An Investigation of the Self-Invoking Trigger Hypothesis

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Abstract

The present study seeks to investigate the self-invoking trigger hypothesis. One aspect of the self-invoking trigger hypothesis states that when individuals activate their self-schema, also known as self-activation, their ability to learn and perform a motor skill will be hindered (Wulf & Lewthwaite, 2010). A self-schema entails a set of beliefs and ideas that people have about themselves and these can affect how an individual acts in various settings (Bargh, 1982; Leite & Kuiper, 2010; Markus, 1977; Stein, 1995). The self-schema may be activated through various types of self-reflection (McKay, Wulf, Lewthwaite, & Nordin, 2015). Experiment 1 involved a pretest of 10 blocks composed of 3 dart throws each, a writing task during the 5 minute intertest interval, and a posttest similar in structure to the pretest (N=42). During the intertest interval the participant was asked to reflect on their strengths and weaknesses as an athlete (n=14), or reflect on the strengths and weaknesses of another athlete (n=14), while the control group performed an alphabet listing task (n=14). Experiment 2 sought to separate the effects of the direction (positive and negative) and relevance (relevant or irrelevant to the task) of self-reflection (N=48). Experiment 2 involved the same methodology as the Experiment 1, but the writing task was replaced by reflecting on either strengths in dart-throwing (n=12), weaknesses in dart-throwing (n=12), strengths in other sports (n=12), or weaknesses in other sports (n=12). Based on analyses of variance and analyses of covariance, the present study fails to reject the null hypothesis, lending support for the notion that self-reflection and self-activation have no statistically significant effect on one's ability to learn and perform a motor skill.

An Investigation of the Self-Invoking Trigger Hypothesis

The present study seeks to investigate the self-invoking trigger hypothesis as proposed by Wulf and Lewthwaite (2010). One aspect of the self-invoking trigger hypothesis states that when individuals activate their self-schema that their ability to learn and perform a motor skill will be hindered (Wulf & Lewthwaite, 2010). A self-schema entails a set of beliefs and ideas that people have about themselves, and these can affect how an individual acts in certain settings (Bargh, 1982; Leite & Kuiper, 2010; Markus, 1977; Stein, 1995). It is interesting to note that the effects of realization of self are not limited to motor skill learning and performance, but affect social aspects of individuals' daily lives by affecting their thoughts, actions, and behaviors (Stapel & Blanton, 2004). Since we usually perform motor learning tasks around others, it makes sense that this self-activation will affect motor performance to some degree when around others (Wulf, Chiviacowsky, Schiller, & Avila, 2010). The self-schema manifests itself physically as a neural network found in the cortical midline brain structures (Gusnard, Akbudak, Shulman, & Raichle, 2001; Northoff, Heinzel, de Greck, Bermpohl, Dobrowolny, & Panksepp, 2006). There are various "selves," which range from a social self, an emotional self, a physical self, etc. (Northoff et al., 2006). Moreover, these recognitions of self are thought to affect motor skills (Blakemore, 2003; Blakemore, Wolpert, & Frith; 2000; Jeannerod, 2003).

Wulf and Lewthwaite (2010), and McKay et al. (2015), refer to environmental or internal cues that cause self-schema activation, or self-activation, as "self-invoking triggers." When performing a motor skill, these "self-invoking triggers may be present in coaching instructions (e.g., internal focus instructions), augmented feedback (e.g., exposure to performance errors), contextual cues (e.g., presence of others or a video camera), stereotype threats (e.g., race, age, or gender-relevant stereotypes about a skill), performance perspectives (e.g., an entity based conception of ability), and perceptions of ability (e.g., low self-efficacy)" (McKay et al., 2015, p. 2).

There is a breadth of research investigating coaching instructions, predominantly in attentional focus. There is a general consensus that an internal attentional focus, or focusing on a certain body part during a movement, is less effective in both the learning and performance of a motor skill than is external attentional focus, which entails focusing on the outcome of a movement (Lohse, Sherwood, Healy, 2010; Wulf, Höß, & Prinz, 1998). Regardless of whether implicit or explicit cues are used to shift to an internal attentional focus, this activation of the self-schema negatively impacts performance while external attentional focus continues to produce better performance outcomes (Wulf, Shea, Lewthwaite, 2010).

Several studies have manipulated the self-schema through verbal instructions during the performance of motor skills and found the same phenomenon. Lohse et al. (2010) instructed participants by telling them to focus on their movements or their arm's motion for the internal attentional focus group and to focus on the board or flight of the dart for the external attentional focus group. They found that in dart-throwing an external attentional focus resulted in improved accuracy (Lohse et al., 2010). Interestingly enough, they also found that external attentional focus results in reduced EMG activity, and therefore more economic movement, of the triceps brachii (Lohse et al., 2010). This reduction in EMG activity as a result of external attentional focus was also found by Lohse, Sherwood, and Healy (2011) in a force production task that aimed to generate 30% of the participants' maximum force on a platform. In this experiment participants were given instructions that referred to muscle contractions for the internal attentional focus group while the external attentional focus group was given instructions referring to the platform (Lohse et al., 2011). External attentional focus led to better control over force production than internal attentional focus (Lohse et al., 2011). Sherwood, Lohse, and Healy (2014) attempted to further isolate the effect of these two types of attentional focus by removing visual processing from the task of dart-throwing. They found that even when visual processing was eliminated by blindfolding participants during their throws, an external focus of attention still produced better performance than an internal focus of attention (Sherwood et al., 2014). After each throw and before participants removed their blindfold for feedback, they were asked to rate their elbow angle and shoulder angle at the time of release for the internal attentional focus group while the external attentional focus group was asked to rate where the dart landed on the board vertically and horizontally (Sherwood et al., 2014). Once again, external attentional focus yielded improved accuracy compared to internal attentional focus (Sherwood et al., 2014). These attentional focus effects are not limited to dart-throwing (Lohse et al., 2010; Sherwood et al., 2014) but also extend to other activities like vertical jumping (Wulf, Zachry, Granados, & Dufek, 2007), volleyball serves (Wulf, McConnel, Gärtner, and Schwarz, 2002), soccer (Wulf et al., 2002), ski-simulators (Wulf et al., 1998), golf (Wulf, Lauterbach, & Toole, 1999), and dynamic balance tasks as measured by a stabilometer (Wulf, McNevin, & Shea, 2001). It is interesting to note that increasing the distance of the external focus will increase the effect of external attentional focus, that is, there will be enhancement in motor learning and performance (McNevin, Shea, & Wulf, 2003).

The process by which self-activation occurs among participants is subtler in the aforementioned studies than in the present study, and this activation manifests itself in the form of an internal focus of attention. The aforementioned studies may cause self-activation among participants to varying degrees, but all of them tend to be more implicit than the present study and McKay et al. (2015) since most self-activation is considered to be implicit (Bargh, Schwader, Hailey, Dyer, & Boothby, 2012). Whether a study is more explicit in their instructions by telling participants to ‘focus inward’ or on a certain body part through the movement (Lohse et al., 2010; Wulf et al., 1999), or more implicit by telling them to rate their elbow angle at the time of a throw (Sherwood et al., 2014), this may be enough to cause self-activation (Wulf & Lewthwaite, 2010). Wulf and Lewthwaite (2010) hypothesize that by shifting attentional focus internally, self-activation occurs and that this self-activation negatively affects motor learning capabilities and performance as a result. Despite the lack of research that specifically addresses the self-invoking trigger hypothesis, there is reason to believe that self-reflection will cause self-activation and that we should see a hindering of one's ability to learn and perform a motor skill based on prior studies investigating attentional focus. However, as stated by McKay et al. (2015), it is "unclear as to whether self-activation alone is detrimental to motor learning and performance." The present study seeks to investigate the self-invoking trigger hypothesis by replicating McKay et al. (2015) with a dart-throwing task.

McKay et al. (2015) lend support for the self-invoking trigger hypothesis, demonstrating that self-reflection degrades the learning and performance of a new motor skill through two experiments. Their first experiment involved performing a throwing task with the dominant hand accompanied by an intertest task of self-reflection with a self-reflection group and a control group. It was hypothesized that throwing accuracy would be degraded relative to the control group following the intertest in the self-reflection group compared to the control group. Their first experiment was conducted in a standard-sized indoor racquetball court of 40’ long x 20’ wide x 20’ high) where participants would throw racquetballs overhand at a target (Atec Catch Net) that was hung 2.1 m x 2.1 m x 1.4 m from 5.8 m away. The target was made of eight concentric circles where the bull’s eye was 1 m above the ground. The center circle had a diameter of 7.5 cm and each successive circle had a radius that was 7.5 cm larger than its smaller neighbor. The largest circle had a diameter of 60 cm. The scoring system allocated 8 points for hitting the center circle, 7 points for hitting the 15 cm circle and so on. One point was awarded for the 60 cm circle while 0 points were allocated for missing the target. The self-reflection (M = 45.9, SD = 11.0) and control (M = 44.9, SD = 13.1) groups had similar accuracy scores on the pretest. On the posttest, the self-reflection group (M = 40.3, SD = 11.7) experienced a degradation in performance compared to the control group (M = 45.8, SD = 11.8). Using an ANCOVA that used pretest performance as a covariate, the main effect of group was significant, $F(1,33) = 4.55$, $p = .04$, $\eta_p^2 = .12$.

The second experiment in McKay et al. (2015) was conducted over the course of three days and involved hitting wiffleballs into certain parts of a room with a point system different from the first experiment. The purpose of this experiment was to provide a control condition that included writing tasks between blocks of trials different from their first experiment and "to examine the effect of self-reflection on the learning of a novel skill" (McKay et al., 2015, p.4). The practice phase was composed of 4 times on each of the first two days. The self-reflection group was given writing tasks meant to cause self-activation while the control group was given a neutral writing task for the intertest task. Temporary performance effects were evaluated during the practice phase (first two days) and the permanent learning effects were evaluated on the third day by comparing retention and transfer tests. During the practice phase, the control group (M = 15.8, SD = 6.5) performed more effectively than the self-reflection group (M = 14.61, SD = 6.0). Based on an ANCOVA that used pretest performance as a covariate, the main effect of group was significant, $F(1,33) = 6.85$, $p = .013$, $\eta_p^2 = .17$. The retention test with no writing manipulation indicated that the control group (M = 18.8, SD = 6.3) performed better than the self-reflection group (M = 14.5, SD = 5.4). Based on an ANCOVA that used initial performance as the covariate, the main effect of group was significant, $F(1,33) = 18.81$, $p < .001$, $\eta_p^2 = .36$. During the transfer task, which involved participants hitting balls at a faster rate than what was practiced, the control group ($M = 17.1$, $SD = 6.9$) still performed better than the self-reflection group ($M = 13.4$, $SD = 7.8$). Based on an ANCOVA that used pretest performance as a covariate, the main effect of group was significant, $F(1,33) = 8.02$, $p = .008$, $\eta_p^2 = .20$.

The results for both of the experiments conducted by McKay et al. (2015) support the self-invoking trigger hypothesis. The present study was predominantly based on the first experiment conducted by McKay et al. (2015), adopting a similar point system but using dart-throwing as the motor skill.

Experiment 1

Experiment 1 sought to make participants activate their self-schema and did not discriminate between positive and negative self-reflection, or reflection relevant or irrelevant to the task, but rather tried to distinguish between the effects of internal and external reflection.

Method

Participants. There were a total of 42 participants and each of the three groups (internal reflection, external reflection, and control) was composed of 14 participants. The participants ranged from 18 to 24 years of age and were recruited from an introductory psychology course at the University of Colorado at Boulder. There were 10 men and 32 women in total. Out of all the participants, 3 were left-handed and 38 were right-handed. According to the questionnaire, 9 participants never played darts before, 31 rarely play darts (1-3 times per year), and 1 played often (3 or more times per month). One participant did not properly fill out the questionnaire, so no data other than gender was recorded for that one participant.

Apparatus and measurements. Experiment 1 was conducted in a room with a competition bristle dartboard that was 45 cm in diameter. The dartboard was set to a standard regulation height of 1.73 m off the ground and participants threw darts from 2.37 m away from the dartboard. The dartboard was mounted on a 91 cm x 121 cm plywood board covered with burlap. The participants threw regulation steel tip darts that weighed 22 g with their dominant hand.

The participants' performance was assessed from the pretest to the posttest through the mean radial error (MRE) and mean bivariate variable error (BVE), to measure if improvement, degradation, or nothing occurred. MRE measures accuracy (Sherwood et al., 2014) while BVE measures precision (Hancock, Butler, & Fischman, 1995; Sherwood et al., 2014). The dartboard was divided into quadrants, similar to a Cartesian coordinate system. The X and Y measurements of where the darts landed were recorded. Darts that landed outside the boundaries of the board were included in the measurements. Radial error (RE) was used to measure accuracy and is the absolute distance the dart is from the bull's eye using the origin (point 0,0). RE for each throw was calculated using Equation 1.1. The MRE was then calculated and is the average RE of all the throws in a test as indicated by Equation 1.2:

$$RE_i=\sqrt{(X_i^2+Y_i^2)} \qquad \text{(Equation 1.1)}$$

Where:

X_i = x-coordinate of individual dart

Y_i = y-coordinate of individual dart

$$MRE=\frac{1}{k}\sum_{i=1}^{k} RE_i \qquad \text{(Equation 1.2)}$$

Where:

RE_i = Radial error of individual dart

k = total number of individual throws being averaged, also the final value of i

i = The first RE_i being summed

BVE was used to measure precision and is the distance of each throw from the average distance of all throws within a test (X_C and Y_C) on the X and Y axes. BVE is the variation of throws from the centroid location (X_C, Y_C) for that block and is calculated with Equation 2.1:

$$BVE=\sqrt{\frac{1}{k}\sum_{i=1}^{k}(X_i - X_C)^2 + (Y_i - Y_C)^2} \quad \text{(Equation 2.1)}$$

Where:

X_i = x-coordinate of individual dart

Y_i = y-coordinate of individual dart

X_C = x-coordinate of centroid location calculated for a block

Y_C = y-coordinate of centroid location calculated for a block

k = total number of individual throws being averaged, also the final value of i

i = The first value of $((X_i - X_C)^2 + (Y_i - Y_C)^2)$ being summed

In order to compare the results of the present study to McKay et al. (2015), the RE data were transposed into a point system. The target used by McKay et al. (2015), had 8 concentric circles and was 60 cm in diameter. The dartboard in the present study that was 45 cm in diameter was divided into 8 concentric circles. The point system of the present study is as follows:

8 points if the dart is between 0 and 2.8125 cm from the center

7 points if the dart is between 2.8126 and 5.6250 cm from the center

6 points if the dart is between 5.6251 and 8.4375 cm from the center

5 points if the dart is between 8.4376 and 11.2500 cm from the center

4 points if the dart is between 11.2501 and 14.0625 cm from the center

3 points if the dart is between 14.0626 and 16.8750 cm from the center

2 points if the dart is between 16.8751 and 19.6875 cm from the center

1 point if the dart is between 19.6876 and 22.5000 cm from the center

0 points if the dart is beyond 22.5000 cm from the center

Procedure

All participants volunteered and were given an informed consent form by the experimenter with all necessary information before experimentation began (Refer to Appendix A). The participants were also given a questionnaire in order to gather more information about the demographic data about the sample (Refer to Appendix B). The participants were randomly assigned into one of three groups: internal reflection, external reflection, and control. During the interval between the pretest and the posttest, the internal reflection group was instructed to reflect on their strengths and weaknesses as an athlete, the external reflection group was instructed to reflect on the strengths and weaknesses of an athlete other than themselves, and the control group performed a simple task involving the alphabet (Refer to Appendix C). Both oral and written instructions were given to the participants. After the intertest task was complete, the reflection responses were read by the experimenter and orally summarized their points aloud to the participant before they were to engage in the posttest. The reading aloud of responses was to increase the self-activating effect and to give the experimenter an idea of what the participants wrote. The reading back of responses did not occur for the control group as it was deemed unnecessary. All participants participated in a pretest of 10 blocks composed of 3 throws each. The participants then took 3 minutes to perform the intertest task, which depended on the experimental condition in which they were placed. Soon after, a posttest of 10 blocks composed of 3 throws each was conducted. All participants were debriefed about the study immediately after their participation.

Data Analysis

A 3 (Group, internal reflection/external reflection/control) x 2 (Test, pretest/posttest) x 10 (Block) mixed analysis of variance (ANOVA) was performed for the MRE and the mean BVE with repeated measures on the last two factors.

In addition, to compare the present study's results to the point-system used to measure performance in the McKay et al. (2015), the raw data for RE were transposed so darts landing in certain regions of the dartboard received a certain number of points based on the point system outlined in the method section. The mean total points accumulated by each subject on the pretest and posttest were analyzed via a 3 (Group) x 2 (Test) ANOVA with repeated measures on the last factor. An analysis using the pretest scores as a covariate with a one way analysis of covariance (ANCOVA) by Group (3) was also performed.

Results

The means and standard deviations for pretest RE for each group were as follows: internal reflection (M = 11.24, SD = 2.94), external reflection (M = 10.60, SD = 2.73), control (M = 10.98, SD = 3.62). The means and standard deviations for posttest REs for each group were as follows: internal reflection (M = 10.27, SD = 3.34), external reflection (M = 9.56, SD = 2.00), control (M = 10.68, SD = 4.20). All groups improved their mean accuracy from pretest to posttest as indicated by the lower MREs. Analyzing RE, there was no main effect of group, $F(2,39) = .281$, $p = .756$, $\eta_p^2 = .014$. There was no Group x Test interaction, $F(2,39) = .328$, $p = .722$, $\eta_p^2 = .017$, and no Group x Test x Block interaction, $F(18,351) = 1.331$, $p = .165$, $\eta_p^2 = .064$. There was a nearly significant main effect of test, $F(1,39) = 3.527$, $p = .068$, $\eta_p^2 = .083$ and a significant main effect of block, $F(9,351) = 4.633$, $p < .001$, $\eta_p^2 = .106$. There was a significant Test x Block interaction, $F(9,351) = 2.955$, $p = .002$, $\eta_p^2 = .070$. When analyzing the block means of RE across all groups on the pretest, the trend analysis revealed a 6th order decrease in variability, $F(1,39) = 7.121$, $p = .011$, $\eta_p^2 = .154$. The block means of RE across all groups on the posttest revealed a 5th order decrease in variability, $F(1,39) = 6.306$, $p = .016$, $\eta_p^2 = .139$. The MRE of each group across blocks in pretest and posttest can be seen in Figure 1.

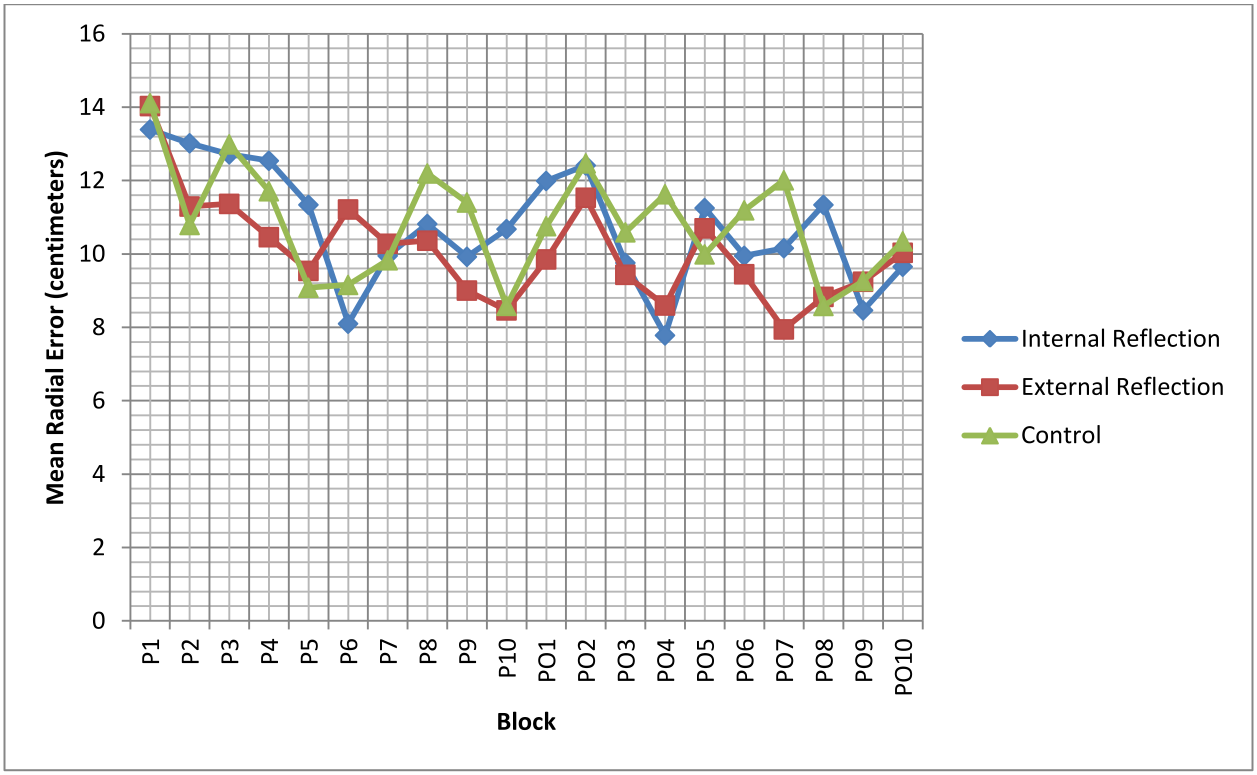

Figure 1: MRE among groups across blocks for Experiment 1 (N=42). P = pretest, and PO = posttest.

The means and standard deviations for pretest BVE for each group were as follows: internal reflection ($M = 9.41$, $SD = 2.47$), external reflection ($M = 8.64$, $SD = 2.21$), control ($M = 8.94$, $SD = 2.95$). The means and standard deviations for posttest BVE for each group were as follows: internal reflection ($M = 8.57$, $SD = 2.64$), external reflection ($M = 8.11$, $SD = 1.74$), control ($M = 8.91$, $SD = 3.73$). All groups improved their mean precision from pretest to posttest as indicated by the lower mean BVEs. When analyzing the BVE, there was no main effect of group, $F(2,39) = .266$, $p = .768$, $\eta_p^2 = .013$. There was also no Group x Test interaction, $F(2,39) = .489$, $p = .617$, $\eta_p^2 = .024$, or Group x Test x Block interaction, $F(18,351) = 1.096$, $p = .354$, $\eta_p^2 = .053$. There was not a significant main effect of test, $F(1,39) = 1.924$, $p = .173$, $\eta_p^2 = .047$, and no significant main effect of block, $F(9,351) = 1.023$, $p = .081$, $\eta_p^2 = .042$. There was a significant Test x Block interaction, $F(9,351) = 2.437$, $p = .011$, $\eta_p^2 = .059$. When analyzing the block means of BVE across all groups on the pretest, the trend analysis revealed a 6th order decrease in variability $F(1,39) = 5.251$, $p = .027$, $\eta_p^2 = .119$. When analyzing the block means of BVE across all groups in the posttest, the trend analysis revealed a 7th order decrease in variability, $F(1,39) = 4.253$, $p = .046$, $\eta_p^2 = .098$. The mean BVE of each group across blocks in pretest and posttest can be seen in Figure 2.

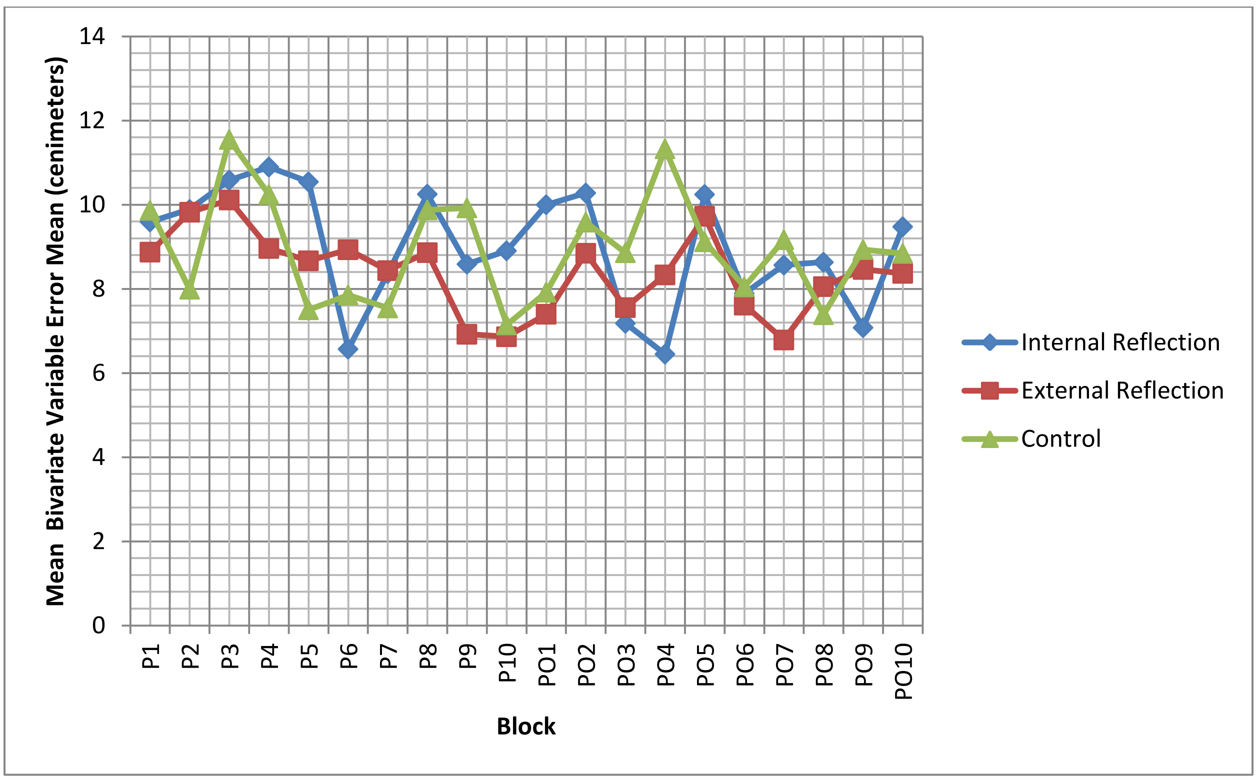

Figure 2: Mean BVE among groups across blocks for Experiment I (N=42). P = pretest, and PO = posttest.

The pretest radial data were transposed into a point system and the average total score for the internal reflection group (*M* = 140.50, *SD* = 25.79), external reflection group (*M* = 145.43, *SD* = 25.77), and control group (*M* = 141.14, *SD* = 33.95) were calculated. The posttest radial data were also transposed into a point system and the average total score for the internal reflection group (*M* = 149.31, *SD* = 28.86), external reflection group (*M* = 154.45, *SD* = 20.40), and control group (*M* = 148.43, *SD* = 32.61) were calculated. The main effect of group was not significant, $F(2,39) = .032$, $p = .969$, $\eta_p^2 = .002$ according to the ANOVA. When controlling for pretest performance, the main effect of group was not significant, $F(2,38) = .086$, $p = .918$, $\eta_p^2 = .004$. The covariate, pretest performance, was significantly related to posttest performance, $F(1,38) = 50.342$, $p < .001$, $\eta_p^2 = .570$ according to the ANCOVA.

Discussion

Experiment 1 failed to support the self-invoking trigger hypothesis. In order for the data to support the self-invoking trigger hypothesis, there would have to be a statistically significant Group x Test interaction as it would parallel the results found by McKay et al. (2015). Although a significant main effect of group or a significant Group x Test x Block interaction could also potentially support the self-invoking trigger hypothesis, these are not preferred. A significant main effect of group alone does not account for the differences in performance between pretest and posttest, which is the objective of the present study. A significant Group x Test x Block interaction can be caused by any difference large enough between two groups in any given block. The lack of any of the aforementioned main effects or interactions indicates that the manipulations of self-reflection did not have any statistically significant effect on performance. Even when transposing the data to match the point system methodology used in McKay et al. (2015), there was still no statistically significant effect on performance as a result of our manipulations that would support the self-invoking trigger hypothesis. Moreover, the trend suggested by the averages indicated improvement as accuracy (decreased MRE), precision (decreased mean BVE), and increase in accumulated points occurred from pretest to posttest for all groups.

The significant main effect of test in RE indicated that pretest performance was different from posttest performance. The significant main effect of block in RE indicates that the performance across blocks is different and does not, by itself, allow us to draw any conclusions about the effect of our manipulations of group other than that corresponding blocks were different from one another. The significant Test x Block interaction for both RE and BVE simply means that from pretest to posttest, the performance in each respective block was different from one another. That is, the rate of improvement on the pretest was different from the posttest as indicated by the graphical trends of block means across all groups for MRE from pretest to posttest. Trend analysis across blocks of RE revealed the function changed from a 6^{th} order decrease in variability to a 5^{th} order decrease in variability from pretest to posttest. Although there was no main effect of block for BVE, there was a Test x Block interaction. This was indicated in the trend analysis of block for BVE which revealed the function changed from a 6^{th} order decrease in variability to a 7^{th} order decrease in variability from pretest to posttest. The combination of the aforementioned main effects and interactions are indicative of practice effects, which will be discussed later.

The benefits of the point system were 1) it helps us compare the results of the present study to the results of McKay et al. (2015) and 2) it helps reduce variance by removing certain errors that are deemed too large which could have potentially decreased the present study's statistical power and prevented statistical significance. However, this was not realized until after the completion of both Experiments 1 and 2, so power was not calculated and this speculation cannot be verified.

As stated earlier, the statistically significant main effects and interactions found for RE and BVE, along with the trend of improvement from pretest to posttest are indicative of a practice effect, which means that participant performance improved as time progressed. This is because of the Test x Block interaction, the improvement in performance, and the lack of any group effects of interactions. Even if the effect of self-activation was present, practice may have outweighed such an effect so much so that it improved performance because practice is closely related to performance of a task (Ericsson, Krampe, & Tesch-Römer, 1993). It is also possible that the effect of self-activation was simply not present and that the practice effect was responsible for the improvement in performance. Therefore, the absence of the degradation effect predicted by the self-invoking trigger hypothesis is either because of the experiment's inability to induce proper self-activation among participants or because the degradation effect does not exist.

Experiment 1 had some limitations that could have had an effect on the results. As in McKay et al. (2015), the assumption was made that self-activation occurred with the brief instruction given. Two differences in the methodologies were the motor skill being tested and the amount of time allocated to self-reflection, for a total of 1 minute in McKay et al. (2015) and 3 minutes in the present study. However, because statistically significant results were found by McKay et al. (2015), these differences in methodology were not considered limitations during the design of the present study. One of the biggest limitations of the present study was that the effects of positive and negative reflection were not isolated. It is well known that positive reinforcements or positive thoughts of one's own abilities tend to lead to enhanced performance (Chiviacowsky & Wulf, 2002, 2005, 2007; Hutchinson, Sherman, Martinovic, & Tenenbaum, 2008; Jourden, Bandura, & Banfield, 1991; McKay, Lewthwaite, & Wulf, 2012; Moritz, Feltz, Fahrbach, & Mack, 2000) and are present in activities from diving (Feltz, Chow, & Hepler, 2008) to softball (Chang et al., 2014). As such, it could be that self-activation through positive cues in the form of self-reflection may yield a different result in performance than if the self-activation occurs through negative cues. In Experiment 1, participants were asked to focus on both strengths and weaknesses for both the internal reflection and external reflection manipulations. Most participants had a fairly equal number of strengths and weaknesses in their reflections for both the internal and external reflection groups. However, some participants focused more on strengths or weaknesses (refer to Appendix C for examples) which may have impacted motor learning and performance. Moreover, it is difficult to say whether the participants were focusing predominantly on strengths or weaknesses throughout the course of the experiment regardless of what was written. If the reflection was predominantly positive it may have re-activated motor patterns from another throwing task that were transferable to dart-throwing or that had not been activated for long periods of time. If the individuals ruminated too much on negative reflections, this may have outweighed any positive reflection that occurred and may have even hindered certain motor patterns (McKay et al., 2015).

Another limitation of Experiment 1 was that it did not replicate the wording of the intertest tasks exactly how they were in McKay et al. (2015). Individuals in the present study were told to reflect on their strengths and weaknesses as an athlete while those in McKay et al. (2015) were told to reflect on their strengths and weaknesses as a thrower. The present study was more concerned with the effects of internal and external reflection on motor performance rather than whether or not relevance had an effect.

Due to the results in Experiment 1, Experiment 2 was designed in order to isolate the effects of positive and negative reflection on the learning and performance of a new motor skill. It also sought to investigate whether or not reflecting on the task at hand or about an irrelevant task affected performance as proposed by McKay et al. (2015). By isolating the direction (positive or negative) and relevance (relevant or irrelevant to the task) of participant self-reflection, the present study sought to improve participant self-activation. This isolation would serve the purposes of 1) showing if the degradation effect predicted by the self-invoking trigger hypothesis exists at all and 2) increasing the presence of the degradation effect caused by the self-invoking trigger hypothesis, if it exists, to prevent other effects, like the practice effect, from outweighing the degradation effect after self-activation occurs.

Experiment 2

Based on the results of Experiment 1, Experiment 2 was devised as a way to address the limitations present in Experiment 1. Experiment 2 sought to further isolate the effects of positive and negative self-reflection on the learning and performance of a new motor skill. It is well known in sports psychology that positive reinforcements tend to produce better performance (Chiviacowsky & Wulf, 2002, 2005, 2007; Hutchinson et al., 2008; Jourden et al., 1991; McKay et al., 2012; Moritz et al., 2000). As such, Experiment 2 seeks to learn whether self-activation through positive reflection produces the same effect on learning and performance as self-activation through negative reflection (direction). Experiment 2 also investigates whether or not reflecting on the task at hand has any effect on performance, relative to reflection about an irrelevant task (relevance). Relevant self-reflection may cause an individual to think more about their movements and motor patterns for that given motor task, which may be enough to change those motor patterns. If the individual performs that given motor task after changing their motor patterns for that motor skill we might expect a greater deterioration in performance, as predicted by the self-invoking trigger hypothesis, than if they reflected over a task that uses different motor patterns that are not as directly applicable to the motor task they are about to perform.

Method

Participants. There were a total of 48 participants and each of the four groups (positive relevant, negative relevant, positive irrelevant, negative irrelevant) were composed of 12 participants. The participants ranged from 18 to 26 years of age and were recruited from an introductory psychology and an introductory statistics course at the University of Colorado at Boulder. There were 19 men and 29 women in total. Out of all the participants, 4 were left-handed and 44 were right-handed. According to the questionnaire, 12 participants never played darts before, 32 rarely play darts (1-3 times per year), 3 played sometimes (1-3 times per month), and 1 played often (3 or more times per month).

Apparatus and measurements. The apparatus used in Experiment 2 was identical to that used in Experiment 1. Participants' performance was assessed in the same way as in Experiment 1 using MRE and BVE. In order to compare the results of the present study to McKay et al. (2015), RE data were transposed into the point system used in Experiment 1.

Procedure

Experiment 2 used the same procedure as Experiment 1, with the only difference being the intertest task (Refer to Appendix D). The following manipulations of self-reflection were included: positive relevant (n=12), negative relevant (n=12), positive irrelevant (n=12), and negative irrelevant (n=12). Reflecting on strengths was called positive reflection whereas reflecting on weaknesses was called negative reflection. Reflection regarding dart-throwing was considered relevant reflection whereas reflection regarding other physical activities was considered irrelevant.

Data Analysis

A 4 (Group, positive relevant/negative relevant/positive irrelevant/negative irrelevant) x 2 (Test, pretest/posttest) x 10 (Block) mixed analysis of variance (ANOVA) was performed for the MRE and the mean BVE with repeated measures on the last two factors. Due to a significant Group x Test x Block interaction found analyzing RE, a post-hoc test of Fischer's Least Significant Difference (LSD) was conducted only on the RE data.

The mean total points accumulated by each subject on the pretest and posttest were analyzed via a 4 (Group) x 2 (Test) ANOVA with repeated measures on the last factor. An analysis using the pretest scores as a covariate with a one way analysis of covariance (ANCOVA) by Group (4) was also performed just as in Experiment 1.

In addition to the similar analyses performed in Experiment 1, the MRE and BVE data from the pretest and posttest were analyzed using separate 2 (Relevance, relevant/irrelevant) x 2 (Direction, positive/negative) x 2 (Test, pretest/posttest) x 10 (Block) ANOVA with repeated measures on the last two factors. The point system data from pretest to posttest were also analyzed using a 2 (Relevance) x 2 (Direction) x 2 (Test) ANOVA with repeated measures on Test.

Results

The means and standard deviations for pretest RE for each group were as follows: positive relevant (M = 10.16, SD = 3.92), negative relevant (M = 11.13, SD = 3.06), positive irrelevant (M = 10.50, SD = 4.14), and negative irrelevant (M = 10.20, SD = 2.52). The means and standard deviations for posttest RE for each group were as follows: positive relevant (M =

9.37, *SD* = 4.19), negative relevant (*M* = 9.95, *SD* = 2.29), positive irrelevant (*M* = 9.23, *SD* = 2.53), and negative irrelevant (*M* = 9.63, *SD* = 2.47). All groups improved their mean accuracy from pretest to posttest as indicated by the lower mean REs. Analyzing RE, there was no significant main effect of group, $F(1,44) = .161$, $p = .922$, $\eta_p^2 = .011$. There was also no significant Group x Test interaction, $F(3,44) = .276$, $p = .843$, $\eta_p^2 = .018$. There was a significant Group x Test x Block interaction, $F(27,396) = 1.936$, $p = .004$, $\eta_p^2 = .117$. Due to the significant Group x Test x Block interaction, the post-hoc test of Fischer's LSD was conducted. The LSD revealed a significant difference between the positive relevant group and the negative relevant group at block 6 of pretest, $p = .046$. The LSD also revealed a significant difference between the positive irrelevant group and the negative irrelevant group at block 6 of the posttest, $p = .037$. This was considered the source of the Group x Test x Block interaction, which will be discussed later.

There was a significant main effect of test, $F(1,44) = 9.083$, $p = .004$, $\eta_p^2 = .171$ and a significant main effect of block, $F(9,396) = 9.083$, $p < .001$, $\eta_p^2 = .180$. There was also a significant Test x Block interaction, $F(9,396) = 4.031$, $p < .001$, $\eta_p^2 = .084$. When analyzing the block means of RE across all groups on the pretest, the trend analysis revealed a cubic decrease in variability, $F(1,44) = 8.517$, $p = .006$, $\eta_p^2 = .162$. When analyzing the block means of RE across all groups on the posttest, the trend analysis revealed a linear decrease in variability, $F(1,44) = 13.553$, $p = .001$, $\eta_p^2 = .235$. The MRE of each group across blocks in pretest and posttest can be seen in Figure 3.

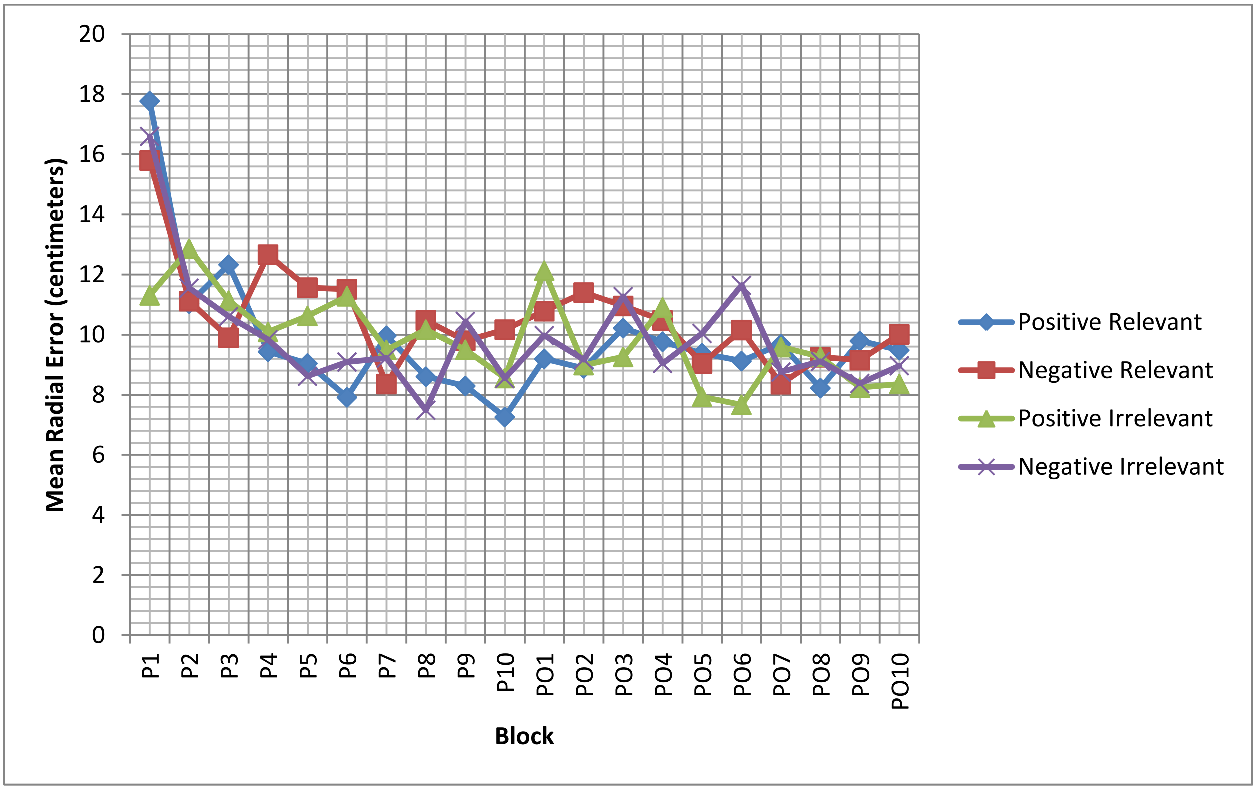

Figure 3: MRE among groups across blocks for Experiment 2 (N=48). P = pretest, and PO = posttest.

The 2 (Relevance) x 2 (Direction) x 2 (Test) x 10 (Block) ANOVA with repeated measures on the last two factors for RE revealed that there were no main effects of either relevance or direction and no Relevance x Direction interaction (all *F's* < 1, all *p's* > .64).

The means and standard deviations for pretest BVE for each group were as follows: positive relevant (*M* = 8.26, *SD* = 3.31), negative relevant (*M* = 8.85, *SD* = 2.40), positive irrelevant (*M* = 8.17, *SD* = 3.02), and negative irrelevant (*M* = 8.45, *SD* = 2.11). The means and standard deviations for posttest BVE for each group were as follows: positive relevant (*M* = 8.19, *SD* = 4.16), negative relevant (*M* = 8.19, *SD* = 1.64), positive irrelevant (*M* = 8.05, *SD* = 2.02), and negative irrelevant (*M* = 7.96, *SD* = 2.62). All groups improved their mean precision from pretest to posttest as indicated by the lower mean BVEs. When analyzing the BVE, there was no significant main effect of group, $F(3,44) = .054$, $p = .983$, $\eta_p^2 = .004$, and there was no significant Group x Test interaction, $F(3,44) = .329$, $p = .804$, $\eta_p^2 = .022$. There was an almost significant Group x Test x Block interaction, $F(27,396) = 1.488$, $p = .058$, $\eta_p^2 = .092$. Fischer's LSD was not conducted for BVE due to the lack of a significant Group x Test x Block interaction. There was no significant main effect of test, $F(1,44) = 1.761$, $p = .191$, $\eta_p^2 = .038$, but there was a significant effect of block, $F(9,396) = 2.396$, $p = .012$, $\eta_p^2 = .052$. There was no significant Test x Block interaction, $F(9,396) = 1.631$, $p = .104$, $\eta_p^2 = .036$. When analyzing the block means of BVE across all groups on pretest, the trend analysis revealed a linear decrease in variability $F(1,44) = 14.104$, $p = .001$, $\eta_p^2 = .243$. When analyzing the block means of BVE across all groups on the posttest, the trend analysis revealed a linear decrease in variability, $F(1,44) = 5.522$, $p = .023$, $\eta_p^2 = .112$. The mean BVE of each group across blocks in pretest and posttest can be seen in Figure 4.

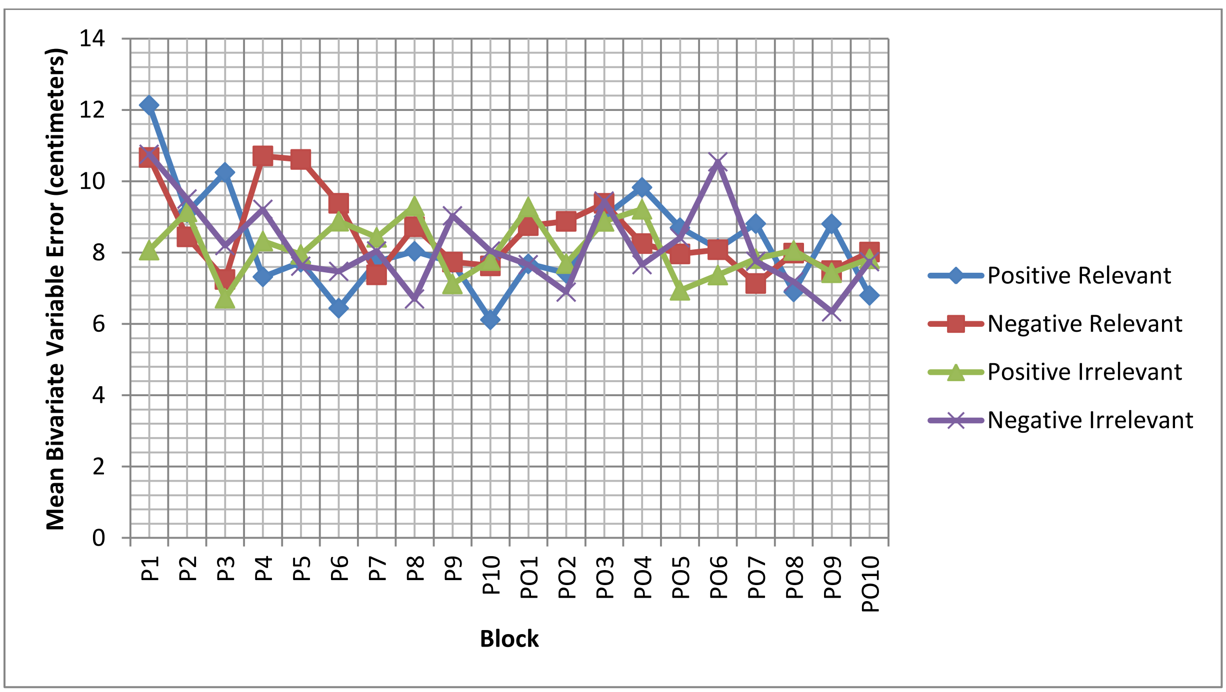

Figure 4: Mean BVE among groups across block for Experiment 2 (N=48). P = pretest, and PO = posttest.

The 2 (Relevance) x 2 (Direction) x 2 (Test) x 10 (Block) ANOVA with repeated measures on the last two factors for BVE revealed that there were no main effects of either relevance or direction and no Relevance x Direction interaction (all F's < 1, all *p's* > .77).

The pretest RE data were transposed into a point system and the average total score for the positive relevant (*M* = 154.08, *SD* = 32.74), negative relevant (*M* = 141.41, *SD* = 27.87), positive irrelevant (*M* = 148.33, *SD* = 34.84), and negative irrelevant (*M* = 149.50, *SD* = 24.01) groups were calculated. The posttest RE data were also transposed into a point system and the average total score for the positive relevant (*M* = 159.08, *SD* = 38.46), negative relevant (*M* = 148.91, *SD* = 23.74), positive irrelevant (*M* = 157.16, *SD* = 25.13), and negative irrelevant (*M* = 154.75, *SD* = 24.20) groups were calculated. The main effect of group was not significant, $F(3,44) = .101$, $p = .959$, $\eta_p^2 = .007$ according to the ANOVA. When controlling for pretest performance, the main effect of group was not significant, $F(3,43) = .082$, $p = .969$, $\eta_p^2 = .006$. The covariate, pretest performance, was significantly related to posttest performance, $F(1,43) = 61.827$, $p < .001$, $\eta_p^2 = .590$ according to the ANCOVA.

The 2 (Relevance) x 2 (Direction) x 2 (Test) ANOVA with repeated measures on Test for the point system revealed that there were no main effects of either relevance or direction and no Relevance x Direction interaction (all *F*'s < 1, all *p*'s > .45).

Discussion

No significant Group x Test interaction was found. However, the 4 (Group) x 2 (Test) x 10 (Block) mixed analysis of variance (ANOVA) performed for the MRE with repeated measures on the last two factors revealed a statistically significant Group x Test x Block interaction. Normally, this could provide support for the self-invoking trigger hypothesis. However, this interaction is likely due to chance alone. Although this interaction was suspected to be caused by an outlier in block 1 of pretest, as noted by Figure 3, the LSD revealed it was actually due to a significant difference between the positive relevant reflection group and the negative relevant reflection group in block 6 of pretest as well as by a significant difference between the positive irrelevant reflection group and the negative irrelevant reflection group in block 6 of posttest. There is no specific reason that these differences would be present in these blocks between the groups that are shown to be significantly different as a result of the manipulations on self-reflection. As such, it is likely these differences occurred due to chance and do not support the hypothesis. It should be noted that this is one of the reasons that a Group x Test interaction is preferred over a Group x Test x Block, simply because the latter can indicate a significant difference in performance from pretest to posttest that is not caused by the manipulation of the independent variable. Interestingly enough, performance on all measures actually improved for all groups from pretest to posttest, which is the opposite trend one would expect to find with the self-invoking trigger hypothesis. Based on all of this information, the manipulations of self-reflection did not affect performance in a statistically significant way consistent with the self-invoking trigger hypothesis.

The main effect of test in RE signifies that the pretest and posttest scores are different. The main effect of block in both RE and BVE indicates that the performance across blocks is different and does not, by itself, allow us to draw any conclusions about the effect of our manipulations of group other than that corresponding blocks were different from one another. The significant Test x Block interaction for RE simply means that from pretest to posttest, the performance in each respective block was different from one another. That is, the rate of improvement on the pretest was different from the posttest as indicated by the graphical trends of block means across all groups for MRE from pretest to posttest. This was shown in the trend analysis across blocks of RE which revealed the function changed from a cubic decrease in variability to a linear decrease in variability from pretest to posttest. BVE did not have a significant Test x Block interaction and this is indicated by the trend analysis across blocks of BVE which revealed the function remained as a linear decrease in variability from pretest to posttest. The Test x Block interaction, along with the trend of improved performance from pretest to posttest indicates the presence of a practice effect, which will be discussed later.

Neither of the 2 (Relevance) x 2 (Direction) x 2 (Test) x 10 (Block) ANOVAs with repeated measures on the last two factors for RE and BVE revealed any main effects of either relevance or direction. There was also no Relevance x Direction interaction. This means that the relevance or direction of self-reflection did not impact performance in terms of RE or BVE.

Even when transposing the data to match the point system methodology used in McKay et al. (2015), there was still no statistically significant effect on performance as a result of our manipulations that would support the self-invoking trigger hypothesis. Even the 2 (Relevance) x 2 (Direction) x 2 (Test) ANOVA with repeated measures on Test that was conducted for the point system methodology failed to show any significant main effects or interactions involving relevance and direction.

General Discussion

Neither Experiments 1 nor 2 supports the aspect of the self-invoking trigger hypothesis stating that self-activation impairs motor learning and performance. Experiment 1 demonstrated that there was no significant difference in performance between the internal reflection, external reflection, and control groups. In Experiment 1, there were varying degrees of focus on strengths and weaknesses among participants during the intertest task (refer to Appendix C), making it difficult to determine whether participants were thinking more about strengths or weaknesses after the task when they returned to take the posttest. Just as in McKay et al. (2015), it was unknown "whether participants were thinking of their performance in the previous block, of potential movement pattern adjustments, or of their experience with throwing in general" (p. 3). Moreover, Experiment 1 failed to replicate the intertest reflection task wording used in McKay et al. (2015). The present study prompted participants to reflect on their strengths and weaknesses as athletes while McKay et al. (2015) prompted participants to reflect on their strengths and weaknesses as throwers. This discrepancy was thought to potentially be a reason for why Experiment 1 failed to replicate the findings of McKay et al. (2015). As such, both direction and relevance of self-reflection needed to be tested.

Experiment 2 was devised as a way to address the limitations of Experiment 1 and to respond to the proposals of McKay et al. (2015) by studying how the direction and relevance of self-reflection affect motor learning and performance. Although a statistically significant interaction of test, block, and group was observed in Experiment 2, it appears to have been due to chance. Even so, the trend observed contradicted the effects predicted by the self-invoking trigger hypothesis as improvement was shown from pretest to posttest for all groups among all measurements of performance. Furthermore, no significant main effects or interactions involving relevance and direction were found for any of the measurements of performance, meaning that these do not significantly impact motor learning and performance.

Performance was measured by using BVE (precision) and RE (accuracy) in both experiments. These measurements were taken in centimeters and error was included in the data set even if the dart did not land on the dartboard. This method was intended to provide a more precise way of measuring error and performance in hopes of creating a more accurate representation of the phenomenon of interest. Since McKay et al. (2015) had statistically significant results, it was believed that a more precise method of measurement would help test the self-invoking trigger hypothesis more rigorously. However, the present study showed no statistically significant results with a trend of degradation in either Experiments 1 or 2.

The discrepancy could potentially be explained by the precision of measurements in the present study compared to the methodology of McKay et al. (2015). McKay et al. (2015) used a method of measuring in which participants threw their balls into certain areas. Each area had a certain whole integer value associated with it, and from this the error rate was calculated and statistical analyses performed. This method naturally decreases variance due to its lack of precision while also preventing errors that are too large from contributing to the total points accumulated. The present study collected raw data in centimeters, making the measurements of the present study more precise while increasing variability and variance. In a way, it can be beneficial to have greater precision because doing so can make it harder to see a statistically significant effect, which in turn more vigorously tests the phenomenon of interest.

The failure of the present study to replicate the same results is unlikely due to methodology since a similar methodology was performed in both studies. The 3 minutes allocated for the intertest task in the present study was not that different from the 1 minute allocated for the intertest task in McKay et al. (2015). A similar total sample size was used and the effect sizes were similar. One thing to note is that McKay et al. (2015) had a smaller number of groups than the present study, which could have increased their power enough to the point that they found significant results. Likewise, because the present study had a higher number of groups and therefore fewer participants per group, the power in the present study may have been relatively low compared to McKay et al. (2015). Unfortunately, power was not calculated for either of the studies, so this is simply speculation as to what this discrepancy in results is attributable to. Even though the questions asked during the intertest tasks in Experiment 1 did not exactly mirror the questions asked in the intertest tasks of the first experiment in McKay et al. (2015), these were addressed in Experiment 2. The reading aloud of responses from McKay et al. (2015) was replicated as to reinforce the self-activation and activation of participants' self-schemas that were occurring as a result of the manipulation. However, it is difficult to compare the present study to McKay et al. (2015) with complete accuracy since the two involve different tasks.

The discrepancy between the results of the present study and McKay et al. (2015) may simply be due to some inherent difference in dart-throwing and overhand ball throwing that may cause the self-invoking trigger hypothesis to be observed in one and not the other. It could be that the degradation effect predicted by the self-invoking trigger hypothesis exists and occurs in the dart-throwing task, but that it is simply not observed because it is being overridden by other phenomena. For example, most of the participants had little experience with dart-throwing, so it is possible that the effect of practice could outweigh any effect caused by our manipulations of self-reflection since the amount one practices is closely related to their performance of a task (Ericsson et al., 1993). Even for those who had never thrown darts, the reflection could have activated certain motor patterns from other throwing motor skills that were transferable to dart-throwing, therefore increasing performance. Evidence for the presence of practice effects are reflected in statistically significant main effects of test and block, but mainly in any Test x Block interactions for either MRE or BVE. The practice effect manifests itself in the improvement in performance from pretest to posttest among all groups. It is also possible that the degradation effect on performance predicted by the self-invoking trigger hypothesis simply does not exist. Alternatively, it may be that the present study simply failed to induce self-activation among participants or that this particular method of self-activation is ineffective. Even McKay et al. (2015) stated that it is unknown whether or not self-reflection is enough to hinder motor performance. More implicit methods that use attentional focus, like those used by Lohse et al. (2011) for example, could potentially be more effective, especially because most forms of self activation are implicit (Bargh et al., 2012).

It could also be that, in general, the degradation effects of self-reflection on performance only emerge after more practice. That is, it could be that self-reflection may only have a detrimental effect on motor skill learning and performance if the skill is more automated in the individual. Because many individuals in the sample did not have much experience with dart-throwing and likely did not have dart-throwing as an automated motor skill, this could be why self-reflection did not deteriorate motor learning and performance and could explain the presence of the practice effect and why performance improved in the present study. In order to address the limitations present with Experiment 2, studies on "experts" of a motor task of interest would need to be conducted. These "experts" would have the motor skills that are automated and would not experience as much of a practice effect as novices. This would reveal the effects predicted by the self-invoking trigger hypothesis assuming it exists. Unfortunately, these observations do not quite explain why McKay et al. (2015) and the present study had different results. Regardless, more research must be conducted to confirm any one of these proposed hypotheses.

McKay et al. (2015) state that a strong version of the self-invoking trigger hypothesis would demonstrate performance degradation in any type of self-reflection regardless of direction or relevance whereas a weak version would predict that the self-reflection be relevant to the motor task. The aspect of the self-invoking trigger hypothesis stating that self-activation leads to a degradation in performance is a fairly new area of research and requires more study before conclusions can be drawn. The present study fails to lend support for the self-invoking trigger hypothesis due both to a lack of significant results and a trend demonstrating improvement in performance.

Acknowledgements

I would like to acknowledge Dr. David E. Sherwood for his mentorship and guidance in both this project and other endeavors throughout my collegiate career. A special thanks to all of the undergraduate research assistants who helped to collect and analyze data in the Motor Behavior Laboratory, your efforts are much appreciated. I would also like to extend thanks to the other members of my committee, Dr. Steven Hobbs and Dr. Alice Healy, for taking the time out of their busy schedules to review my thesis and defense.

References:

Bargh, J. A. (1982). Attention and automaticity in the processing of self-relevant information. *Journal of Personality and Social Psychology*, *43*, 425–436.

Bargh, J. A., Schwader, K. L., Hailey, S. E., Dyer, R. L., & Boothby, E. J. (2012). Automaticity in social cognitive processes. *Trends in Cognitive Sciences*, *16*, 593–605.

Blakemore, S. J. (2003) Deluding the motor system. *Consciousness and Cognition*, *12*, 647-655.

Blakemore, S.J., Wolpert, D., & Frith, C. (2000). Why can't you tickle yourself? *NeuroReport*, *11*, R11–R16.

Chang, Y.-K., Ho, L.-A., Lu, F. J.-H., Ou, C.-C., Song, T.-F.,& Gill, D. L. (2014). Self-talk and softball performance: The role of self-talk nature, motor task characteristics, and self -efficacy in novice softball players. *Psychology of Sport and Exercise*, *15*, 139–145.

Chiviacowsky S., & Wulf G. (2002). Self-controlled feedback: does it enhance learning because performers get feedback when they need it? *Research Quarterly for Exercise and Sport*, *73*, 408–415.

Chiviacowsky S., & Wulf G. (2005). Self-controlled feedback is effective if it is based on the learner's performance. *Research Quarterly for Exercise and Sport* ,*76*, 42–48.

Chiviacowsky, S., & Wulf, G. (2007). Feedback after good trials enhances learning. *Research Quarterly for Exercise and Sport*, *78*, 40–47.

Erricson, K. A., Krampe, R. T., & Tesch-Römer, C. (1993). The role of deliberate practice in the acquisition of expert performance. *Psychological Review*, *100*, 363-406.

Feltz D. L., Chow D. M., & Hepler T. J. (2008). Path analysis of self-efficacy and diving performance revisited. *Journal of Sport & Exercise Psychology*, *30*, 401–411.

Gusnard, D. A., Akbudak, E., Shulman, G. L., & Raichle, M. E. (2001). Medial prefrontal cortex and self-referential mental activity: Relation to a default mode of brain function. *Proceedings of the National Academy of Sciences*, *98*, 4259–4264.

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

Hutchinson J. C., Sherman T., Martinovic N., & Tenenbaum G. (2008). The effect of manipulated self-efficacy on perceived and sustained effort. *Journal of Applied Sport Psychology*, *20*, 457–472.

Jeannerod, M. (2003). The mechanism of self-recognition in humans. *Behavioural Brain Research*, *142*, 1-15.

Jourden F. J., Bandura A., & Banfield J. T. (1991). The impact of conceptions of ability on self -regulatory factors and motor skill acquisition. *Journal of Sport & Exercise Psychology*. *8*, 213–226

Leite, C., & Kuiper, N. A. (2010). Positive and negative self-worth beliefs and evaluative standards. *Revista De Psihologie*, *56*, 219-230.

Lohse, K. R., Sherwood, D. E., & Healy, A. F. (2010). How changing the focus of attention affects performance, kinematics, and electromyography in dart-throwing. *Human Movement Science*, *29*, 542-555.

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

Markus, H. (1977). Self-schemata and processing information about the self. Journal *of Personality and Social Psychology*, *35*, 63–78.

McKay, B., Lewthwaite, R., & Wulf, G. (2012). Enhanced expectancies improve performance under pressure. *Frontiers in Psychology, 3*, Article 8.

McKay, B., Wulf, G., Lewthwaite, R., & Nordin, A. (2015). The self: Your own worst enemy? A test of the self-invoking trigger hypothesis. *Quarterly Journal of Experimental Psychology*, *68*, 1-10.

McNevin, N.H., Shea, C.H., & Wulf, G. (2003). Increasing the distance of an external focus of attention enhances learning. *Psychological Research*, *67*, 22-29.

Moritz S. E., Feltz D. L., Fahrback K. R., & Mack D. E. (2000). The relation of self-efficacy measures to sport performance: a meta-analytic review. *Research Quarterly for Exercise and Sport*, *71*, 280–294

Northoff, G., & Bermpohl, F. (2004). Cortical midline structures and the self. *Trends in Cognitive Sciences*, *8*, 102–107.

Northoff, G., Heinzel, A., de Greck, M., Bermpohl, F., Dobrowolny, H., & Panksepp, J. (2006). Self-referential processing in our brain – A meta-analysis of imaging studies of the self. *NeuroImage*, *31*, 440–457.

Sherwood, D. E., Lohse, K. R., & Healy, A. F. (2014). Judging joint angles and movement outcome: Shifting the focus of attention in dart-throwing. *Journal of Experimental Psychology: Human Perception and Performance*, *40*, 1903-1914.

Stapel, D. A. & Blanton H. (2004). From seeing to being: subliminal social comparisons affect implicit and explicit self-evaluations. *Journal of Personality and Social Psychology*, *87*, 468-481.

Stein, K. (1995). Schema model of the self-concept. *Journal of Nursing Scholarship*, *27*,187 -193

Wulf, G., Chiviacowsky, S., Schiller, E., & Avila, L. T. G. (2010). Frequent external-focus feedback enhances motor learning. *Frontiers in Psychology*, *1*, 59.

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*, 169–179.

Wulf, G., Lauterbach, B., & Toole, T. (1999). Learning advantages of an external focus of attention in golf. *Research Quarterly for Exercise and Sport*, *70*, 120–126.

Wulf, G., & Lewthwaite, R. (2010). Effortless motor learning? An external focus of attention enhances movement effectiveness and efficiency. In B. Bruya (Eds.), *Effortless attention: A new perspective in attention and action* (pp. 75–101). Cambridge, MA:MIT Press.

Wulf, G., McConnel, N., Gärtner, M., & Schwarz, A. (2002). Enhancing the learning of sports skills through external-focus feedback. *Journal of Motor Behavior*, *34*, 171-182.

Wulf, G., McNevin, N., & Shea, C. (2001). The automaticity of complex motor skill learning as a function of attentional focus. *The Quarterly Journal of Experimental Psychology*, *54A*, 1143-1154.

Wulf, G., Shea, C., & Lewthwaite, R. (2010) Motor skill learning and performance: A review of influential factors. *Medical Education*, *44*, 75-84.

Wulf, G., Zachry, T., Granados, C., & Dufek, J. S. (2007). Increases in jump-and-reach height through an external focus of attention. *International Journal of Sport Science and Coaching*, *2*, 275–282.

Appendix A: Informed Consent

An Investigation of the Self-Invoking Trigger Hypothesis

Principal Investigators: Armando Jauregui

and David Sherwood

PARTICIPANT INFORMED CONSENT FORM
Fall 2014

Please read the following material that explains this research study. Signing this form will indicate that you have been informed about the study and that you want to participate. We want you to understand what you are being asked to do and what risks and benefits-if any are associated with the study. This should help you decide whether or not you want to participate in the study.

CONTACT INFORMATION

You are being asked to take part in a research project conducted by Armando Jauregui and David Sherwood, PhD, Department of Integrative Physiology, 354 UCB, Boulder, CO 80309-0354. Dr. Sherwood can be reached at 303-492-7561.

PROJECT DESCRIPTION

The purpose of this research study is to determine how writing tasks may influence your ability to learn and perform basic motor control tasks.
Today, we are asking you to perform the dart-throwing task. Your goal in this task will be to learn a dart-throwing skill while trying to be as accurate as possible (aiming for the "bulls-eye", or center of the dart board).

You are being asked to participate in this study because you are a healthy adult between 18 and 40 years of age. Participation in this study is entirely your choice. We plan to recruit and test up to 36 adults.

PROCEDURES

Taking part in this study is completely voluntary. You do not have to participate if you don't want to. You may also leave the study at any time. If you leave the study before it is finished, there will be no penalty to you, and you will not lose any benefits to which you are otherwise entitled. The entire study will take approximately 30 minutes , which includes rest periods and practice time.

Initials ___________

Participation will take place at the Motor Behavior Lab, Room 101 in Temporary Building #1 room 101, at the University of Colorado at Boulder.

RISKS AND DISCOMFORTS

There are some potential risks if you take part in this study. Potential risks include fatigue and sore muscles, You will be given rest periods to minimize fatigue and sore muscles. As with any research study, there may be additional unforeseeable risks.

You will not be asked about any illegal activities, but if you should discuss such activities, that information could be requested by authorities such as the police or court system.

BENEFITS

You may not receive any direct benefit from taking part in this study. However, your participation in this study will help us better understand how cognitive variables affect motor skill learning and performance.

COST TO PARTICIPANT

There are no direct costs to you for participation in this study.

ENDING YOUR PARTICIPATION

You have the right to withdraw your consent or stop participating at any time. You have the right to refuse to answer any question(s) or refuse to participate in any procedure for any reason. Refusing to participate in this study will not result in any penalty or loss of benefits to which you are otherwise entitled.

CONFIDENTIALITY

We will make every effort to maintain the privacy of your data. We will maintain research files (data, documents) separate from any information about your identity such as your name. We will use a randomly generated code number to store your research files. Your de-identified data may be shared with other researchers for research purposes not yet known. We will only share your de-identified data with collaborators who agree to maintain the privacy of your data. Any additional data generated from the analyses will be kept separate from your personal identification information.

Other than the researchers, only regulatory agencies such as the Office of Human Research Protections and the University of Colorado at Boulder Institutional Review Board may see your individual data as part of routine audits.

Initials ___________

Self-invoking trigger

Your data will be kept for a maximum of 10 years. After 10 years, electronic data and any paper documents will be destroyed.

QUESTIONS?

If you have any questions regarding your participation in this research, you should ask the investigator before signing this form. If you should have questions or concerns during or after your participation, please contact Dr. Sherwood at 303 492-7561.

If you have questions regarding your rights as a participant, any concerns regarding this project or any dissatisfaction with any aspect of this study, you may report them - confidentially, if you wish -- to the Institutional Review Board, 3100 Marine Street, Rm A15, 563 UCB, (303) 735-3702.

AUTHORIZATION

I have read this paper about the study or it was read to me. I know the possible risks and benefits. I know that being in this study is voluntary. I choose to be in this study. I know that I can withdraw at any time. I have received, on the date signed, a copy of this document containing 3 pages.

Name of Participant (printed) ___________________________________

Signature of Participant ____

Date __________________________

(Also initial all pages of the consent form.)

Appendix B: Questionnaire

Subject Information

Subject # __________

Sex M F

Age ______________ Height (Approximate) __________________

Weight (Approximate) __________________

Hand Dominance L R

How often do you play darts?

______ I have never played darts

______ I rarely play darts (1-3 times per year)

______ I sometimes play darts (1-3 times per months)

______ I often play darts (3+ times per month)

______ I regularly play darts (multiple times per week)

Appendix C: Experiment 1 Intertest Tasks

The participants' self-activation in Experiment 1 was achieved by the following intertest tasks:

Group 1: Internal reflection

On this page you will have 3 minutes to write a few statements about yourself as an athlete. Specifically, what are your strengths and weaknesses as an athlete?

Group 2: External reflection

On this page you will have 3 minutes to write a few statements about an athlete that you are familiar with. Specifically, what are his or her strengths and weaknesses as an athlete?

Group 3: Control*

On this page you will have 3 minutes to complete a simple writing task.

Starting with the letter ____ write every third letter of the alphabet.

Starting with the letter ____ write every third letter of the alphabet.

*Two different letters were chosen at random to fill in the blank for this condition. Both blanks were filled in before the participant began and the participant could move on to the second task after completing the first task

Below are some examples of reflections from participants in different groups to illustrate the varying amount of strengths and weaknesses reported by participants during the intertest task in Experiment 1:

Example 1: Balance of Strengths and Weaknesses

A participant from the internal reflection group who focused fairly equally on both strengths and weaknesses said, "My strengths as an athlete include dedication both on and off the field. For rugby I make sure to go to the gym outside of practice to make sure I can perform my best on the field. A weakness is that sometimes I can get in my own head and psych myself out. If I do that sometimes I can mess up something I have practiced and been successful at. I hope my dedication can help me overcome the mental block in the end. Another strength is that I am competitive. That always makes me push myself but that can be a weakness too.

Self-invoking trigger

Example 2: Focus on Strengths

A participant from the external reflection group who focused mostly on strengths said, “This person is very determined and hard working. He has continually made sacrifices throughout his career to pursue being the best at ski racing. Not only is he strong physically, spending many hours in the off season in the gym, he is also mentally strong, which is one of the most important aspects of being a successful ski racer. One of his weaknesses includes the ability to let go and adapt to things you cannot control—for example, equipment, coaching, etc. He is very good at competing under pressure. (Husband)”

Example 3: Focus on Weaknesses

A participant in the internal reflection group who focused mostly on weaknesses said, “I’ve played sports my whole life and specifically volleyball and track in high school. I am a mental athlete though meaning I am always inside my head and I am my hardest judge. I would say I am a good athlete physically but mentally I struggle to do well consistently.”

Appendix D: Experiment 2 Intertest Tasks

The participants' self-activation in Experiment 2 was achieved by the following intertest tasks:

Group 1: Positive Relevant

On this page you will have 3 minutes to write a few statements about your most recent dart-throwing experience. Specifically, what did you do well?

Group 2: Negative Relevant

On this page you will have 3 minutes to write a few statements about your most recent dart-throwing experience. Specifically, what did you **not** do well?

Group 3: Positive Irrelevant

On this page you will have 3 minutes to write a few statements about yourself as an aerobically trained athlete (for example, running, swimming, or bike riding). Specifically, what are your strengths?

Group 4: Negative Irrelevant

On this page you will have 3 minutes to write a few statements about yourself as an aerobically trained athlete (for example, running, swimming, or bike riding). Specifically, what are your weaknesses?

*The "most recent dart-throwing experience" referred to the pretest that was conducted right before the writing task was given

Below are some examples of reflections from participants in different groups to illustrate the responses reported by participants during the intertest task in Experiment 2:

Example 1: Positive relevant

For the first time throwing darts, I feel like I did a few things well.

1) I kept a consistent throwing motion trying to develop muscle memory
2) I hit the board every time
3) I got one bullseye
4) I never crossed the line for throwing

Example 2: Negative relevant

-I did not take the same approach (angle of my arm) each time

Self-invoking trigger

-I didn’t throw as hard or as soft as certain bullseye tosses each time
-I probably tried to aim a little to much rather then sticking with the form that worked on the best shots
-I let the numbers of the measurements get into my head occasionally
-I almost felt that at times I could’ve shot better from farther back

Example 3: Positive irrelevant

I run and am a triathlete. My strengths in it are my endurance. I am not very fast, but I can do the distance. I am a fast swimmer with triathlons. It is my strongest leg of triathlons. Bike riding is my least favorite, but I have strong legs, so I am pretty good at it. Hills on bikes are my strength, but distance not so much.

Example 4: Negative irrelevant

As an aerobically trained athlete (playing soccer, waterpolo, swimming, and running)

-endurance: I am quick but not always quick for long (using high amounts of energy for long time)
-sort of unreliable with my off hand or foot aka left arm or leg
-not always very fast, would not consider myself to be a fast swimmer or runner