Learning Styles and Feedback Preference:
Use and Effects in the Acquisition and Retention of Dart Throwing

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Abstract

There is limited existing research investigating the use of learning style preferences to enhance the learning and retention of motor skills despite extensive evidence that has been gathered on this topic in the academic setting. This study sought to determine the effect of instruction and feedback styles with regard to preference on learning and retaining motor skills. The motor task of dart throwing with the center bulls eye of a dartboard as the target was used. Forty-one college-aged subjects participated in acquisition trials and a retention test after being given either their preferred or non-preferred method of visual or verbal instruction based on a motor learning preference questionnaire. Subjects were blindfolded while throwing and given both visual and verbal feedback in blocked or random order during the acquisition phase. The immediate retention test consisted of 10 blindfolded throws with no feedback. Error for all trials was measured as radial error in centimeters from the center of the target. Results showed no significant effect for preference in instruction or acquisition. Subjects performed significantly better during acquisition after receiving visual feedback compared to verbal feedback. There was no difference in retention test scores between feedback order groups, however subjects who preferred visual feedback tended to have lower radial error. These findings show that preference played no significant role in learning or retention of the motor task. Subjects were better able to use visual feedback over verbal feedback to improve performance during practice and had similar performance on the retention test regardless of feedback order.
Learning Styles and Feedback Preference: Use and Effects in the Acquisition and Retention of Dart Throwing

The purpose of this study was to investigate and evaluate learning styles as they apply to motor learning, regarding both methods of instruction as well as augmented feedback. More specifically, the effects of receiving different styles of instruction and augmented feedback with regard to the learner’s stated preferences for each will be investigated. “Learning style” is referred to as a learner’s preferred method of receiving instruction and processing augmented feedback. The idea of using learning styles to help students/learners acquire and retain information and skills more effectively has been a topic of research and discussion in the aspect of classroom-style learning. Pashler, McDaniel, Rohrer, and Bjork offered an analysis, Learning Styles: Concepts and Evidence. This provides an in-depth evaluation of research involving learning styles in the classroom as well as current perspectives on using both the preferences of students and methods of instructors. The Learning Styles Hypothesis developed from this previous research claims that learners will perform better when instructed using their preferred style of learning. Even though there is little evidence of a student’s preferred style of learning resulting in better learning, the concept is still marketed and used by instructors. Pashler et al. point out that “It is also natural and appealing to think that all people have the potential to learn effectively and easily if only instruction is tailored to their individual styles” (p. #107).

Literature Review

Relatively little research has been done to look at the effects of learning styles and learning style preferences in the realm of motor learning in contrast to classroom learning. Teaching and learning in a motor learning setting presents distinct characteristics that are
absent or different from the classroom learning setting (Dunn, 2009). Such characteristics include the dependence of motor skill acquisition on time-appropriate cues, mental-physical coordination, and sources of feedback needing to be processed in order to make adjustments in movement. These differences bring up the question of whether learning style preferences play a different and/or more significant role when it comes to motor learning. Dunn (2009) suggested the use of the VARK Inventory, a learning style preference questionnaire, to understand both coach and athlete preferences and better coordinate teacher-learner compatibility. The validity of using this questionnaire was examined in recent research reviews including a more recent publication, *Perspectives on Learning Styles in Motor and Sport Skills* (Fuelscher, Ball, & MacMahon, 2012). This article notes “...the athlete version of the VARK is still based on classroom content learning and not based on learning motor skills... Instead, an athlete learning styles questionnaire to evaluate preferred learning styles for motor skills should include items that are specific to motor skills in sport specific environments” (Fuelscher et al., 2012). Based upon this limitation, a more relevant questionnaire was developed for the purposes of this study.

**Presentation of the Skill.**

One of the primary aspects in the learning of motor skills is the presentation of the task to the learner. This normally occurs during the initial phase of learning. Demonstration or modeling is one strategy of presentation that encourages observational learning (Bandura, 1986, p. #47-49). This method utilizes a visual model for teaching. Existing evidence supports that vision is the preferred source of sensory information, particularly at the novice level. Visual presentation is especially useful in motor learning when the task requires the acquisition of a
new pattern of coordination; the observer is able to pick up the invariant features of the coordinated movement pattern (Magill, 2011, p. #311).

Other research has investigated whether receiving verbal or visual instruction is more effective for motor learning. A study performed by Al-abood, Davids, and Bennett (2001) sought to determine the constraints of visual demonstration versus verbal instruction on the acquisition of movement coordination. The main purpose of this research was to look at the central hypothesis of the visual perception perspective, which states that the observation of visual instruction, especially in early stages of learning, better facilitates acquisition because it conveys relative-motion information essential to movement coordination (Al-abood et al., 2001).

In this study, 15 male graduate students were recruited to participate in a dart-throwing task. All subjects were right-handed and naïve to the task being learned. Subjects were randomly assigned to one of three groups: the Modeling Group (MG) who received visual instructions for the task, the Verbally Directed Group (VDG) who received only verbal instructions for the task, or the Control Group (CG) who did not receive either form of instruction. Visual instructions were given to the MG through a videotape model and verbal instructions were read to the VDG. The dart-aiming task was modified from typical overhand dart throwing to require an underhand throw and aim at a dart board placed on the ground 3 meters from the throwing line. Subjects were instructed to attempt to score as many points as possible by throwing the darts at the board, which was modified to contain 10 concentric circles used for scoring. Subjects participated over two days, with 100 acquisition trials on the first day and 20 retention trials on the second day. Results and statistical analyses of this study showed
no significant group effects for movement outcome in the overall score of the subjects. The results for movement coordination obtained through an online motion analysis system to analyze movement kinematics, however, showed a significant group effect. The MG displayed closer movement approximation to the model than the VDG despite the lack of difference in outcome scores.

The motor task being learned also plays a role in determining the method of instruction that results in better acquisition of the skill. A study performed by Doody, Bird, and Ross (1985) compared the relative effectiveness of auditory and visual models in the acquisition of a timing task. Forty-eight right-handed female college students were instructed to perform a new motor task, the displacement of seven barriers, using only the right hand, over 2100 msec, using either an audio model, visual model, or both. Correct execution of this motor task would produce a distinct, rhythmic auditory pattern. Subjects were divided into four groups: Control, Audio, Visual, and Audio + Visual. Subjects in the control group did not receive any instruction, and were given Knowledge of Results (KR) after each trial, in terms of error from the goal movement time. Subjects in the three modeling groups received brief verbal description of the task before the model presentation. The audio model consisted only of the auditory pattern of task performance, in which the subjects heard the sounds associated with the barrier displacements. The visual model presented consisted of a silent video demonstrating the correct performance. For the Audio + Visual group, both the auditory and visual portions were presented. After each trial, the three modeling groups received immediate KR followed by 5 presentations of the correct model with relevant KR.
Statistical analyses of the results for this study determined that all four groups significantly improved their performance during the acquisition phase. For the acquisition phase of the experiment, the main effect of groups was also significant. Post-hoc analyses showed that the absolute error for all trials in the Audio group and the Audio + Visual group were lower than the Visual group and the Control group. The Audio group and the Audio + Visual group did not significantly differ from each other during this phase. Results from the immediate retention test showed that the Audio group and the Audio + Visual group had smaller error (mean root mean square error, E) than the visual group, with the control group having the largest error of all groups. The main effect of audio/no audio for E was significant, but not for vision/no vision. These data suggest that the presence of an auditory model is the critical factor in the acquisition of this skill, with or without a visual model.

These studies provide evidence that motor skills can be learned with both auditory and/or visual presentation, the use of which may be determined by the specific motor task. Alabood et al. (2001) showed no significant difference between the two methods of instruction in performance outcome, but showed that visual instruction resulted in better coordination of movement in the task. Both studies showed significant improvement in all groups over the course of the trials, and both studies provided KR after each trial. Doody et al. (1985) also provided instruction, depending on the group, with the KR after each trial. With this in mind, it could be suggested that KR and method of feedback is more of a factor in acquisition and improvement of motor skills than instruction. A major weakness of these two studies was that neither study incorporated learning style preferences. Learning might be better if the instruction and augmented feedback style were related to learner preference.
Augmented Feedback

Augmented feedback provides information about the performance of a task that is not readily available to the learner and can be essential for learning when task-intrinsic feedback cannot be used (Magill, 2011, p. 333). There are two types of augmented feedback, Knowledge of Results (KR) and Knowledge of Performance (KP). Knowledge of Results is defined as externally presented information about the outcome of the performance of a skill, while Knowledge of Performance is externally presented information about movement characteristics that led to the outcome.

Massa and Mayer (2006) performed a study to look at different modes of augmented feedback. The study sought to determine the effects of visual versus verbal augmented feedback in subjects who were either visualizers (preferred visual learning) or verbalizers (preferred verbal learning). Both visualizers and verbalizers completed a computer-based science lesson that offered help screens with either glossary definitions (text/verbal group) or illustrations (pictorial group). Three posttests were given after the lesson. A definition test sheet required that subjects write down the definition of six terms defined in the lesson, the reasoning test sheet consisted of four multiple choice questions, and the problem solving sheet consisted of five short-answer questions. Results showed that subjects with visual or verbal preference did not differ on any of the tests and no significant correlations were found between any of the tests and preference. Overall, subjects in the pictorial group outperformed the text/verbal group on the posttest. A limitation, however, is that this study did not involve a motor task.
Ronsse et al. (2011) studied the effects of visual or auditory augmented feedback on motor learning of a bimanual coordination pattern. Thirty-eight right-handed adult subjects were separated into two groups to learn the same task, one group receiving visual feedback and the other receiving auditory feedback during training. The goal was to produce a 90-degree out-of-phase coordination pattern with the hand. The auditory group practiced the task while receiving concurrent audio feedback through turning point pacing with low- and high-pitched tones indicating the movement pattern. The visual group practiced the pattern while continuous visual feedback was provided, displaying the left and right angular wrist displacement. During the acquisition phase, the subjects also performed 0-degree in-phase movement patterns. This served as the control condition, since the in-phase pattern is intrinsic and does not require motor learning. The results of this experiment showed that the visual group performed significantly better on average than the verbal group during practice, but the two groups performed comparably on both the pre- and post-tests. Elimination of the augmented feedback during the post-training trials significantly affected the visual group, whose performance suffered, but not the verbal group, showing a dependence on augmented feedback in the visual group.

Although the previously mentioned studies evaluated different methods of instruction and feedback on motor learning, the results across the studies are inconsistent. Furthermore, only one of the studies incorporated visual versus verbal preference as a factor, and no correlation was found between preference and performance outcomes (Massa & Mayer, 2006). The question of the effects of auditory or visual instruction and augmented feedback with regards to preference in motor learning has not been adequately addressed with such limited
previous research. With this in mind, Pashler et al. suggested guidelines for evidence needed in order to show support for a positive correlation between learning style preferences and learning. In general, evidence must show that the learning style that provided the best outcome for one kind of learner is different from the learning style that optimized the outcome of the other kind of learner. For example, in a study looking at verbal and visual learners, the verbal group must perform better than the visual group when using a verbal method of learning while the visual group must perform better than the verbal group when using a visual method of learning. If learners from both groups perform better using one method of learning while having the same or worse performance with the other method of learning, the evidence is considered unacceptable in terms of supporting the learning-styles hypothesis (e.g., both groups have improved performance with a visual method of learning as compared to a verbal method of learning). The goal of the current study was to determine the role of preference regarding instructional method and style of augmented feedback provided in learning and retention of a motor task.

Methods

Subjects

Forty-one college students, 24 women and 17 men, from classes in the University of Colorado Boulder Department of Integrative Physiology were recruited to participate in this study. Participation in the study was not restricted in any way relating to gender, major area of study, physical ability, or other reasons such as vision or hearing problems or other disability. Subjects wearing corrective lenses or contacts were encouraged to use them normally for the study. Age ranged from 19-47 years old with a mean age of 22 years old. Subjects taking a
statistics course in Spring 2015 and the Dynamics of Motor Learning course in May 2015 were offered one extra credit point in the class to participate. Subjects signed a waiver and were able to withdraw from the study at any point.

Subjects were placed into preference groups based on their completed learning style preference questionnaire and randomly assigned into a preferred or non-preferred group for both instructional style and type of augmented feedback. A total of nine subjects preferred verbal instruction and 32 preferred visual instruction. Every other subject received their preferred mode of instruction; six subjects received preferred verbal instructions, three received non-preferred visual instructions, 15 subjects received their preferred mode of visual instructions, and 17 subjects received non-preferred verbal instructions. A total of 21 subjects preferred to be given verbal feedback while 20 subjects preferred visual feedback. All subjects received both kinds of augmented feedback equally.

**Materials**

The materials utilized in this study include a blank dart board, without the standard numbering for points, mounted to a backboard and wall approximately 2.36 meters from the throwing line, two standard darts, a blindfold, and a measuring tape. An iPhone was used to record the segments of the instructional video and iMovie software was used to produce the final video. Paper copies of the waiver form with a short demographic and preference questionnaire were filled out in pen by each participant. Participants viewed the video using full screen on a 12-inch screen laptop. Error was recorded manually on printed data sheets and entered into an Excel spreadsheet.

**Procedure/Task**
Dart throwing was used as the motor skill to be learned and practiced by the subjects during the study as a simple and discrete motor task. The goal of this task was to hit the center red bulls eye. Most subjects had little to no prior experience with throwing darts – 7% of subjects had never played darts before, 83% of subjects reported that they “rarely” played darts (the subject has played darts before but plays no more than three times per year), while only 10% of subjects claimed to “sometimes” play darts (1-3 times per month).

Participants signed a consent form and filled out a short questionnaire prior to testing (See Appendix A). A slightly longer second questionnaire was also developed to determine a subject’s verbal or visual preference with instruction style and feedback style. This questionnaire was nine questions in length and contained questions pertaining to motor skills and motor learning (See Appendix B). The questionnaire used for this study was based off the VARK questionnaire, but was modified to more directly question the subject about motor learning preferences without using classroom learning preferences as a basis. Three of the questions were used to determine instructional preference, five were used to determine augmented feedback preference, and one question served as a random control question about general preference to be used if any subject fell under the categories of “neither” or “both” verbal and visual preferences.

The preference questionnaire was evaluated for all subjects to determine their placement into the verbal or visual preference group for both instruction and feedback styles. Subjects were then randomly placed into a group to receive either their preferred or non-preferred style of instruction. Before receiving instructions, each subject threw two dart throws at the board which were not measured or recorded. In order to manipulate the instructions
given to each subject to be exclusively visual or verbal in nature, a method for each style of instruction was developed. The best effort was made to include the same quantity and quality of instruction in both methods of instruction. Subjects receiving visual instruction watched an instructional video with no sound while subjects receiving audio instructions only were read a set of instructions aloud. The instructions gave directions on foot placement, body position, arm position, hand grip, and throwing the dart (See Appendix C).

Subjects were blindfolded for the trials consisting of 40 dart throws in sets of two for the acquisition phase and 10 throws in sets of two for the retention test. During the acquisition phase, subjects were allowed to look at the blank dart board before each set in order to stay oriented to the dart board but were blindfolded before throwing. The subject was told to either remove the blindfold after the first throw to look where the dart had landed for visual feedback, or to keep the blindfold on so verbal feedback could be provided. Verbal feedback was given in terms of position on the board using sections on the board numbered one through 20 in the clockwise direction and diagonal distance to the nearest centimeter from the center of the red bulls eye. Feedback was only given after the first throw of each set of two in order to assure that the first throw would be a “KR” throw. The second dart was thrown and no feedback was given, being a “no KR” throw. Radial error (RE) was determined for every throw by measuring the X and Y distance from the center of the red bulls eye to the nearest half centimeter with a standard tape measure, squaring each value, summing them, and taking the square root.

The main measure of performance during acquisition was the difference in RE between the “KR” and the “no-KR” throws. RE difference scores were averaged for each feedback type. A
positive score indicated an improvement in accuracy and a negative score represented less accurate performance after feedback. For retention, the RE was computed for each trial and averaged over the ten trials.

Feedback order for the first twenty-five subjects was determined using a random online generator to assure each subject received ten trials each with verbal and visual feedback in a random order. The order was also randomized every fifth subject, creating five different groups who received feedback in a different random order. The last 16 subjects were placed in the blocked feedback group and were given consistent visual or verbal feedback for the first ten sets and consistent verbal or visual feedback for the last ten sets. The order of receiving visual or verbal feedback first for blocked groups was also changed every fifth subject. The goal of separating subjects into these two groups for feedback order was to determine whether a difference existed between subjects who were unable to predict the method of feedback they would receive compared to subjects who could predict which method of feedback would be used. With a predictable order of feedback, subjects could potentially better adjust to and improve with feedback during the acquisition phase, whereas a random order of feedback might result in higher error during the acquisition phase but lower retention error due to less reliance on feedback.

Statistics

The software program SPSS was used to run statistical analyses of the data. In order to determine the effects of preference, a between-subjects ANOVA was run on the RE from the first recorded throw with a 2 (Group: Preferred/Non-preferred) x 2 (Instruction Mode: Auditory, Visual) design. The RE difference scores following either verbal or visual feedback during
acquisition were analyzed with a 2 (Group: Preferred/Non-preferred) x 2 (Feedback mode: Verbal, Visual) x 2 (Feedback order: Blocked, Random) mixed ANOVA with repeated measures on feedback mode. The RE on retention was analyzed with a 2 (Feedback Order: Blocked/Random) x 2 (Feedback Preference: Audio/Visual) between-subjects ANOVA.

**Results**

**Instructional Preference**

According to our hypothesis, the Preferred group should have had less error overall for the first “instructional throw” than the Non-preferred group whether receiving the visual or verbal method of instruction. Figure 1 shows the RE of the initial throw for subjects who received their preferred method of instruction compared to subjects receiving their non-preferred method of instruction. Subjects receiving visual instruction had greater RE scores (28 cm) than those receiving audio instructions (18 cm), regardless of their preference. However, the effect of instruction mode was not significant, $F(1, 37) = 2.48, p > .15$, and the Group x Instruction Mode interaction was not significant, $F(1, 37) = .29, p > .5$. Subjects receiving their preferred method of instruction had a mean RE of 23.8 cm while the non-preferred group had a mean of 23 cm, but there was no effect of group, $F(1,37) < 1$.

**Effect of Feedback Mode**

The difference in RE between the throws with and without augmented feedback for acquisition is shown in Figure 2. Recall that larger positive values correspond to a greater improvement in performance after feedback whereas negative values represent a decrease in accuracy. Improvements were shown after visual feedback, especially in the verbal preferred group (4.4 cm) compared with the visual preferred group (3.0 cm). Those receiving verbal
feedback did not improve, especially those preferring visual feedback (-4.9 cm) compared to those preferring verbal feedback (-2.7 cm). However, the Group x Feedback Mode interaction was not significant, $F(1,39) < 1$. The mean difference in RE between KR and no-KR trials for subjects receiving verbal feedback was -3.87 cm whereas the mean difference for subjects after receiving visual feedback was +3.74 cm. Subjects had significantly more improvement between throws when receiving visual feedback as opposed to audio feedback $F(1,39) = 44.97, p < .001$.

Although all subjects had more improved performance with visual feedback and an increase in error after receiving audio feedback, the data illustrated in Figure 2 indicates that subjects who preferred audio feedback tended to have less of an increase in error after verbal feedback than those preferring visual feedback. Subjects preferring audio feedback also had greater improvement in performance after receiving visual feedback than subjects who preferred the visual method of augmented feedback.

**Effect of Feedback Order**

The effect of having a random feedback order as compared to a blocked order was analyzed with data from acquisition as well as the retention test. Figure 3 shows the difference in RE for the two practice orders and the two augmented feedback modes for the acquisition phase. Having a random schedule of feedback resulted in greater improvement with visual feedback and a smaller elevation in error with audio feedback compared with the blocked feedback order. However, the Feedback Mode x Feedback Order interaction was not significant, $F(1,37) < 1$. Overall, subjects in the blocked feedback order group had an average difference in RE of -1.43 cm after feedback whereas subjects receiving feedback in a random order had an average difference in RE of 0.83 cm. The effect of feedback order during acquisition was not
significant, $F(1,37) = 2.40, p > .12$. None of the other interactions with practice order were significant, ($ps > .36$).

The retention test compared the RE of subjects in the random feedback group compared to block feedback group. No significant difference was found in RE of the two groups, $F(1,37) = 1.51, p > 0.2$. Figure 4 shows the RE for the retention test in the random and blocked feedback groups in terms of visual versus verbal feedback preference groups. The average RE for the feedback order groups is also presented to compare the overall effect of preference. The interaction of Feedback Order x Feedback Preference was not significant, $F(1,37) = < 1$.

Subjects in the visual preferred group tended to have a lower RE during the retention test in both feedback order groups compared to subjects in the verbal preferred group. However, the effect of feedback preference was not significant, $F(1,37) = 2.884, p = .098$.

**Discussion**

It was expected that subjects who received their preferred method of demonstration would have a lower initial RE. Subjects were expected to have a greater improvement in performance (greater positive difference in RE) after receiving their preferred mode of augmented feedback compared to receiving a non-preferred mode. It was also expected that subjects who received augmented feedback in a random order would have a lower RE on the retention test than subjects who received feedback in a blocked order. The results of this study did not support the hypotheses made regarding learning style preference and the related effects on acquisition and retention.

The results of this study concluded that no significant difference existed in radial error between subjects who received their preferred method of visual or verbal instruction.
Therefore, preference regarding method of demonstration had little to no effect on initial performance. There was almost no difference between the preferred and non-preferred groups, and the radial error of the first throw was largest in the visual group compared to the verbal group. This finding does not agree with the Bandura’s (1986) theory that observational learning would be most effective for novices. This inconsistency could be due to certain factors relating to the study. Bandura’s theory (1986) pertains primarily to learning at the novice level in cases where the subject has rarely or never performed the task before. The majority of subjects in this study had minimal to moderate experience throwing darts previously. Although subjects could not be labeled as experts, most subjects were considered past the most novice stage of learning in this motor task. Due to previous performance of the task and probable previous demonstration by some other outside source, the visual model may have been a less effective mode of instruction for subjects with motor programs already developed for the skill. Still, the lack of significance between the two methods of instruction is consistent with Bandura’s (1986) explanation of different modes of modeling. “In prescribed skills, which must be performed in a uniform way because of custom or natural requirements, words and actions convey equivalent information” (Bandura, 1986, p. 73).

The results pertaining to instruction, however, are consistent with results reported by Al-abood et al. (2001). Their results showed no significant difference in outcome scores based on method of instruction, only in movement characteristics. The visual instruction provided in the current study may have helped subjects in their performance of the movements in the task, but this had little to no effect on the outcome scores measured.
Referring back to Pashler et al., because both preference groups tended to have better performance with verbal instruction and a higher error with visual instruction, this represents unacceptable data to support the learning-styles hypothesis. Data and results pertaining to the second hypothesis also proves to be unacceptable evidence. The significant difference found between verbal and visual feedback regardless of preference supports that visual feedback is more effective than verbal for learning this motor task. Massa and Mayer (2006) showed similar findings in their data with no significant difference in performance based on preference and the visual group having greater improvement. Ronsse et al. (2011) also showed similar data; the visual feedback group performed significantly better during practice than the verbal feedback group during acquisition. These trends support the theory that visual feedback is overall better for performance during practice. Visual feedback in the current study may have provided more accurate information, as subjects were able to see exactly where the dart landed relative to the target. Verbal feedback was provided in terms of the section on the dart board (1-20, clockwise) and diagonal distance in centimeters from the center of the red bulls eye. This method potentially provided less accurate feedback because it required more cognitive processing by the subject in order to determine the error and correction needed. In addition, subjects might not have been accustomed to measuring in centimeters, which could cause difficulty in the ability for a subject to have an accurate estimate of distance from the target.

Auditory feedback has been investigated as a means of providing augmented feedback for motor tasks, but presents a number of limitations. Sigrist, Rauter, Riener, and Wolf (2012) provided an analysis of augmented feedback using visual, auditory, haptic, and multimodal methods. First, the effectiveness of the auditory feedback depends on the correct
interpretation and response of the subject. Like visual feedback, there must be appropriate timing and it must provide accurate information. Audio feedback has been shown to be used effectively with motor tasks, especially with temporal or rhythmic tasks. However, if the audio display used is unfamiliar, it may require a certain period of time before it becomes beneficial for the subject to use (Sigrist et al., 2012).

Typically, in motor learning, random practice has to do with altering the motor program being practiced or practicing different aspects of movement characteristics of the skill such as practicing different types of swings in a random order when learning to play tennis (Magill & Hall, 1990). Although variation of feedback order is not conventionally considered one of the pertinent aspects of motor learning, the manipulation was set as part of the experiment to account for differences in performance that might occur if a subject receives feedback in a predictable order compared to a subject that receives feedback in a random, unpredictable order. No significant differences between the blocked and random feedback groups were found either in practice or retention, providing evidence that having such variation has no effect on learning motor tasks. However, there is very strong evidence that true random practice can improve transfer and retention of motor skills (Magill & Hall, 1990).

**Strengths**

This study has a number of strengths, including a large enough sample size to provide a high statistical power. Forty-one subjects participated in this study, providing a comparable number to similar studies performed such as Massa and Mayer (2006) with 52 subjects, Ronsse et al. (2010) with 38 subjects, Al-abood et al. (2001) with 15 subjects, and Doody et al. (1985) with 48 subjects. The sample group also had a relatively consistent level of previous experience
with the given motor task. The questionnaire was developed with the goal of creating a more valid test relating to motor learning preference, based on the previously used VARK questionnaire but modified based on suggestions from research to make it more relatable to motor skills. The motor skill used in this study was a discrete and simple task that could be learned in the amount of time given for each trial. Consistent methods of verbal and visual instruction and feedback were used. Error was measured using consistent means for every subject, and each subject was evaluated and tested by the same person.

Limitations

One limitation of this study involves the previous experience of subjects with the motor skill to be learned. Most subjects had performed the task at least once before and were familiar with the general characteristics of execution. During the practice trials, visual feedback was eliminated by means of wearing a blindfold, but subjects were still able to interpret audio feedback created from the sound of the dart hitting the target. The dartboard, backboard, and wall each presented subjects with distinct sounds that could give subjects an idea of the magnitude of error. The subjects’ familiarity with estimating in centimeters might also have played a part in determining the usefulness of verbal feedback.

Future Directions

With the results and limitations of this study in mind, there is a clearer direction for future research in the area of learning styles and motor learning. First, future research should attempt to create and/or validate a method of determining preferences in motor learning. Although this study attempted to create a more valid questionnaire that focused completely on aspects of motor skill learning, it has not been empirically validated. Fuelscher et al. (2012)
suggests using a questionnaire that identifies preferences across different sports or tasks (e.g. soccer, tennis, etc.). Also, similar to suggestions made by Pashler et al. for classroom-related studies, the design of a study should be set up in such a way that subjects are tested using all learning styles included in the testing. The purpose of this design is to provide data proving that subjects preferring one method of learning perform best with that method compared to the others whereas subjects preferring a different method perform best when that method is used, and that the method that is best for one preferred group is different from the method best utilized for the alternative preferred groups.

Second, either a test of proficiency in the skill prior to testing each subject or modifying the motor task in such a way that all subjects must learn a new modified skill, as seen in the study by Al-abood et al. (2001) is suggested. Because subjects in the current study were familiar with the motor task used to varying degrees, their relative experience levels were accounted for prior to testing in terms of how often the subject played darts. Subjects with the same amount of reported experience, however, may vary in their proficiency with the task which could potentially have an effect on acquisition and amount of improvement. For example, a novice subject might start out with a very large error and have more room to show improvement over acquisition whereas a proficient subject will begin with less error and might have a lower improvement score in acquisition even if their scores overall are more accurate.

Another aspect to consider is the effects of augmented feedback in creating a dependence. Ronsse et al. (2011) showed that subjects receiving visual feedback while learning a new motor task developed a dependence on the augmented feedback not found in the audio feedback group. Data showed that the visual areas of the brain exhibited higher activity in the
visual feedback group whereas the audio feedback group showed broader activation (e.g. prefrontal areas) including regions involved in auditory processing. Performance dropped significantly for subjects in the visual group when the augmented feedback was removed. However, no decrease in performance was seen in the audio group after feedback was removed. The current study was unable to determine retention error based on specific feedback style and reliance because all subjects received both styles of feedback equally. Building upon these findings, further testing could be done to determine if reliance on specific augmented feedback results in higher error on retention tests by including a subject group to receive strictly verbal feedback and one to receive strictly visual feedback. Subjects in the verbal group may need more time to acclimate to the type of feedback being given with this study design.

Lastly, measures used to assess the learning and retention of motor tasks could be expanded even further. This study focuses on measuring acquisition during practice and retention through an immediate retention test. Future studies may develop these measures further to provide a more comprehensive analysis. This could include a better analysis of instructional effectiveness through measuring kinematics, further analyzing performance during the acquisition phase by providing KP as well as KR, and measuring retention using both an immediate retention test as well as a delayed retention test. A final transfer test in which the context, environment, or other characteristic of the task is altered would also provide an effective means of evaluating learning and retention.
References


Footnotes

1The random online generator used to vary feedback order can be found here: https://www.random.org/lists/
**Figure 1.** Average RE (cm) measured for the first throw after instruction in the non-preferred and preferred groups comparing visual versus verbal instruction. Error bars for all figures use standard error.

![Figure 1](image1.png)

**Figure 2.** Average difference in RE (cm) between no-KR and KR throws during acquisition phase after verbal or visual feedback comparing the verbal preferred to visual preferred group. * represents significantly higher scores in both groups when visual feedback was given compared to verbal feedback ($p<.001$).

![Figure 2](image2.png)
Figure 3. Average difference in RE during the acquisition phase after being given verbal or visual feedback comparing random and blocked feedback order groups.

Figure 4. Average RE (cm) measured during the retention test comparing verbal preferred vs visual preferred feedback groups with random and blocked feedback orders.
PARTICIPANT INFORMED CONSENT FORM
Spring 2015

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 Danielle Alvine, 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 learning styles 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) while blindfolded.

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.
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. 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.)
Subject Information Sheet

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 B

Learning Preference Questionnaire and Key

Questionnaire

1. Which would you do if you needed to learn to perform a task you have never done before?
   a. Have someone tell you how to do it
   b. Watch a video of the task being done
   c. Neither

2. How would you teach a friend who has never done so before to play your favorite sport?
   a. Explain it to them in detail
   b. Show them or have them watch a video of the sport
   c. Neither

3. You make a mistake during a sports practice. It helps you improve the most when your coach:
   a. Tells you specifically what you did wrong
   b. Shows you a video replay of your mistake
   c. Neither

4. You see someone performing an exercise wrong at the gym in a way that may cause them to have an injury. How would you help them correct the exercise?
   a. Explain to them what was wrong and how to do it right
   b. Show them the correct way by doing it once for them
   c. Neither

5. How did you learn all the rules of your favorite sport when you were younger?
   a. You listened to someone explain the rules to you
   b. You watched the sport and picked up on the rules
   c. Neither

6. If you got injured while playing a sport but didn’t know what was wrong, how would you prefer the doctor to explain it?
   a. Tell you what happened
b. Show you the x-ray or use a model to demonstrate the injury
c. Neither

7. How do you keep up with your favorite sports team?
   a. Listen to the games on the radio
   b. Go to the games or watch them on TV
   c. Neither

8. If you want to improve your performance in the sport you are playing you would most likely:
   a. Ask your coach to tell you ways you can improve your performance
   b. Watch professional games or video demonstrations of the sport
   c. Neither

9. If you perform a movement correctly, would you rather someone affirm that you have done it correctly or see a replay of the movement?
   a. Verbal affirmation
   b. See a replay
   c. I don’t need any information

Preferred Instructional Style:
Preferred Feedback Style:
Group:
Questionnaire Key:

**Preferred Instruction:** Questions #1, 2, and 5

**Preferred Feedback:** Questions #3, 4, 6, 8, and 9

**Random/Control:** #7 (*not needed to determine preferred instruction or feedback*)

Answer Key:

a) Verbal preference

b) Visual preference

c) Neither (Neutral)
Verbal Instructions

Foot Placement:

The subject should step up to the line and stand with both feet behind it in a comfortable but athletic position. The feet may either be perpendicular to the dart board or one or both feet may be at an angle. The subject should feel balanced and steady.

Holding the dart:

The subject should hold the dart in his or her dominant hand in a way that is most comfortable for them. For beginners, it might be easiest to hold the metal grip between the thumb, middle, and pointer fingers for a three finger grip, almost like holding a pen to write. The dart should be held perpendicular to the dart board and parallel to the floor.

Arm positioning and throwing the dart:

The arm should start at a 45-degree angle out in front of the body. Flex the elbow to about 20-30 degrees and extend the arm, releasing the dart between 90 and 120 degrees.