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Does learning a skill with the expectation of teaching it impair the skill’s execution under psychological pressure if the skill is learned with analogy instructions?

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Abstract

Objective: Having learners practice a motor skill with the expectation of teaching it (versus an expectation of being tested on it) has been revealed to enhance skill learning. However, this improvement in skill performance is lost when the skill must be performed under psychological pressure due to ‘choking under pressure.’ The present study will investigate whether this choking effect is caused by an accrual of declarative knowledge during skill practice and could be prevented if a technique (analogy instructions) to minimize the accrual of declarative knowledge during practice is employed.

Design: We will use a 2 (Expectation: teach/test) x 2 (Instruction: analogy/explicit) x 2 (Posttest: high-pressure/low-pressure) mixed-factor design, with repeated measures on the last factor.

Methods: A minimum of 148 participants will be quasi-randomly assigned (based on sex) to one of four groups. Participants in the teach/analogy and teach/explicit groups will practice golf putting with the expectation of teaching putting to another participant, and analogy instructions or explicit instructions, respectively. Participants in the test/analogy and test/explicit groups will practice golf putting with the expectation of being tested on their putting, and analogy instructions or explicit instructions, respectively. The next day all participants will complete low- and high-pressure putting posttests, with their putting accuracy serving as the dependent variable.

Keywords: expecting to teach; motor learning; choking under pressure; implicit learning; reinvestment theory
Introduction

Determining practice conditions that enhance motor learning is important to facilitate motor behavior. The value of practice conditions that enhance motor learning depends on whether the learning benefits are transferred to novel contexts (Schmidt & Lee, 2019), particularly those likely to be encountered while performing the skill and those with high importance. For example, a practice condition may improve a learner’s encoding and consolidation of a skill, however the practice condition’s efficacy is limited if the skill cannot be successfully retrieved and performed in high-stakes environments, under psychological pressure.

As many skills must be performed in high-stakes environments, such as sports competition, it is crucial to determine practice conditions that enhance learning and preserve learning benefits under psychological pressure. Recently, Daou, Hutchison, et al. (2019) revealed that practicing a motor skill with the expectation of teaching it to another person loses its benefit when the learned skill is performed under psychological pressure. Therefore, the purpose of the present study is to determine whether the expecting to teach approach can be modified to preserve its learning advantage, and, in so doing, shed light on the mechanisms underlying the loss of the benefit under psychological pressure.

Some initial research of the expecting to teach approach showed that when participants study academic information with the expectation of teaching it, they exhibit augmented learning (Bargh & Schul, 1980; Benware & Deci, 1984; Nestojko, Bui, Kornell, & Bjork; 2014). However, other studies failed to reveal this effect (Renkl, 1995; Ross & Di Vesta, 1976) or demonstrated ambiguous learning effects (enhancements on short-term, but not long-term, test performance; Fiorella & Mayer, 2013; Fiorella & Mayer, 2014). Daou, Buchanan, Lindsey, Lohse, and Miller (2016) conducted the first investigation into whether expecting to teach
enhances learning of motor skills, which rely more heavily on procedural knowledge than
academic information does (Rosenbaum, Carlson, & Gilmore, 2001). Daou, Buchanan et al.
observed having learners practice and study a motor skill with the expectation of teaching it to
another person enhanced skill learning in comparison to having learners practice and study a skill
with the expectation of being tested, and this effect has been replicated several times (Daou,
Hutchison et al., 2019; Daou, Lohse, & Miller, 2016; Daou, Lohse, & Miller, 2018; Daou,
Rhoads, Jacobs, Lohse, & Miller, 2019). Although research has failed to reveal the mechanisms
underlying the learning benefit of expecting to teach, studies have consistently shown that the
learning advantage occurs concomitant to large gains in declarative knowledge about the learned
skill (Daou et al., 2018; Daou, Buchanan et al., 2016; Daou, Hutchison et al., 2019; Daou, Lohse
et al., 2016; Daou, Rhoads et al., 2019). As motor skills acquired with large gains in declarative
knowledge are highly susceptible to decrement under psychological pressure (Hardy, Mullen, &
Jones, 1996; Koedijker, Oudejans, & Beek, 2007; Lam, Maxwell, & Masters, 2009a, 2009b;
Liao & Masters, 2001; Masters, 1992), it was unsurprising that Daou, Hutchison et al. (2019)
revealed that the expecting to teach benefit vanished under psychological pressure, due to
participants who practiced with the expectation of teaching ‘choking’ in a high-pressure posttest.
Daou, Hutchison et al. concluded that participants who practiced with the expectation of teaching
choked likely due to their accrual of declarative knowledge while practicing, however the
authors were unable to provide evidence to support this conclusion. Nonetheless, their
conclusion is consistent with the reinvestment theory (Masters & Maxwell, 2008), which
contains that dispositional and situational factors, such as psychological pressure, trigger
individuals to use declarative knowledge acquired earlier in learning to attempt to consciously
monitor and control practiced movements. This focus of attention on movement, ironically,
impairs performance (Wulf, 2013). Critically, learners who accrue more declarative knowledge
during skill practice are more likely to exhibit performance decrement under pressure, because
they have more declarative knowledge to ‘reinvest’ in motor control.

A corollary of reinvestment theory is that motor skills learned relatively implicitly, with
minimal gains in declarative knowledge, should be resilient to psychological pressure (Maxwell
& Masters, 2008), and research generally supports this proposition (Hardy et al., 1996; Koedijker
et al., 2007; Lam et al., 2009a, 2009b; Liao & Masters, 2001; Masters, 1992). An effective
strategy to encourage implicit motor learning is to provide learners with an analogy about how to
perform the skill rather than explicit rules, strategies, and techniques regarding skill performance
(Lam et al., 2009a, 2009b; Liao & Masters, 2001). With an analogy, declarative knowledge
about multiple rules is reduced into a single, comprehensive rule. For example, Lam et al.
(2009a) instructed participants in an analogy practice condition to “shoot as if you are trying to
put cookies into a cookie jar on a high shelf” (p.344) while practicing a basketball free throw,
whereas participants in an explicit practice condition group were instructed to follow a list of
eight specific rules while practicing. Participants in both conditions performed low- and high-
pressure posttests and were asked to recall free throw shooting rules. Participants who practiced
in the analogy condition reported fewer rules, indicative of more implicit learning, and
performed equally well under low- and high-pressure posttests, whereas the explicit condition
group performed worse under the high-pressure than the low-pressure posttest (i.e., they choked
under pressure).

Since the expecting to teach approach is a practical way to enhance motor learning, it
would be beneficial to determine a way to maintain the learning advantage under psychological
pressure. As Daou, Hutchison et al. (2019) attributed the choking effect exhibited by participants
who practiced with the expectation of teaching to the accrual of declarative knowledge, a promising means to prevent the choking effect is to promote implicit learning by instructing learners to use an analogy to practice a motor skill rather than a list of rules. Indeed, Daou, Hutchison et al. asked participants to study an instruction booklet containing a list of rules to follow while practicing the skill, likely prompting learners who expected to teach to attend to the rules so that they could disseminate them to another person; an analogy instruction would reduce this attention to rules. Importantly, it is unlikely that minimizing the accrual of declarative knowledge by learners who expect to teach will reduce their learning advantage, as declarative knowledge has been found to not significantly relate to motor learning in an expecting to teach paradigm (Daou, Buchanan et al., 2016). Even with analogy instructions, it is possible that learners who expect to teach could accrue greater declarative knowledge by engaging in more learning activities, such as discovery learning and hypothesis testing, than those who expect to test. Nonetheless, the practical question of whether the choking effect associated with the expecting to teach approach is prevented by using analogy instructions can still be answered.

The present study will investigate whether having learners practice a motor skill with the expectation of teaching it and using an analogy to practice it preserves the learning advantage of expecting to teach under psychological pressure. Specifically, participants will be assigned to four groups. One group will practice with the expectation of teaching a motor skill and will receive an analogy instruction (teach/analogy); one group will practice with the expectation of teaching the skill and will receive specific explicit rules related to the skill (teach/explicit); one group will practice with the expectation of being tested on the skill and will receive an analogy instruction (test/analogy); and one group will practice with the expectation of being tested on the skill and will receive explicit rules about the skill (test/explicit). One day after skill practice (6
blocks of 10 putts on a single day), all groups will perform low- and high-pressure posttests.

With this 2 (Expectation: teach/test) x 2 (Instruction: analogy/explicit) x 2 (Posttest: low-pressure/high-pressure) design, we predict a 3-way interaction. In particular, we predict participants in the teach groups will exhibit superior posttest performance on the low-pressure posttest relative to their test group counterparts, but the effect of expecting to teach on performance in the high-pressure posttest will be moderated by instruction. Specifically, expecting to teach will be advantageous for participants who trained with analogy instructions, but not for participants who trained with explicit instructions. This result would indicate that practicing a motor skill with the expectation of teaching and an analogy imparts a learning advantage that can be manifested in a high-stakes environment. Crucially, this result would also strongly suggest that the reason learners who practice with the expectation of teaching choke under pressure is due to their accrual of declarative knowledge while practicing, thus addressing a shortcoming of Daou, Hutchison et al. (2019). However, if the choking effect associated with the expecting to teach approach is not prevented by employing analogy instructions, this would not eliminate the possibility that the choking effect is caused by the accrual of declarative knowledge. Specifically, learners who practice with the expectation of teaching may accrue a relatively large amount of declarative knowledge despite receiving analogy instructions and use this knowledge during the high-pressure posttest. Importantly, we can use free recall tests of declarative knowledge use during the high-pressure posttest to shed light on this possibility.

Methods

Sample
Men and women between the ages of 18 and 30 years will participate in the study and may receive course credit for participation. This demographic is convenient to the investigators and has been used in similar past studies (e.g., Daou, Hutchison et al., 2019). Participants must have putted (anything from playing miniature golf to playing 18 holes on a standard golf course) between one and thirty times in their lifetime and not more than twenty times in the past year. Participants with this amount of experience were most sensitive to the expecting to teach and pressure manipulations in past experiments (Daou, Hutchison et al., 2019). Since these participants have at least minimal putting experience, the instructions and practice likely afford them an opportunity to improve their skill by internalizing the analogy/explicit rules rather than guiding them through a completely novel movement, and participants who expect to teach may especially take advantage of this opportunity in preparation for their teaching episode.

Participants must be free from physical illness, injury, or disability that could make putting difficult. Participants will be asked to refrain from alcohol/drug consumption within 24 h of both days of the study, caffeine consumption within 3 h of both days of the study, and to get a good amount of sleep the night before each day of the study while also trying to get the same amount of sleep each night.

**Sample Size Calculation**

Since our study is novel, we are unable to estimate the effect size for an Expectation x Instruction x Posttest interaction. Thus, we are powering our study to detect an Expectation x Posttest interaction, which we estimate to be medium ($\eta^2_p = .093$) in our sample, based on the effect size observed in our past research among participants who meet the inclusion and outlier criteria for the present study (Daou, Hutchison et al., 2019). We are powering the study to detect this interaction because the given instructions to the participants should moderate it to a
relatively large degree, based on past research investigating the effects of instructions on posttest performance (Lam et al., 2009a; Lia & Masters, 2001). To do the power analyses, we used G*Power 3.1.9.2 (Faul, Erdfelder, Lang, & Buchner, 2007) and entered the aforementioned effect size (as in SPSS) along with the following parameters: $\alpha = .05$, power = .9, number of groups = 4, number of measurements = 2, and nonsphericity correction $\varepsilon = 1$ into an ANOVA with repeated-measures testing for a within-between interaction. The required sample size was determined to be 148, but we will collect data from 164 participants to account for data loss (e.g., participant dropout, problems with data entry). The final sample submitted to statistical analysis will include at least 148 participants, and we will ensure equal $n$ in each group (by recruiting additional participants, if necessary). In terms of data exclusion, we will only exclude participants if there is a technical error in recording their putts at the posttest or if one of their average low- or high-pressure posttest radial error values has a $z$-score > 3.00. In the latter case, we will report the primary statistical results with and without the inclusion of the participant.

**Task**

All participants will use a standard (88.9 cm) golf putter to putt a standard golf ball from a starting position indicated by a 5 cm line painted in white washable paint on an artificial grass surface to a target cross (+) comprised of two 10.8 cm lines painted in white washable paint and located 300 cm away from the starting position (Daou, Hutchison et al., 2019). Participants’ objective will be to make the ball stop as close to the center of the target as possible.

**Procedure**

All participants will complete the experiment individually. After consenting to the experiment, participants will complete a demographic questionnaire asking their sex, age, putting experience, any illness, injury, or disability that could make putting difficult, whether they
consumed alcohol/drugs within the last 24 h, whether they consumed caffeine within the last 3 h, and how long they slept the previous night (see Appendix A). Once the experimenter confirms that the participants meet the inclusion criteria (see Sample section), participants will complete the Movement Specific Reinvestment Scale (Masters, Eves, & Maxwell, 2005). The Movement Specific Reinvestment Scale is frequently used to examine individual tendencies to reinvest in motor control (Huffman, Horslen, Carpenter, & Adkin, 2009; Kal, van der Kamp, Houdijk, Groet, Bennekom, & Sherder, 2015; Klämpfl, Lobinger, & Raab, 2013; Malhorta, Poolton, Wilson, Ngo, & Masters, 2012; Vine, Moore, Cooke, Ring, & Wilson, 2013) and possesses good psychometric properties (Masters et al., 2005). The Movement Specific Reinvestment Scale consists of the conscious motor processing and movement self-consciousness subscales, which ask participants to indicate how strongly they agree with statements related to their tendency to attempt to control their movements and monitor their movements, respectively. Participants will respond on a 6-point scale anchored by "strongly disagree" and "strongly agree”. (See Appendix B.) The Movement Specific Reinvestment Scale data may be used to explore whether individual tendencies toward reinvestment explain residual variance in the model, thus increasing the amount of variance explained by the other factors in the model, as was the case in Daou, Hutchison et al. (2019). Next, participants will put a physiological monitoring device around their chest (BioHarness 3.0, Zephyr Technology, Annapolis, MD) to get used to wearing it, which they will be asked to do the following day as well. Physiological data such as heart rate and heart rate variability may be extracted from the device for supplemental/exploratory analyses.

**Pretest.** After completing the demographic questionnaire, participants will perform the pretest phase, which will consist of one block of ten putts.
**Practice.** After pretest, participants will be quasi-randomly assigned (based on sex) to the teach/analogy, teach/explicit, test/analogy, or test/explicit groups, and the corresponding expectation manipulation will occur. Participants in the teach groups will be told, “Tomorrow you will teach another participant how to putt,” and participants in the test group will be told, “Tomorrow you will be tested on your putting skills.” Next, the instruction manipulation will occur. Participants in the analogy groups will read the following: “Keep your body still like a grandfather clock and use your arms the same way that the pendulum of the clock operates. (A pendulum is a weight hung from a fixed point so that it can swing freely backward and forward. [See diagram on the right].)” (Vine, Moore, Cooke, Ring, & Wilson, 2013). Participants in the explicit groups will read the following:

1. Take your stance with your legs shoulder-width apart.
2. Set your position so that your head is directly above the ball looking down.
3. Keep your clubhead square to the ball.
4. Allow your arms and shoulders to remain loose.
5. In the putting action, your arms should swing freely backward and forward from your body, which should be still. Make sure that you accelerate through the ball.
6. After contact, follow through but keep your head still and facing down"

(adapted from Vine et al., 2013). (See Appendix C for the instruction sheets participants will read.)

Participants in all groups will have 2 min to read and study the analogy or explicit instructions (Daou, Hutchison et al.). Next, participants will complete the practice phase by performing six blocks of ten putts, taking a 1 min break between each block (participants will sit
in a chair during the breaks). When participants stop practicing, they will complete the Intrinsic
Motivation Inventory (IMI; Ryan, 1982; see Appendix D). IMI data may be used for exploratory
analyses.

**Posttests.** Twenty-two to twenty-six hours after completing pretest and practice,
participants will return to complete the experiment. Participants will respond to the
demographics questionnaire questions about drug/alcohol use, caffeine use, and previous night
sleep. Participants in the teach groups will be told, “The participant who you were going to teach
did not show up today, so you will actually be tested on your putting instead.” Then, participants
will put on the physiological recording device. Next, they will complete low-pressure and high-
pressure tests in counterbalanced order. For the low-pressure test, the experimenter will tell
participants, “In this set of ten putts, your goal is to make the ball stop as close to the center of
the target as possible. Please, try to do the best you can.” For the high-pressure test, the
experimenter will tell participants, “In the next set of ten putts, you will be recorded and
critically analyzed by a golf expert who will give you a grade.” The experimenter will affix an
iPad to the edge of a table, approximately 45° to the right and 225 cm in front of participants.
The iPad’s screen will face participants so that they can see themselves being recorded. After the
iPad is set-up, the experimenter will tell participants, “The combination of the golf expert grade
and your performance during this set will allow you to compete against the rest of the
participants for the 1\textsuperscript{st} prize of $50, 2\textsuperscript{nd} prize of $40, 3\textsuperscript{rd} prize of $30, 4\textsuperscript{th} prize of $20, and 5\textsuperscript{th}
prize of $10. In summary, you will be putting for money.” As the experimenter explains the
rewards, he will take an envelope from a cabinet, pull money from it, and display the potential
monetary rewards to participants, after which he will place the money on a 91 cm high
countertop, approximately 30° to the left and 100 cm in front of participants. Our pressure
manipulation involves two types of pressure revealed to elicit choking in previous studies:

- performance-contingent outcomes and monitoring by others (e.g., DeCaro et al., 2011).

After each posttest, participants will complete the Revised Competitive State Anxiety Inventory-2 (Cox, Martens, & Russell, 2003) to determine manipulation efficacy. The Revised Competitive State Anxiety Inventory-2 is frequently used to assess anxiety in motor skill studies (Allsop & Gray, 2014; Elliot, Polman, & Taylor, 2014; Kinrade, Jackson, & Ashford, 2015; Kuan, Morris, Kueh, & Terry, 2018; Mullen, Jones, Oliver, & Hardy, 2016) and possesses good psychometric properties (Cox et al., 2003). The cognitive and somatic anxiety subscales are of interest since the pressure manipulation is intended to modulate anxiety (nonetheless, participants will complete the self-confidence subscale as well) (Jackson, Ashford, & Norsworthy, 2006). The cognitive and somatic anxiety subscale items ask participants to report how much they are currently feeling various indicators of anxiety. All responses will be made by reporting a number between 0 and 100 on a scale with “not at all” corresponding to 0, followed by “somewhat”, then “moderately so”, and finally “very much so”, which corresponds to 100. (See Appendix E.)

Data Processing
**Putting.** Putts will be recorded with an iPad mounted to the ceiling above the target cross. We plan to measure the ball’s location relative to the target using a custom-developed program written in the National Instruments LabVIEW graphical programming language by Neumann and Thomas (2008). However, we have not been able to verify if this will be feasible in our laboratory because of work restrictions caused by the COVID-19 pandemic. If we are unable to use the LabVIEW program, then we will use Dartfish Live 9.0® motion analysis software. We have compared the output from these two programs when measuring a beanbag’s location relative to a target and observed nearly perfect correlations (e.g., \( r_s \geq .995 \)).

Putting accuracy will be indexed by recording radial error as recommended by Hancock, Butler, and Fischman (1995): \( \text{Radial Error} = (x^2 + y^2)^{1/2} \), where \( x \) and \( y \) represent the magnitude of error along the respective axes (i.e., how far away from the target cross the ball stops in the horizontal and vertical directions). Precision will be indexed by recording bivariate variable error as recommended by Hancock et al.: \( \text{Bivariate Variable Error} = \left\{ \left( \frac{1}{k} \right) \sum_{i=1}^{k} [(x_i - x_c)^2 + (y_i - y_c)^2] \right\}^{1/2} \), where \( k \) = trials in a block and \( (x, y) = \) centroid along the given axis (\( x \) or \( y \)) for that block. Radial error and bivariate variable error will be calculated over pretest (10 putts) and may be used as covariates in exploratory analyses. Crucially, we are not using either as an a priori covariate. Radial error and bivariate variable error will be calculated for the first, third, and sixth blocks of the practice phase to get a glimpse into improvement during performance without overly slowing data processing. To assess motor learning and choking under pressure, radial error and bivariate variable error will be calculated for the low- and high-pressure posttests.

**Self-reported anxiety.** Chronbach’s \( \alpha \) will be calculated to determine the reliability of the Competitive State Anxiety Inventory-2 cognitive and somatic anxiety subscales for the low- and high-pressure posttests. If reliability is good (\( \alpha \geq .700 \)), then items will be averaged within
the subscales. Next, a Pearson’s correlation coefficient will be calculated between the cognitive and somatic anxiety subscales for each posttest, and if \( r \geq .500 \), the subscales will be averaged together for each posttest. Otherwise, the subscales will not be combined for statistical analysis.

If the subscales do not exhibit good reliability, then physiological data will serve as the primary measure of anxiety. Specifically, Bioharness data will be extracted and analyzed using Omnisense software (Zephyr Technology, Annapolis, MD). Heart rate will be averaged from the time participants were read test instructions until they completed the test for the low- and high-pressure posttest. Heart rate variability (root mean square of successive differences and high frequency [0.150 – 0.400 Hz]) will also be assessed for these same periods.

**Free recall.** Two indices of declarative knowledge use will be extracted from participants’ responses on the free recall test. First, ‘all concepts’ will refer to the number of statements about a concept (rule) (e.g., “I held my left hand over above my right”), ignoring statements irrelevant to technical performance (e.g., “I was told to putt ten times to the target”). Second, hypothesis testing will refer to statements indicating that the participant had tested hypotheses related to their putting stroke (e.g., “I adjusted the swing path of the putter after each missed ball” or “I tried to keep my head still throughout my putting stroke”). That is, hypothesis testing statements will be those that indicate the participant made a prediction about the relationship between their putting movement and putt outcome (Maxwell et al., 2001). We will ignore retrospective statements (e.g., "I held my left hand above my right" or "My feet were shoulder-width apart") that may not have been used or thought about while putting, and we also will ignore statements irrelevant to technical performance.

**Movement Specific Reinvestment Scale.** Chronbach’s \( \alpha \) will be calculated to determine the reliability of the Movement Specific Reinvestment Scale. Daou, Hutchison et al. (2019)
found the Movement Specific Reinvestment Scale had good reliability when all items were considered as one scale rather than dividing the Movement Specific Reinvestment Scale into its movement self-consciousness and conscious motor processing subscales. Further, we do not expect that either subscale should account for more residual variance in our data than the other subscale. Thus, we will assess the reliability across all items and sum them into a single scale if $\alpha \geq .700$. If the Movement Specific Reinvestment Scale has an $\alpha < .700$, then we will not consider conducting exploratory analyses with it.

**Statistical Analysis**

We will conduct a 2 (Expectation) x 2 (Instruction) ANOVA with pretest radial error serving as the dependent variable. If the $\eta^2_p$s of the main effects or interaction $\geq .0099$ (Richardson, 2011), then pretest putting performance will be included as a covariate in all subsequent analyses involving putting performance.

Our primary analysis of interest will be a 2 (Expectation) x 2 (Instruction) x 2 (Posttest) mixed-factor ANOVA with repeated-measures on the last factor, and radial error serving as the dependent variable. This follows because radial error (accuracy) was more sensitive to the Expectation x Posttest interaction observed by Daou, Hutchison et al. (2019) and reflects the objective of the putting task (accuracy with respect to target). Nonetheless, we will conduct a secondary analysis using the same model with bivariate variable error serving as the dependent variable. We predict an Expectation x Instruction x Posttest interaction, which will follow up with separate 2 (Expectation) x 2 (Instruction) ANOVAs for the low- and high-pressure posttests. For the low-pressure posttest, we predict a main effect of expectation, such that the teach groups exhibit lower radial error (greater accuracy) than the test groups. For the high-pressure posttest, we predict an Expectation x Instruction interaction. We will follow up this
interaction with separate one-tailed $t$-tests (expectation) for the analogy and explicit groups. For the analogy groups, we predict a significant effect of expectation, such that the teach/analogy group exhibits lower radial error than the test/analogy group. For the explicit groups, we do not predict a significant effect of expectation. Movement Specific Reinvestment Scale score and/or pretest error scores may be used as covariates/between-subjects factors in exploratory analyses of putting data.

To assess practice performance, we will conduct a 2 (Expectation) x 2 (Instruction) x 3 (Block: 1/3/6) mixed-factor ANOVA with repeated-measures on the last factor separately for radial error and bivariate variable error. We predict a main effect of block, such that participants exhibit a linear increase in radial error and bivariate variable error as a function of block (Daou, Hutchison et al., 2019).

To assess anxiety, we will conduct a 2 (Expectation) x 2 (Instruction) x 2 (Posttest) mixed-factor ANOVA, with repeated-measures on the last factor and the total Revised Competitive State Anxiety Inventory-2 score serving as the dependent variable. If cognitive and somatic anxiety are not strongly correlated (see Self-reported anxiety section), then we will conduct a MANOVA instead, with the Revised Competitive State Anxiety Inventory-2 cognitive and somatic anxiety subscales serving as dependent variables. We predict a main effect of posttest, with higher anxiety occurring on the high-pressure posttest. If heart rate and heart rate variability need to be used to assess anxiety, they will be submitted to a 2 (Expectation) x 2 (Instruction) x 2 (Posttest) MANOVA.

To assess declarative knowledge use during high-pressure posttest, a 2 (Expectation) x 2 (Instruction) MANOVA will be conducted with all concepts and hypothesis testing free recall scores serving as the dependent variables. We predict an Expectation x Instruction interaction for
all concepts (Daou, Hutchison et al., 2019). We will then conduct separate one-tailed $t$-tests (expectation) for the analogy and explicit groups. For the explicit groups, we predict that teach participants will recall using more concepts than test participants. We do not predict an effect for the analogy groups.

The mixed-factor ANOVAs should be robust to violations of homogeneity of variance since we will ensure equal $n$s. For the practice performance ANOVA, which has three levels of the repeated-measure, we will apply the Greenhouse-Geisser correction if sphericity is violated. Although ANOVAs should be robust to violations of normality, the one-tailed $t$-tests that follow them may not be (Field, 2012). Thus, we will test for violations of normality using the Shapiro-Wilk test and Q-Q plots, both of which we will consider when determining whether the data are non-normal. Since data from similar past research (Daou, Hutchison et al., 2019) suggests a positive skew is possible, a natural log transformation will be applied to data exhibiting a non-normal distribution. To test MANOVA assumptions, a Box test will be used to assess homogeneity of covariance matrices, and a Shapiro test will be used to determine multivariate normality. If these tests are failed, then multiple ANOVAs will be conducted instead of MANOVAs.

We will conduct sensitivity analyses excluding participants who consumed alcohol/drugs within 24 h of the first or second day of the experiment, caffeine within 3 h of the first or second day of the experiment, or report differences in sleep duration $>2$ h between the night before the first and second day of the experiment. If the statistical significance of results of the primary analysis does not change when excluding these participants, then they will remain in the dataset. If the statistical significance of results of the primary analysis does change when excluding these
participants, then they will be removed, and we will recruit additional participants to ensure $N = 148$ with equal $ns$ per group.

We have received ethics board approval for a similar protocol (Daou, Hutchison et al., 2019) in the past, and thus anticipate an expedited ethics board approval process. We plan to begin data collection in the fall 2020 semester, in which we expect to collect data from 20 participants. We expect to collect data from 40 participants in the spring 2021 semester and 20 participants in the summer 2021 semester. We expect to collect data from 40 participants per semester in the fall 2021 and spring 2022 semesters. We plan to finish data collection in the summer 2022 semester, but our data collection forecast is uncertain given the COVID-19 pandemic. We plan to process data as it is collected, so we expect to conduct statistical analyses and write as well as submit Stage 2 of the manuscript in the fall 2022 semester.
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Appendix A

Demographic Questionnaire

Please respond to the following questions about your sex and age:

1. What is your sex? ________

2. What is your age (years)? ________

Please respond to the following questions about your golf experience. This includes any form of golf (e.g., playing 18 holes on a standard golf course, playing miniature golf, etc...)

3. Please estimate how many times in your life have you played golf, as defined above (CIRCLE ONE)?
   - Never
   - 1 – 10 times
   - 11 – 20 times
   - 21 – 30 times
   - 31 – 40 times
   - 41 – 50 times
   - 51 – 60 times
   - 61 – 70 times
   - 71 – 80 times
   - 81 – 90 times
   - 91 – 100 times
   - More than 100 times

4. Please estimate how many times in the past year you played golf, as defined above (CIRCLE ONE)?
   - Never
   - 1 – 10 times
   - 11 – 20 times
   - 21 – 30 times
   - More than 30 times

Please respond to the following questions about your health, alcohol/drug use, caffeine use, and last night’s sleep.

5. Do you have any illness, injury, or disability that could make putting difficult? If so, please describe below.
6. Have you consumed alcohol or drugs within the past 24 hours? (CIRCLE ONE)? Yes  No

7. Have you consumed caffeine in the last 3 hours? (CIRCLE ONE)? Yes  No

8. Please indicate how long you slept last night: _____ hours _____ minutes
Appendix B

Movement Specific Reinvestment Scale

Below are a number of statements about your movements. The possible answers go from ‘strongly agree’ to ‘strongly disagree’. There are no right or wrong answers so circle the answer that best describes how you feel for each question.

1. I rarely forget the times when my movements have failed me, however slight the failure.

| Strongly Disagree | Moderately Disagree | Weakly Disagree | Weakly Agree | Moderately Agree | Strongly Agree |
|-------------------|---------------------|----------------|-------------|------------------|---------------|
|                   |                     |                |             |                  |               |

2. I’m always trying to figure out why my actions failed.

| Strongly Disagree | Moderately Disagree | Weakly Disagree | Weakly Agree | Moderately Agree | Strongly Agree |
|-------------------|---------------------|----------------|-------------|------------------|---------------|
|                   |                     |                |             |                  |               |

3. I reflect about my movement a lot.

| Strongly Disagree | Moderately Disagree | Weakly Disagree | Weakly Agree | Moderately Agree | Strongly Agree |
|-------------------|---------------------|----------------|-------------|------------------|---------------|
|                   |                     |                |             |                  |               |

4. I am always trying to think about my movements when I carry them out.

| Strongly Disagree | Moderately Disagree | Weakly Disagree | Weakly Agree | Moderately Agree | Strongly Agree |
|-------------------|---------------------|----------------|-------------|------------------|---------------|
|                   |                     |                |             |                  |               |

5. I’m self conscious about the way I look when I am moving.

| Strongly Disagree | Moderately Disagree | Weakly Disagree | Weakly Agree | Moderately Agree | Strongly Agree |
|-------------------|---------------------|----------------|-------------|------------------|---------------|
|                   |                     |                |             |                  |               |

6. I sometimes have the feeling that I’m watching myself move.

| Strongly Disagree | Moderately Disagree | Weakly Disagree | Weakly Agree | Moderately Agree | Strongly Agree |
|-------------------|---------------------|----------------|-------------|------------------|---------------|
|                   |                     |                |             |                  |               |

7. I’m aware of the way my mind and body works when I am carrying out a movement.

| Strongly Disagree | Moderately Disagree | Weakly Disagree | Weakly Agree | Moderately Agree | Strongly Agree |
|-------------------|---------------------|----------------|-------------|------------------|---------------|
|                   |                     |                |             |                  |               |
8. I’m concerned about my style of moving.

- Strongly disagree
- Moderately disagree
- Weakly disagree
- Weakly agree
- Moderately agree
- Strongly agree

9. If I see my reflection in a shop window, I will examine my movements.

- Strongly disagree
- Moderately disagree
- Weakly disagree
- Weakly agree
- Moderately agree
- Strongly agree

10. I am concerned about what people think about me when I am moving.

- Strongly disagree
- Moderately disagree
- Weakly disagree
- Weakly agree
- Moderately agree
- Strongly agree
Appendix C

Keep your body still like a grandfather clock and use your arms the same way that the pendulum of the clock operates. (A pendulum is a weight hung from a fixed point so that it can swing freely backward and forward. [See diagram on the right].)

Analogy Group Instructions

Explicit Group Instructions

1. Take your stance with your legs shoulder-width apart.
2. Set your position so that your head is directly above the ball looking down.
3. Keep your clubhead square to the ball.
4. Allow your arms and shoulders to remain loose.
5. In the putting action, your arms should swing freely backward and forward from your body, which should be still. Make sure that you accelerate through the ball.
6. After contact, follow through but keep your head still and facing down.
Appendix D

Intrinsic Motivation Inventory

For each of the following statements, please indicate how true it is for you, using the scale below each item. PLEASE MAKE YOUR RESPONSES IN REFERENCE TO THE PRACTICE SESSION (NOT THE PUTTING THAT OCCURRED BEFORE THE PRACTICE SESSION).

1. I enjoyed doing this activity very much

   1 2 3 4 5 6 7  
   not at all true somewhat true very true

2. I put a lot of effort into this activity

   1 2 3 4 5 6 7  
   not at all true somewhat true very true

3. It was important to me to do well at this activity

   1 2 3 4 5 6 7  
   not at all true somewhat true very true

4. I was anxious while working on this activity

   1 2 3 4 5 6 7  
   not at all true somewhat true very true
588 5. I think this is an important activity

| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|
| not at all true | somewhat true | very true |

589

590

591 6. I think I am pretty good at this activity

| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|
| not at all true | somewhat true | very true |

592

593 7. I felt like it was not my own choice to do this activity

| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|
| not at all true | somewhat true | very true |

594

595 8. I did not feel nervous at all while doing this activity

| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|
| not at all true | somewhat true | very true |

596

597 9. I didn’t put much energy into this activity

| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|
| not at all true | somewhat true | very true |

598

599
10. I felt like I had to do this activity

1 2 3 4 5 6 7
not at all true somewhat true very true

11. This was an activity that I couldn’t do very well

1 2 3 4 5 6 7
not at all true somewhat true very true

12. I thought this was a boring activity

1 2 3 4 5 6 7
not at all true somewhat true very true

13. I believe I had some choice about doing this activity

1 2 3 4 5 6 7
not at all true somewhat true very true

14. I think doing this activity is useful for improving golf putting

1 2 3 4 5 6 7
not at all true somewhat true very true
15. I did this activity because I had to
   1 2 3 4 5 6 7
   not at all true somewhat true very true

16. I felt pressured while doing this activity
   1 2 3 4 5 6 7
   not at all true somewhat true very true

17. I believe doing this activity could be beneficial to me
   1 2 3 4 5 6 7
   not at all true somewhat true very true

18. This activity did not hold my attention at all
   1 2 3 4 5 6 7
   not at all true somewhat true very true

19. After working at this activity for a while, I felt pretty competent
   1 2 3 4 5 6 7
   not at all true somewhat true very true
20. I would describe this activity as very interesting

1 2 3 4 5 6 7
not at all true somewhat true very true

21. I tried very hard on this activity

1 2 3 4 5 6 7
not at all true somewhat true very true

22. I think this activity is important to do because it can improve golf putting

1 2 3 4 5 6 7
not at all true somewhat true very true

23. I did this activity because I wanted to

1 2 3 4 5 6 7
not at all true somewhat true very true

24. I was very relaxed in doing this activity

1 2 3 4 5 6 7
not at all true somewhat true very true
25. I didn’t try very hard to do well at this activity

not at all true    somewhat true    very true

26. This activity was fun to do

not at all true    somewhat true    very true

27. I did this activity because I had no choice

not at all true    somewhat true    very true

28. I felt very tense while doing this activity

not at all true    somewhat true    very true

29. While I was doing this activity, I was thinking about how much I enjoyed it

not at all true    somewhat true    very true
30. I am satisfied with my performance at this activity

1 2 3 4 5 6 7
not at all true somewhat true very true

31. I believe this activity could be of some value to me

1 2 3 4 5 6 7
not at all true somewhat true very true

32. I was pretty skilled at this activity

1 2 3 4 5 6 7
not at all true somewhat true very true

33. I would be willing to do this activity again because it has some value to me

1 2 3 4 5 6 7
not at all true somewhat true very true

34. I think doing this activity could help me to improve golf putting

1 2 3 4 5 6 7
not at all true somewhat true very true
35. I think I did pretty well at this activity, compared to other participants

1 2 3 4 5 6 7
not at all true somewhat true very true

36. I didn’t really have a choice about doing this activity

1 2 3 4 5 6 7
not at all true somewhat true very true

37. I thought this activity was quite enjoyable

1 2 3 4 5 6 7
not at all true somewhat true very true
### Appendix E

**Revised Competitive State Anxiety Inventory-2**

Directions: A number of statements that athletes have used to describe their feelings before competition are given below. Read each statement and then the appropriate location and write the self-determined associated number to the right of the statement to indicate how you feel **right now** – at this moment. There are no right or wrong answers. Do not spend too much time on any one statement, but choose the answer that describes your feelings **right now**.

| Not | Somewhat | Moderately | Very Much |
|-----|----------|------------|-----------|
| At All | So | So |

1. I feel jittery.  
(0…………………………………………….100)_____

2. I am concerned that I may not do as well in this competition as I could.  
(0…………………………………………….100)_____

3. I feel self-confident.  
(0…………………………………………….100)_____

4. My body feels tense.  
(0…………………………………………….100)_____

5. I am concerned about losing.  
(0…………………………………………….100)_____

6. I feel tense in my stomach.  
(0…………………………………………….100)_____

7. I’m confident I can meet the challenge.  
(0…………………………………………….100)_____

8. I am concerned about choking under pressure.  
(0…………………………………………….100)_____

9. My heart is racing.  
(0…………………………………………….100)_____

10. I’m confident about performing well.  
(0…………………………………………….100)_____

11. I’m concerned about performing poorly.

12. I feel my stomach sinking.

13. I’m confident because I mentally picture myself reaching my goal.

14. I’m concerned that others will be disappointed with my performance.

15. My hands are clammy.

16. I’m confident of coming through under pressure.

17. My body feels tight.
Appendix F

Free Recall

Report, in as much detail as possible, any rules, methods, or techniques you recall using to putt during the posttest when you were putting for money while being videotaped.
Declaration of interests

☑ The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

☐ The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: