparation Time

[c] *n* = 21; *n* = 20; *n* = 24; *n* = 24

Table 4. Frequency data for each group.

Frequency Data by Group	Skilled / Verbal (n = 22)	Skilled / No Verbal (n = 20)	Novice / Verbal (n = 26)	Novice / No Verbal (n = 25)
Gender	14 Males 8 Females	13 Males 7 Females	9 Males 17 Females	10 Males 15 Females
Handedness	20 Right[a] 1 Left	20 Right 2 Left	23 Right 3 Left	21 Right 4 Left
Years of Exp.[b]	2 Four years 20 Five+ years	3 Four years 17 Five+ years		
Level of Playing Exp.	2 College 20 H.S.	3 College 17 H.S.		
General Verbal Exp.	18 Yes 4 No	16 Yes 4 No	15 Yes 11 No	18 Yes 7 No
Task Specific Verbal Exp.	15 Yes 7 No	13 Yes 7 No	0 Yes 26 No	0 Yes 25 No

[a] One participant reported dominance in both hands.
[b] Exp. = Experience

6.2. Motor learning and performance

Confidence intervals are 95% for all reported results. Results of the 2 Condition (Verbal/No Verbal) x 2 Skill (Novice/Skilled) x 3 Test Type (Pretest/Immediate/Delayed) ANOVA revealed a main effect of skill ($F(1, 89) = 80.3$, $p < .001$, $\eta^2_p = .474$), such that skilled participants (M = 3.12, CI = 3 – 3.24) were more accurate than novice participants (M = 1.88, CI = 1.75 – 2.01). Also, results revealed a main effect of test type ($F(2, 178) = 7.16$, $p = .001$, $\eta^2_p = .074$). Specifically, participants performed better in immediate (M = 2.57, CI = 2.36 – 2.78, $p \leq .001$) and delayed retention tests (M = 2.45, CI = 2.26 – 2.64, $p = .05$) compared to pretest (M = 2.31, CI = 2.11 – 2.51), but retention tests did not differ from one another ($p = .09$). There was no effect of condition ($p = .471$), and no interactions among factors (ps $\geq .227$). See Figure 4 for mean values of shooting performance for each group in all testing phases of experiment.

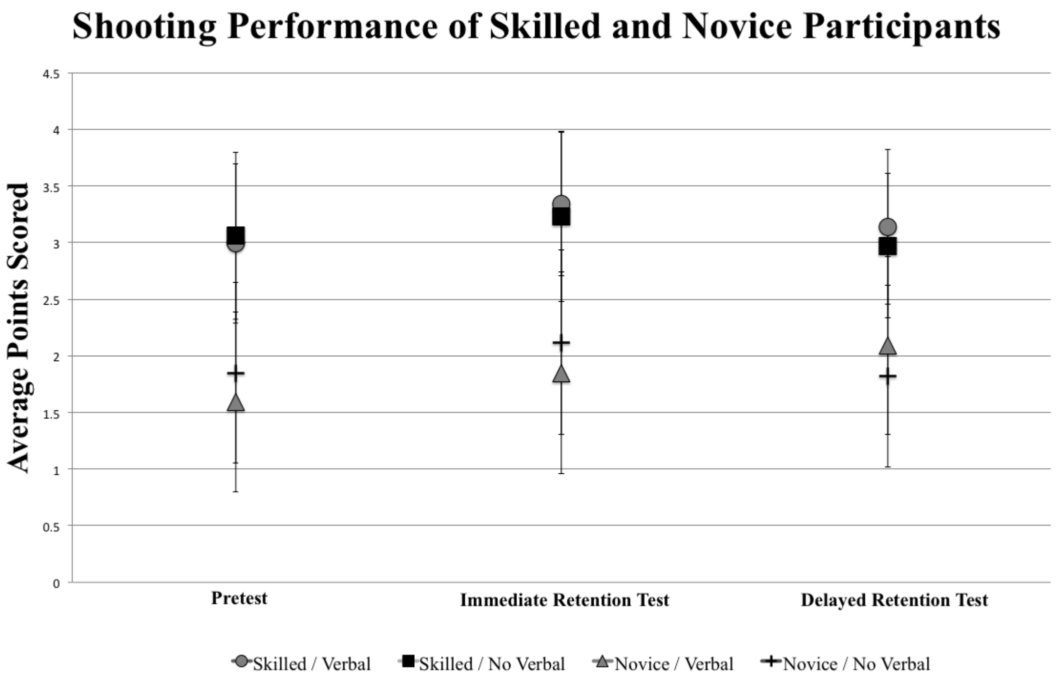

Figure 4. Displays the mean shooting performance for each group in every testing phase of the experiment. Importantly, Pretest and Immediate Retention Test occur on Day 1 of experiment; Delayed Retention Test is recorded on Day 2 (i.e., approximately 24 h after Day 1).

6.3. Cognitive processing

Eighty-nine participants were included in this analysis due to a video recording error for 4 participants (N = 89 [41 skilled, 48 novices], M_{age} = 22.2, SD = ±4.09 years). Mauchly's Test of Sphericity was violated for this 2 Condition (Verbal/No Verbal) x 2 Skill (Novice/Skilled) x 3 Test Type (Pretest/Immediate/Delayed) ANOVA (W = .89, p = .008). Therefore, the Greenhouse-Geisser correction was applied for these results. Results revealed a main effect of skill ($F(1, 85) = 17.8$, $p < .001$) with the skilled participants (M = 0.40 sec, CI = 0.35 – 0.45) exhibiting a longer motor preparation time compared to the novice participants (M = 0.19 sec, CI = 0.16 – 0.22). There was no effect of test type or condition (ps ≥ .079), and no interaction among factors (ps ≥ .396).

See Figure 5 for mean values of motor preparation time for each group in all testing phases of experiment.

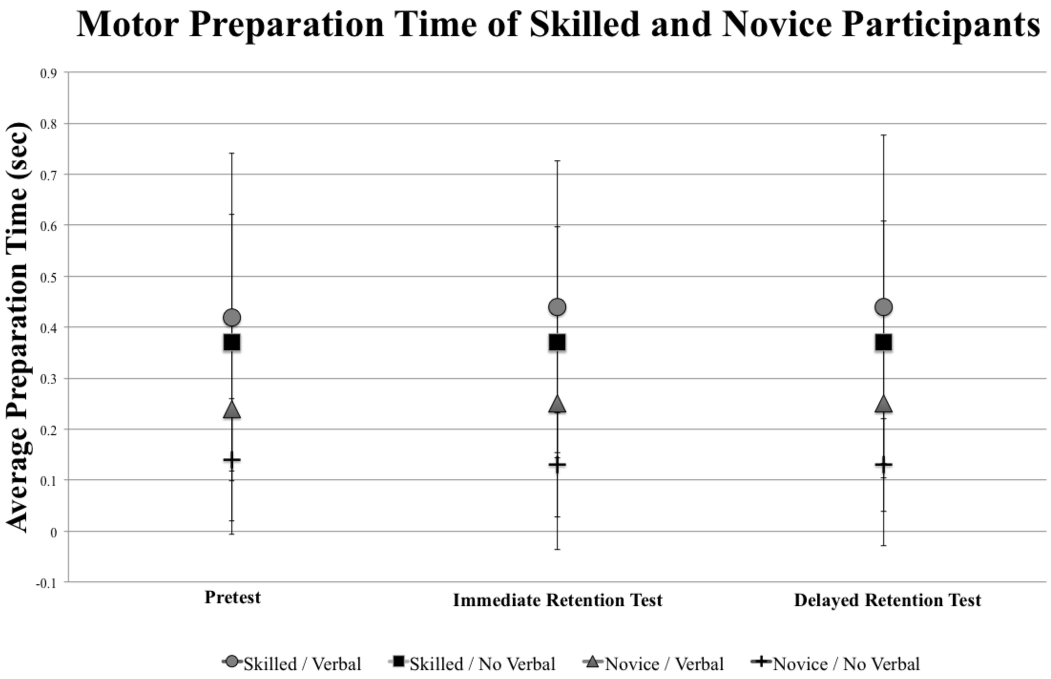

Figure 5. Displays the mean motor preparation time for each group in every testing phase of the experiment. Importantly, Pretest and Immediate Retention Test occur on Day 1 of experiment; Delayed Retention Test is recorded on Day 2 (i.e., approximately 24 h after Day 1).

6.4. Secondary analyses

6.4.1. Experience with verbalization and task-relevant verbal knowledge

The secondary analyses revealed that the verbalization experience did not moderate interactions of interest. Specifically, Verbal Experience (General and Task-Specific) and Verbal Knowledge (Free Recall) did not reveal interactions with skill, condition, or test as the extant literature suggested. Thus, these variables will not be discussed further in the current investigation.

7. Discussion

The current experiment was designed to investigate the impact of verbalization on the performance and learning of a motor skill in novice and skilled populations. The protocol was designed to allow for an adequate consolidation period (i.e., 24 hours), thus providing an appropriate observation of motor memory retrieval. We predicted the verbalization task would alter the motor memory retrieval process of both skilled and novice participants. The skilled participants' performance was expected to decline from pretest to immediate retention test in verbal groups compared to no verbal groups. Novice participants' performance was predicted to increase from pretest to immediate retention test in verbal groups compared to no verbal groups. Due to the novel inclusion of a delayed retention test, we did not have a prediction for task performance on Day 2 for novice or skilled participants. Additionally, this experiment investigated a potential mechanism of the verbal overshadowing effect within the motor domain. Cognitive processing indexed by movement preparation time was explored to provide insight into processing prompted by the verbalization paradigm. We predicted verbalization groups would exhibit greater movement preparation time after the verbalization tasks. Importantly, longer movement preparation time may reflect an alteration in the cognitive processing related to task execution.

Results revealed a significant difference in skill level for the free throw shooting task. Specifically, skilled participants exhibited greater accuracy in the shooting task compared to the novice participants. Additionally, results indicated a significant difference in skill level for the cognitive processing variable. Skilled participants demonstrated longer motor preparation time than the novice participants. The longer motor preparation time for the skilled participants may be related to the retrieval of a more complex motor program compared to the novice participants (Henry & Rogers, 1960). Alternatively, the longer motor preparation time may be associated with shooting routines of skilled participants (although the current protocol attempted to avoid such routines). That is, these participants have established shooting patterns that may require more time to execute compared to novice participants, who have no prior experience with the task.

Test type was also influential in performance on shooting task; participants performed better in the retention tests compared to the pretest (regardless of skill). However, scores generally did not differ between the retention tests. These results indicate participants improved from pretest to immediate retention test, but no changes occurred between immediate retention test and delayed retention test. The improvement from pretest to immediate retention test may be explained by a warm-up effect for the novice and skilled participants. The warm-up provided within the protocol (3 shots into the air) may have not been sufficient for the participants to prime their shooting form and acclimate to the experimental environment (e.g., gymnasium, basketball hoop, lighting). Thus, the pretest shots served as an additional warm-up and allowed for appropriate adjustments resulting in improved performance on immediate retention test regardless of condition. Importantly, the participants did not display continued improvement on the delayed retention test after a period of consolidation (i.e., no change from immediate retention test to delayed retention test). Perhaps, the immediate retention test performance can be considered the true baseline of the participants and the delayed retention test is a continued observation of that baseline. Despite these differences in skill level and test type, results did not reveal an impact of condition or an interaction between variables. A verbal overshadowing effect was not apparent for either skill or novice participants. The verbalization condition did not influence motor performance, motor learning, or motor preparation time compared to the control condition. Thus, the results failed to support the current hypotheses concerning cognitive processing and motor learning and performance. However, there are several plausible explanations for the incongruence with predicted results.

7.1. Declarative knowledge and verbal overshadowing

The current experiment did not replicate results of previous verbal overshadowing experiments concerning the impact of verbalization on motor performance (i.e., immediate retention test). Specifically, the present results did not reveal a change from pretest to immediate retention test performance as a result of the verbalization task. These divergent results may be explained by the current participants' declarative knowledge of the skill. Previous literature suggests performance may be disrupted by declarative mechanisms provoked by verbalization when declarative knowledge already exists for the motor skill. Specifically, Flegal and Anderson (2008) suggest skilled participants exhibit a performance decrement after verbalization because it causes them to revert back to a reliance on declarative knowledge for motor control. Chauvel et al. (2013) suggest that novice participants will only experience a performance decrement if verbalization disrupts declarative knowledge that is being used for performance (e.g., explicit learning condition). However, the current results suggest that verbalization did not interfere with declarative knowledge. Perhaps, the current participants did not possess a sufficient amount of declarative knowledge in order to observe a verbal overshadowing effect. The skilled participants appear to have had minimal amounts of declarative knowledge (total possible key concepts = 8; average key concepts reported on verbalization task = 3.33; average key concepts reported on Free Recall = 2.60), which may have protected them from a verbal overshadowing effect. That is, individuals who have little declarative knowledge are unlikely to attempt to use it in order to control their movement (Masters & Maxwell, 2008). Similarly, the novice participants did not have the time to acquire declarative knowledge because the current experimental protocol did not provide task instructions or an acquisition period (as with the novices in Chauvel et al, 2013). Thus, the novice participants did not possess declarative knowledge subject to disruption by verbalization. Ultimately, the current participants may have lacked the appropriate amount of declarative knowledge to observe a verbal overshadowing effect on immediate motor performance.

7.2. Motor behavior – memory framework and verbal overshadowing

The current results did not support the notion of verbalization altering relatively immediate task execution (i.e., motor performance). The present results also failed to display an effect of verbalization on motor learning assessed by way of a delayed retention test. Considering the motor behavior – memory framework and learning-performance distinction, a delayed retention test was included within the protocol to observe the impact of verbalization on recoding and reconsolidation of a procedural memory representation for later retrieval. The results revealed a significant difference between pretest and delayed retention test, but no change in motor performance from immediate retention test to delayed retention test. Perhaps, the results indicate little to no alterations in motor memory representations as a result of verbalization. Motor memories are susceptible to alteration after retrieval before being reconsolidated and stored for later retrieval (Walker, Brakefield, Hobson, & Stickgold, 2003; Trempe & Proteau, 2012). Yet, a paradigm or experience must provide a sufficient stimulus in order to provoke a modification of the memory representation (Alberini, 2005). The current verbalization task may not have been an appropriate stimulus for alteration of motor memory representation in the novice and skilled participants. That is, the verbalization task may not have provided adequate stimuli to cause recoding or reconsolidation of memory representation.

Chauvel and colleagues (2013) suggest a verbalization task may alter (i.e., recode) a newly formed memory representation because the memory is not yet stable (assuming no consolidation period), subsequently impacting motor performance. Importantly, this process may only impact representations associated with declarative knowledge (Chauvel et al., 2013). The present results do not support this hypothesis. The current verbalization task did not influence motor performance or learning for novice participants. Thus, results suggest recoding did not occur due to verbalization regardless of the characteristics of the memory representation encoded (procedural or declarative). Furthermore, the verbalization task may not have provided enough stimuli to induce recoding of a motor memory. A specific motor learning paradigm may need to be provided in order to observe benefits of a verbalization. Specifically, novices may need to be provided more instructions (beyond verbalization alone) in order to experience a beneficial effect of verbalization. For example, Chauvel and colleagues (2013) provided an implicit and explicit learning paradigm for the novice participants in their experiment. This paradigm allowed for a training period within the protocol, which provided an observation of the type of knowledge impacted by verbalization.

The current results suggest the novice participants' memory representation was not impacted by verbalization. The same may be true for the skilled participants. Flegal and Anderson (2008) suggest a verbalization task may alter the cognitive processing for task execution, which may influence a previously existing proceduralized motor memory. However, the current results revealed no change in motor behavior as a result of verbalization for the skilled participants. The skilled participants' memory representation may have been stable enough to withstand the effects of the verbalization task. Thus, the preexisting proceduralized memory representation was left intact. Alternatively, the verbalization task may simply have not provided sufficient stimuli to modify the motor memory representation. Therefore, the preexisting proceduralized memory representation was not affected. Ultimately, the current experiment did not reveal a recoding effect due to the verbalization task for skilled participants. Future research should explore possible scenarios in which verbalization is supplemented with other experimental variables, particularly psychological pressure or social presence. These variables may augment the stimuli prompted by verbalization in order to invoke a beneficial or detrimental modification in a motor memory representation. For example, verbalization paired with social presence (e.g., teaching or coaching others) may provide a benefit greater than verbalization in the form of teaching to a video camera or writing (Hoogerheide, Deijkers, Loyens, Heijltjes, & van Gog, 2016). Social presence may be a catalyst for a rewarding social interaction (Rhoads et al., in press), which has been shown to release dopamine in brain (Clark & Dumas, 2015). Importantly, dopamine is important for skill acquisition and learning (Wise, 2004). Social presence may provide appropriate additional stimuli to verbalization for an impact on performance or learning. It is important to investigate these factors due to the possible transfer to 'real-world' settings (e.g., in-game interviews, teaching motor skills, providing performance analyses).

7.3. Procedural knowledge and verbal overshadowing

Rationale has been presented describing the null results of the current experiment. It was suggested the participants' lack of declarative knowledge protected them from a verbal overshadowing effect on immediate motor performance. Likewise, the verbalization task does not appear to have altered the procedural memory representations, which lead to no change in delayed motor performance and no learning effect. Despite the given explanations, the current results are not in alignment with previous verbal overshadowing literature in the procedural domain. Previous studies found a significant difference in immediate motor performance after a verbalization task for skilled and/or novice participants (Flegal & Anderson, 2008; Chauvel et al., 2013). Therefore, evidence is currently contradictory regarding a verbal overshadowing effect on immediate motor performance. Future research should investigate this conflicting evidence to determine the beneficial, detrimental, or null effect of verbalizing a skill on motor performance. However, this conflicting evidence is only associated with performance on an immediate retention test. The current results are in alignment with previous literature associated with the verbal overshadowing effect on a delayed retention test or motor learning.

Rhoads et al. (in press) investigated the effects of expecting to teach and teaching on motor learning and performance. Participants were required to study and practice golf putting with the expectation of teaching. Then, they were required to teach the skill to a fictitious other participant, presumably verbalizing the steps of golf putting within their teaching requirement. Results revealed no effect of teaching on a delayed retention test approximately 24 h after the experimental manipulation. Although there were other variables involved, one could suggest there was no effect of verbalization on delayed motor performance. These results are in alignment with the results of the current study. Rhoads et al. (in press) and the current study are both well-powered studies that do not reveal an impact of verbalization on delayed motor performance or motor learning. The presence of these well-powered studies suggests the verbal overshadowing effect may not impact motor learning or delayed motor performance. Specifically, verbalizing a motor skill may not impact later retrieval of a procedural memory representation. The memory representation is left intact after a period of time. It is important to consider this evidence moving forward in the investigation of verbal overshadowing. Verbalizing a motor skill may impact immediate performance, but it may not alter delayed motor performance (approximately 24 h later). Future research should investigate the ‘wash out’ period of the verbal overshadowing effect. In other words, research should attempt to determine how long the effect is present and at what point does performance return to baseline. Overall, the verbal overshadowing effect may be present for motor performance, but not motor learning. Research should continue to examine the effect of verbalization on motor performance to determine whether the effect is ‘real’ and the longevity of the effect.

8. Conclusion

Although memory representations are susceptible to alteration after retrieval, a stimulus or experience must provoke a change in order for an alteration to occur. The current verbalization task may not have incited a change in the motor memory representations for novice and skilled participants. Therefore, motor behavior (i.e., motor performance and motor learning) did not vary as a result of verbalization for either skill level. Future research should investigate paradigms that may supplement stimuli provoked by verbalization in inducing a modification of a motor memory representation (e.g., implicit/explicit learning paradigm, social presence). Furthermore, the current participants may have lacked the necessary declarative knowledge to observe an impact of verbalization on motor performance as seen in previous experiments. Future research should delve into influence of preexistent declarative knowledge in the verbal overshadowing effect. Additionally, future research should observe precise changes in motor control as a result of verbalization utilizing electroencephalography (EEG) and biomechanical metrics (e.g., coordination, movement variability). In conclusion, the current results failed to show a verbal overshadowing effect for either skilled or novice participants. The verbalization task did not incite the predicted changes in motor performance and learning. The current results did not align with previous literature regarding the impact of verbalization on motor performance. Future research should investigate the presented contradictory results. Conversely, the current results were in alignment with evidence associated with the impact of verbalization on motor learning. This evidence suggests the verbal overshadowing effect is not present for delayed motor performance. Future research should consider this suggestion moving forward in the investigation of the verbal overshadowing effect in the procedural domain.

References

Abbas, Z. A., & North, J. S. (in press). Good-vs. poor-trial feedback in motor learning: The role of self-efficacy and intrinsic motivation across levels of task difficulty. *Learning and Instruction*. doi: 10.1016/j.learninginstruc.2017.09.009

Allen, V. L., & Feldman, R. S. (1973). Learning through tutoring: Low achieving children as tutors. *Journal of Experimental Education*, *42*, 1 - 5.

Ait-Said, E. D., Maquestiaux, F., & Didierjean, A. (2014). Verbal overshadowing of memories for fencing movements is mediated by expertise. *Plos One*, *9*, e89276. doi: 10.1371/journal.pone.0089276

Alberini, C. M. (2005). Mechanisms of memory stabilization: Are consolidation and reconsolidation similar or distinct processes? *Trends in Neurosciences*, *28*, 51-56. doi: 10.1016/j.tins.2004.11.001

Anderson, J.R. (1983). *The Architecture of Cognition.* Cambridge, MA: Harvard University Press.

Bargh, J. A., & Schul, Y. (1980). On the cognitive benefits of teaching. Journal of Educational Psychology, 72, 593-604. doi: 10.1037/0022-0663.72.5.593

Beilock, S. L., Carr, T. H., MacMahon, C., & Starkes, J. L. (2002). When paying attention becomes counterproductive: impact of divided versus skill-focused attention on novice and experienced performance of sensorimotor skills. *Journal of Experimental Psychology: Applied*, *8*, 6. doi: 10.1037/1076-898X.8.1.6

Beilock, S. L., Wierenga, S. A., & Carr, T. H. (2002). Expertise, attention, and memory in sensorimotor skill execution: Impact of novel task constraints on dual-task performance and episodic memory. *The Quarterly Journal of Experimental Psychology Section A, 55*, 1211-1240. doi: 10.1080/02724980244000170

Bernstein, N. A. (1967) *The co-ordination and regulation of movements.* Edinburgh, Scotland: Pergamon Press.

Borragán, G., Slama, H., Destrebecqz, A., & Peigneux, P. (2016). Cognitive fatigue facilitates procedural sequence learning. *Frontiers in human neuroscience*, *10,* 86. doi: 10.3389/fnhum.2016.00086

Brady, F. (1998). A theoretical and empirical review of the contextual interference effect and the learning of motor skills. *Quest*, *50*, 266-293. doi: 10.1080/00336297.1998.10484285

Brandimonte, M. A. & Collina, S. (2008). Verbal overshadowing in visual imagery is due to recoding interference. *European Journal of Cognitive Psychology*, *20,* 612-631. doi: 10.1080/09541440701728441

Brandimonte, M. A., Hitch, G. J., & Bishop, D. V. (1992). Verbal recoding of visual stimuli impairs mental image transformations. *Memory & Cognition*, *20,* 449-455. doi: 10.3758/BF03210929

Chauvel, G., Maquestiaux, F., Ruthruff, E., Didierjean, A., & Hartley, A. A. (2013). Novice motor performance: better not to verbalize. *Psychonomic Bulletin & Review, 20,* 177-183. doi: 10.3758/s13423-012-0331-x

Christina, R. W. (1997). Concerns and issues in studying and assessing motor learning. *Measurement in Physical Education and Exercise Science*, *1,* 19-38. doi: 10.1207/s15327841mpee0101_2

Clark, I., & Duman, G. (2015). Toward a neural basis for peer-interaction: what makes peer-learning tick? Frontiers in Psychology, 6, e1 – e12. doi: 10.3389/fpsyg.2015.00028

Cohen, J., Cohen, P., West, S. G., & Aiken, L. S. (2003). Applied multiple regression/correlation Analysis for the behavioral sciences (3rd Ed.). Routledge: New York.

Cross, E. S., Schmitt, P. J., & Grafton, S. T. (2007). Neural substrates of contextual interference during motor learning support a model of active preparation. *Journal of Cognitive Neuroscience*, *19*, 1854-1871. doi: 10.1162/jocn.2007.19.11.1854

Daou, M., Buchanan, T. L., Lindsey, K. R., Lohse, K. R., & Miller, M. W. (2016). Expecting to teach enhances learning: Evidence from a motor learning paradigm. *Journal of Motor Learning and Development*, *4*, 197-207. doi: 10.1123/jmld.2015-0036

Daou, M., Lohse, K. R., & Miller, M. W. (2016). Expecting to teach enhances motor learning and information processing during practice. *Human Movement Science*, *49*, 336-345. doi: 10.1016/j.humov.2016.08.009

Daou, M., Lohse, K. R, & Miller, M. W. (2018). Does practicing a skill with the expectation of teaching alter motor preparatory cortical dynamics? International Journal of Psychophysiology, 127, 1 – 10. doi: 10.1016/j.ijpsycho.2018.02.013

Darley, C. F., & Glass, A. L. (1975). Effects of rehearsal and serial list position on recall. *Journal of Experimental Psychology: Human Learning and Memory*, *1*, 453-458. doi: 10.1037/0278-7393.1.4.453

Davids, K., Bennett, S., & Newell, K. M. (2006) *Movement system variability*. Chicago, IL: Human Kinetics.

DeVellis, R. F. (2003). Scale Development: Theory and applications (2nd Ed. Vol. 26). Thousand Oaks, CA: Sage.

Dyke, F., Godwin, M. M., Goel, P., Rehm, J., Rietschel, J. C., Hunt, C. A., & Miller, M. W. (2014). Cerebral cortical activity associated with non-experts' most accurate motor performance. Human Movement Science, 37, 21-31. doi: 10.1016/j.humov.2014.06.008

Faul, F., Erdfelder, E., Lang, A. G., & Buchner, A. (2007). G* Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behavior Research Methods*, *39*, 175-191. doi: 10.3758/BF03193146

Fiorella, L., & Mayer, R. E. (2013). The relative benefits of learning by teaching and teaching expectancy. *Contemporary Educational Psychology*, *38*, 281-288. doi: 10.1016/j.cedpsych.2013.06.001

Fiorella, L., & Mayer, R. E. (2014). Role of expectations and explanations in learning by teaching. *Contemporary Educational Psychology*, *39*, 75-85. doi: 10.1016/j.cedpsych.2014.01.001

Fitts, P. M., & Posner, M. (1967). *Human performance*.

Flegal, K. E., & Anderson, M. C. (2008). Overthinking skilled motor performance: Or why those who teach can't do. *Psychonomic Bulletin & Review*, *15*, 927-932. doi: 10.3758/PBR.15.5.927

Fuster, J. M. (1995). Memory in the cerebral cortex. Cambridge, MA: MIT Press.

Grand, K. F., Bruzi, A. T., Dyke, F. B., Godwin, M. M., Leiker, A. M., Thompson, A. G., … Miller, M. W. (2015). Why self-controlled feedback enhances motor learning: Answers from electroencephalography and indices of motivation. Human Movement Science, 43, 23 – 32. doi:10.1016/j.humov.2015.06.013

Grand, K. F., Daou, M., Lohse, K. R., & Miller, M. W. (2017). Investigating the Mechanisms Underlying the Effects of an Incidental Choice on Motor Learning. Journal of Motor Learning and Development, 5, 207 – 226. doi: 10.1123/jmld.2016-0041.

Hancock, G. R., Butler, M. S., & Fischman, M. G. (1995). On the problem of two-dimensional error scores: Measures and analyses of accuracy, bias, and consistency. Journal of Motor Behavior, 27, 241-250.

Hardy, L. & Parfitt, G. (1991) A catastrophe model of anxiety and performance. *British Journal of Psychology, 82,* 621-636. doi: 10.1111/j.2044-8295.1991.tb02391.x

Henry, F. M., & Rogers, D. E. (1960). Increased response latency for complicated movements and a "memory drum" theory of neuromotor reaction. Research Quarterly, 31, 448–458.

Hoogerheide, V., Loyens, S. M., & van Gog, T. (2014). Effects of creating video-based modeling examples on learning and transfer. *Learning and Instruction, 33,* 108-119. doi: 10.1016/j.learninstruc.2014.04.005

Hoogerheide, V., Deijkers, L., Loyens, S. M., Heijltjes, A., & van Gog, T. (2016). Gaining from explaining: Learning improves from explaining to fictitious others on video, not from writing to them. *Contemporary Educational Psychology, 44,* 95-106. doi: 10.1016/j.cedpsych.2016.02.005

Intrinsic Motivation Inventory (IMI). Retrieved from http://selfdeterminationtheory.org/intrinsic-motivation-inventory/

Johnson, K. R., Sulzer-Azaroff, B., & Maass, C. A. (1977). The effects of internal proctoring upon examination performance in a personalized instruction course. Journal of Personalized Instruction, 1, 113 - 117.

Kantak, S. S., & Winstein, C. J. (2012). Learning–performance distinction and memory processes for motor skills: A focused review and perspective. *Behavioural Brain Research,* 228, 219-231. doi: 10.1016/j.bbr.2011.11.028

Kirkpatrick, M., Wytch, R., Cole, G., & Helms, P. (1994). Is the objective assessment cerebral palsy gait reproducible? *Journal of Pediatric Orthopedics, 14*, 705-708.

Krakauer, J. W., & Shadmehr, R. (2006). Consolidation of motor memory. Trends in Neurosciences, 29, 58-64. doi: 10.1016/j.tins.2005.10.003

Lam, W. K., Maxwell, J. P., & Masters, R. S. W. (2009). Analogy versus explicit learning of a modified basketball shooting task: Performance and kinematic outcomes. *Journal of sports sciences, 27*, 179-191. doi: 10.1080/02640410802448764

Lam, W. K., Maxwell, J. P., & Masters, R. S. W. (2010). Cognitive demands of error processing associated with preparation and execution of a motor skill. *Consciousness and Cognition, 19*, 1058-1061. doi: j.concog.2008.11.005

Leiker, A. M., Bruzi, A. T., Miller, M. W., Nelson, M., Wegman, R., & Lohse, K. R. (2016). The effects of autonomous difficulty selection on engagement, motivation, and learning in a motion-controlled video game task. Human Movement Science, 49, 326 – 335. doi: 10.1016/j.humov.2016.08.005

Leiker, A. M., Miller, M., Brewer, L., Nelson, M., Siow, M., & Lohse, K. (2016). The relationship between engagement and neurophysiological measures of attention in motion-controlled video games: A randomized controlled trial. JMIR serious games, 4. doi: 10.2196/games.5460

Lohse, K. R., Sherwood, D. E., & Healy, A. F. (2011). Neuromuscular effects of shifting the focus of attention in a simple force production task. *Journal of Motor Behavior*, *43*, 173-184. doi: 10.1080/00222895.2011.555436

Lohse, K. R., Jones, M., Healy, A. F., & Sherwood, D. E. (2014). The role of attention in motor control. *Journal of Experimental Psychology: General*, *143*, 930-948.

doi: 10.1037/a0032817

Lohse, K. R., Boyd, L. A., & Hodges, N. J. (2016). Engaging environments enhance motor skill learning in a computer gaming task. Journal of Motor Behavior, 48, 172-182. doi: 10.1080/00222895.2015.1068158

Lohse, K. R., Buchanan, T. L., & Miller, M. W. (2016). Underpowered and overworked: Problems with data analysis in motor learning studies. Journal of Motor Learning and Development, 4, 37 – 58. doi: 10.1123/jmld.2015-0010

Masters, R. S. W. (1992). Knowledge nerves and know-how: The role of explicit versus implicit knowledge in the breakdown of a complex motor skill under pressure. British Journal of Psychology, 83, 343 – 358.

Masters, R. S. W. & Maxwell, J. P. (2008). The theory of reinvestment. *International Review of Sport and Exercise Psychology, 1*, 160-183. doi: 10.1080/17509840802287218

Maxwell, J. P., Masters, R. S. W., & Eves, F. F. (2000). From novice to no know-how: A longitudinal study of implicit motor learning. *Journal of Sports Sciences, 18*, 111-120. doi: 10.1080/026404100365180

McAuley, E., Duncan, T., & Tammen, V. V. (1989). Psychometric properties of the Intrinsic Motivation Inventory in a competitive sport setting: A confirmatory factor analysis. Research Quarterly for Exercise and Sport, 60, 48-58.
doi: 10.1080/02701367.1989.10607413

McKeachie, W. J., & Kulik, J. (1975). Effective college teaching. Review of Research in Education, 3, 165 – 209.

Meissner, C. A., Brigham, J. C., & Kelley, C. M. (2001). The influence of retrieval processes in verbal overshadowing. *Memory & Cognition,* 29, 176-186. doi: 10.3758/BF03195751

Melcher, J. M., & Schooler, J. W. (1996). The misremembrance of wines past: Verbal and perceptual expertise differentially mediate verbal overshadowing of taste memory. *Journal of memory and language*, *35*, 231-245. doi: 10.1006/jmla.1996.0013

Melcher, J. M., & Schooler, J. W. (2004). Perceptual and conceptual training mediate the verbal overshadowing effect in an unfamiliar domain. *Memory & Cognition*, *32*, 618-631. doi: 10.3758/BF03195853

Muellbacher, W., Ziemann, U., Wissel, J., Dang, N., Kofler, M., Facchini, S., ... & Hallett, M. (2002). Early consolidation in human primary motor cortex. *Nature*, *415*, 640-644. doi: 10.1038/nature712

Naveh-Benjamin, M., Kilb, A., & Fisher, T. (2006). Concurrent task effects on memory encoding and retrieval: Further support for an asymmetry. *Memory & Cognition*, *34*, 90-101. doi: 10.3758/BF03193389

O'Brien, H. L., & Toms, E. G. (2010). The development and evaluation of a survey to measure user engagement. Journal of the Association for Information Science and Technology, 61, 50-69. doi: 10.1002/asi.21229

Post, P. G., Aiken, C. A., Laughlin, D. D., & Fairbrother, J. T. (2016). Self-control over combined video feedback and modeling facilitates motor learning. Human Movement Science, 47, 49-59. doi: 10.1016/j.humov.2016.01.014

Preatoni, E., Hamill, J., Harrison, A. J., Hayes, K., Van Emmerik, R. E. A., Wilson, C., & Rodano, R. (2013). Movement variability and skills monitoring in sports, *Sports Biomechanics*, *12*, 69-92. doi: 10.1080/14763141.2012.738700

Robertson, E. M. (2009). From creation to consolidation: a novel framework for memory processing. *Plos Biology*, *7,* e1000019. doi: 10.1371/journal.pbio.1000019

Robertson, E. M., & Cohen, D. A. (2006). Understanding consolidation through the architecture of memories. *The Neuroscientist*, *12*, 261-271. doi: 10.1177/1073858406287935

Robertson, E. M., Press, D. Z., & Pascual-Leone, A. (2005). Off-line learning and the primary motor cortex. *Journal of Neuroscience*, *25*, 6372-6378. doi: 10.1523/JNEUROSCI.1851-05.2005

Rosenbaum, D. A., Carlson, R. A., & Gilmore, R. O. (2001). Acquisition of intellectual and perceptual-motor skills. *Annual Review of Psychology*, *52*, 453-470. doi: 10.1146/annurev.pysch.52.1.453

Salmoni, A. W., Schmidt, R. A., & Walter, C. B. (1984). Knowledge of results and motor learning: a review and critical reappraisal. *Psychological Bulletin*, *95*, 355-386. doi: 10.1037/0033-2909.95.3.355

Schooler, J. W. (2002). Verbalization produces a transfer inappropriate processing shift. *Applied Cognitive Psychology*, *16*, 989-997. doi: 10.1002/acp.930

Schooler, J. W., & Engstler-Schooler, T. Y. (1990). Verbal overshadowing of visual memories: Some things are better left unsaid. *Cognitive psychology*, *22*, 36-71. doi: 10.1016/0010-0285(90)90003-M

Shea, J. B., & Morgan, R. L. (1979). Contextual interference effects on the acquisition, retention, and transfer of a motor skill. *Journal of Experimental Psychology: Human Learning and Memory*, *5*, 179-187. doi: 10.1037/0278-7393.5.2.179

Siengsukon, C. F., & Boyd, L. A. (2009). Does sleep promote motor learning? Implications for physical rehabilitation. *Physical Therapy*, *89*, 370-383. doi: 10.2522/ptj.20080310

Sigrist, R., Rauter, G., Riener, R., & Wolf, P. (2013). Augmented visual, auditory, haptic, and multimodal feedback in motor learning: a review. *Psychonomic Bulletin & Review, 20*, 21-53. doi: 10.3758/s13423-012-0333-8

Stanley, J., & Krakauer, J. W. (2013). Motor skill depends on knowledge of facts. Frontiers in Human Neuroscience, 7, e1 – 11. doi: 10.3389/fnhum.2013.00503

Ste-Marie, D. M., Carter, M. J., Law, B., Vertes, K., & Smith, V. (2016). Self-controlled learning benefits: Exploring contributions of self-efficacy and intrinsic motivation via path analysis. Journal of Sports Sciences, 34, 1650 – 1656. doi: 10.1080/02640414.2015.1130236.

Timperman, E., & Miksza, P. (2017). Verbalization and musical memory in string players. *Musicae Scientiae,* 1-19. doi: 10.1177/1029864917727332.

Trempe, M., & Proteau, L. (2012). 11 Motor skill consolidation. *Skill acquisition in sport: Research, theory and practice* (pp. 192-210). New York: Routledge.

Walker, M. P., Brakefield, T., Hobson, J. A., & Stickgold, R. (2003). Dissociable stages of human memory consolidation and reconsolidation. *Nature, 425*, 616-620. doi: 10.1038/nature01930

Walker, M. P., & Stickgold, R. (2004). Sleep-dependent learning and memory consolidation. *Neuron, 44*, 121-133. doi: 10.1016/j.neuron.2004.08.031

Whittle, M. W. (1996). Clinical gait analysis: A review. *Human Movement Science*, 15, 369–387. doi: 10.1016/0167-9457(96)00006-1

Wise, R. A. (2004). Dopamine, learning, and motivation. Nature Reviews Neuroscience, 5, 1 – 12. doi: 10.1038/nrn1406

Wulf, G., Dufek, J. S., Lozano, L., & Pettigrew, C. (2010). Increased jump height and reduced EMG activity with an external focus. *Human Movement Science, 29*, 440-448. doi: 10.1016/j.humov.2009.11.008

Wulf, G., Höß, M., & Prinz, W. (1998). Instructions for motor learning: Differential effects of internal versus external focus of attention. *Journal of motor behavior*, *30*(2), 169-179. doi: 10.1080/00222899809601334

Wulf, G., & Lewthwaite, R. (2016). Optimizing performance through intrinsic motivation and attention for learning: The OPTIMAL theory of motor learning. Psychonomic bulletin & review, 23, 1382-1414. doi: 10.3758/s13423-015-0999-9

Zachry, T., Wulf, G., Mercer, J., & Bezodis, N. (2005). Increased movement accuracy and reduced EMG activity as the result of adopting an external focus of attention. *Brain Research Bulletin*, *67*, 304-309. doi: 10.1016/j.brainresbull.2005.06.035

Appendix A

Demographics

1. **Please report your current age.**

2. **Please report your dominant hand.**

Right	Left	Both

3. **Please report your gender.**

Male	Female

4. **Please indicate how many years you have played organized basketball.**

0 years	1-3 years	4 years	5+ years

5. **Please indicate the highest level of basketball that you have played.**

No experience	Youth League	Recreation League	High School	Intramural/ Club	College	Professional

<u>Presented only to skilled participants:</u>

6. **Please indicate your estimated free throw shooting percentage. (How many shots do you think you would make out of 100?)**

Appendix B

Participant ID:

Please describe in as much detail as possible the free throw shooting task you just completed. You should attempt to describe the task such that someone else could execute the task based on your description.

Appendix C

Participant ID:

Please describe in as much detail as possible the weather outside today. You should attempt to describe the weather such that someone else could envision the weather based on your description.

Appendix D

Verbal Experience Survey

General Verbal Experience:

1) Do you have experience with providing instruction to others (e.g., personal training, coaching, teaching)?

2) Please describe your experience with providing instruction to others (e.g., personal training, coaching, teaching).

3) Please indicate the quantity of this experience (i.e., years of experience).

0-1 years	2-4 years	5-7 years	8-10 years	Over 10 years

Task Specific Verbalization:

1) Do you have experience providing basketball instruction to others (e.g., providing individual skill lessons, summer camp counselor, youth league coach)?

2) Please describe your experience providing basketball instruction to others (e.g., providing individual skill lessons, summer basketball camp counselor, youth league coach).

3) Please indicate the quantity of this basketball instruction experience (i.e., years of experience).

0-1 years	2-4 years	5-7 years	8-10 years	Over 10 years

Appendix E

Free Recall

Please report in as much detail as possible any rules, techniques, or methods that you used to complete the task.