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The Effects of Applying Increasing Precision In Knowledge of Results When Practicing a Novel Motor Skill

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THE EFFECTS OF APPLYING INCREASING PRECISION IN KNOWLEDGE OF RESULTS WHEN PRACTICING A NOVEL MOTOR SKILL

by

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The purpose of this study was to determine whether increasing the precision of augmented feedback affected motor learning. The primary hypothesis was that the group that received only directional feedback would perform with higher accuracy scores during the transfer and retention tests compared to participants that received both directional and magnitude of error feedback. Participants in the study (N=36) were randomly assigned to conditions and all participants performed a total of 50 practice trials. The task required participants to toss a hacky sack, blindfolded, with their dominant arm to a target that was placed on the ground three meters away After every trial, participants in the "KR" group received KR consisting of either "Hit" or "Miss, the "KR-precision 1" group received "Hit" or "Missed" as well as direction of error feedback, and the "KR-precision 2" group received "Hit" or "Missed" plus the direction and magnitude of error feedback. All participants returned after 24-hours and performed a 10-trial retention test and a 10-trial transfer test without KR. Retention test results revealed that the KR-precision 2 group was significantly more accurate on the retention test compared to the KR-precision 1 group. Transfer test results suggest that there were no significant differences between any of the groups. This result suggests that the precision of the feedback provided during practice did not influence the participant's ability to adapt to different performance characteristics.

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Introduction

Numerous studies have been conducted showing that augmented feedback has a direct impact on motor learning and performance (Wulf, Chiviacowsky, & Lewthwaite, 2010). Providing feedback, along with practice, is considered one of the most effective ways to learn a motor skill (Rink, 2002; Van Dijk, Jannink, & Hermens, 2005); and as a result, when feedback is provided in an appropriate manner motor skill acquisition improves significantly (Bortoli, Bertollo, Messina, Chiariotti, & Robazza, 2010). The term feedback generically describes information a person receives about his or her performance during or after the execution of a motor skill (Bortoli et al., 2010). Feedback that is coming from the person's own sensory-perceptual system (i.e., task-intrinsic feedback) is a natural consequence of movement (Bortoli et al., 2010). "Augmented" feedback refers to information that is provided from an external source that adds to or enhances task-intrinsic feedback (Van Dijk et al., 2005). Augmented feedback provides information to the performer comparative to the outcome of the previous response, this information is processed and a decision is made regarding the nature of the adjustments required to the action plan on succeeding trials so that the level of performance may be improved. Thus, the informational content of the feedback is viewed as an important determinant of the success of the ensuing action (Dijk, Molder, & Hermens, 2007). Coaches and teachers usually provide their athletes and students with augmented feedback to help them correct errors, emphasize proper execution, and motivate them to persevere and progress in the face of difficulties and obstacles (Coker, Fischman, & Oxendine, 2006; Smith, 2006). Additionally, augmented feedback is sometimes provided to assist individuals who have an underdeveloped understanding of the practiced motor skill, or for those individuals who cannot sufficiently detect their own mistakes (Shewokis, Kennedy, & Marsh, 2000).

Augmented feedback can be delivered in two forms: knowledge of results, and knowledge of performance. Knowledge of performance provides individuals information about the pattern of their actions (Schmidt & Lee, 2005). The form of this feedback can range from casual comments about the performance to complex video feedback (Schmidt & Lee, 2005). For example, a coach informing an athlete that they should keep their knees bent while playing defense in a basketball game after watching that athlete try to defend while standing straight up is an example of knowledge of performance because the information provided by the coach references the athlete's movement characteristics.

Feedback that represents the success of a performer for a given response is considered a critical factor in both motor performance and motor learning (Guadagnoli & Kojl, 2001). This form of augmented feedback is known as knowledge of results (KR), and it is defined as augmented information about the outcome of the performance (Schmidt & Lee, 2005). Among the many variables found to influence learning, feedback in the form of KR has been shown to be essential for performance and learning in a variety of settings (Rice & Hernandez, 2006). The presentation of feedback is provided after (i.e., terminal) or during (i.e., concurrent) the performance of the motor skill. Typically, KR is provided after the completion of a motor task, and it is provided to facilitate the learning process and as performance directive information for the learner (Shewokis et al., 2000). Early information-processing perspectives suggested that KR is primarily used for motor learning in two ways: 1) A learner needs KR to test a hypothesis about the correctness of the previous response and 2) each tested response hypothesis contributes to a better memory of that response (Guadagnoli & Kojl, 2001). This suggests that the learner estimates how successful they were after a trial by comparing their own self-assessment to the KR that they received in order to better understand if they should repeat the previous behavior or modify future performances.

There have been numerous studies that measure KR frequency to determine how much feedback is too much (Guadagnoli & Kojl, 2001; Rice & Hernandez 2006; Badets & Blandin, 2004). Earlier theories suggested that providing KR after every trial (i.e., 100%) allowed participants to maximize their learning, however this viewpoint has since evolved. It is now understood that when participants are provided a lower (i.e., less than 100%) frequency of KR it encourages the working memory system to work harder and therefore increases the capabilities of the learner (Guadagnoli & Kojl, 2001). For example, a study completed by Guadagnoli and Kojl (2001) used two amounts of KR frequency (i.e., 100% & 20%) to assess the influence KR had on motor skill learning. The 100% groups received KR after each trial and the 20% groups received KR after every fifth trial. The study consisted of the participants striking a padded force transducer with one blow with the right fist while attempting to reproduce a target force. The goal of the participant was to reduce force-production error. The results showed that, while the group with 100% KR decreased error during the acquisition phase, the group with 20% KR performed with more precision during the retention test. Similarly, Rice and Hernandez (2006) conducted a study with individuals who did and did not have developmental disabilities. Participants in the group without developmental delay were yoked and age-matched (within 12 months) to a participant with developmental delay. In that study participants were given a chance to become familiarized with the computer equipment, ensuring the ability to identify the colors blue, yellow, and green, and were given enough trial manipulations of the access device to demonstrate an understanding of its use. It was explained to all participants that their task was to make the yellow bar match the position of the blue bar on the computer screen by moving the access device. Participants received KR in the form of a green bar that indicated the level of success in matching the blue bar to the position of the yellow bar on the computer screen. It was explained that the height of the green bar indicated how well they were doing. There were 30 trials during the acquisition phase and, after a 10-minute delay, a retention phase in which the participants received zero feedback. Rice and Hernandez (2006) found that participants who were assigned to the 100% KR group performed better during the acquisition phase than participants assigned to the 50% KR group. However, participants who were assigned to the 50% KR group performed better than those assigned to the 100% KR group on the retention test. These findings were found in both the developmentally delayed and non-developmentally delayed groups.

In a review article, Salmoni, Schmidt, and Walter, (1984) proposed the guidance hypothesis to help explain the role of KR frequency in motor skill learning. Based on this hypothesis, additional authors have proposed that although frequent KR given during practice guides the learner to the correct response, it also leads to dependency and can be detrimental to learning (Badets & Blandin, 2004). Frequent KR can block either the processing of intrinsic feedback or the memory processes that are needed for planning the next action (Badets & Blandin, 2004). It has also been suggested that frequent KR urges the participant to correct small response errors that are inherent to the variability of the motor system (Badets & Blandin, 2004). Badets and Blandin (2004) conducted a study where they wanted to dissociate the guidance effect of KR during physical practice from the guidance role played during observation. In that study there were four experimental groups: three groups who observed and completed acquisition trials and a control group. Participants received verbal instructions regarding the goal of the task before their first phase of practice, and then watched the same model. That model received verbal KR about their movement for each trial for the 100%-100% observation group, that is the group that received 100% feedback for both the observed and acquisition trials. Participants in a second group received KR about the movement for one out of three trials for the observation trials and 100% feedback throughout the acquisition trials. Participants in a third group received KR about the movement for one out of three trials for the observation and acquisition trials. For the second phase of practice, also called immediate retention, the participants completed 18 trials of physical practice without KR. The authors wanted to dissociate the guidance hypothesis effect of KR during physical practice from the guidance role played by the representation acquired during observation. In order to do so the participants physically performed the task with either the same or a different KR frequency than what they experienced during the observation phase. Consistent with previous findings, the results showed that the group that received 33% KR had less error during the retention test compared to the other groups that received higher frequencies of feedback. Those results occurred whether the retention test was 10-min following or 24-hours following the acquisition trials. This study also showed that the group who had 33% KR during observation as well as during physical practices had less error than the group with 33% KR during observation and 100% KR during practice. The 33%/100% group was more accurate than the 100%/100% group throughout the retention trials. This study showed that a lower frequency of feedback helped individuals become more accurate.

There has not, however, been much research conducted to investigate whether too much precision given in KR influences the motor learning process. Precision of KR indicates the degree of exactness of the provided information (Schmidt & Lee, 2005). For example, if the goal of an action is to make a 24-foot jump-shot in basketball and the actual movement resulted in a 24.25-foot jump-shot, there are a variety of ways KR can be given. The participant could be told that they “made” or “missed” the shot. But as an increase of precision on a “missed” jump-shot, you may also be told that the shot was .25 feet long of the target. Results can become even more precise as well. You can measure the movement accuracy to very fine quantitative degrees. That may include taking the measurement to the nearest nanometer.

Information about the direction of the error is presented in some forms of KR; information can also be given about the magnitude of error, without providing information about the direction of the error. It has been suggested that there is some benefit in providing information about magnitude of error, but it is far more useful if the direction is also specified (Schmidt & Lee, 2005). Past studies done by Newell and Salmoni (1981, 1984) have shown that the more precise the KR the more accurate the performance, up to a certain point, beyond which there are no more increases in accuracy. This is more than likely because individuals feel as if they are unable to change errors that may be very small and that the variability of the movement may be uncontrollable (Schmidt & Lee, 2005). Additionally, Participants may convert very precise KR to a more general interpretation to better understand the provided feedback. For instance, in the example from earlier where the basketball shot was .25 feet long, the jumper may simplify the distance of .25 feet to a quarter of a foot so it’s easier for them to comprehend. In their minds .25 feet may be difficult to fully understand, while thinking about the distance as a quarter of a foot may be more readily interpretable.

The lack of research on the topic of precision in feedback makes more research necessary. There has not been much recent research regarding how being more precise with feedback effects the motor learning process. Past research suggests there is an increase in accuracy up to a certain point, but no one has done any research to determine what that point is (Newell & Salmoni 1981, 1984). The present study focused on the precision of feedback to determine how providing increasingly more precise information influenced the motor learning process of an accuracy based task. To do this, the level of precision was systematically increased in the KR that was provided to the participants in their respective groups. Specifically; the purpose of this study was to determine whether increasing the precision of augmented feedback affected motor learning. It was hypothesized that:

- The group that received both directional and magnitude of error feedback would become more accurate throughout the practice trials than both of the other groups receiving less precise feedback.
- The “hit” or “miss” feedback group will be the least accurate throughout the practice trials.
- The group that received only directional feedback will perform with higher accuracy scores during the transfer and retention tests compared to participants that received both directional and magnitude of error feedback.
- Participants that received general “hit” and “miss” feedback would perform with lower accuracy scores compared to those with only directional feedback and those who receive both directional and magnitude of error feedback during the transfer and retention test.

Method

Participants

Participants were 36 volunteers recruited from Southern Illinois University ranging in age from 18-34 (*M*age = 22.14 years, SD = 3.21 years). All participants were made aware of the purpose of our study. Informed consent was obtained from the participants prior to participation. The experiment was conducted in accordance with Southern Illinois University’s ethical guidelines for research involving human participants.

Apparatus and Task

The task used was similar to one used in a previous study (Saemi, Porter, Ghotbi-Varzaneh, Zarghami, & Maleki, 2012). Participants were required to toss a hacky sack with their dominant arm to a target that had a diameter of 122 cm placed on the ground three meters away from the participant. Participant's dominant arm was determined by asking which arm they use when they throw. During the performance of all practice and retention test trials participants were blindfolded in order to prevent them from observing the outcome of their toss. The target had a center ring with a diameter of 12 cm. The center was encircled by a series of nine concentric rings, each ring increased by a diameter of 12 cm. Those zones served as zones to evaluate throwing accuracy. More specifically, if the hacky sack came to rest on the center target 10 points were awarded; the point value decreased as the ball landed further away from the center target. If it landed in one of the other zones, or outside the outer circle 9, 8, 7, 6, 5, 4, 3, 2, 1, or 0 points were awarded, respectively. Failure to hit the target resulted in zero points. If the hacky sack hit the target but did not come to rest on the target, the researcher determined where the hacky sack landed. If it is was too close to decide the participant was asked to throw again. If the hacky sack landed on a line separating two rings the points for the inner circle were awarded. All practice and transfer trails were completed in a research space with the same researcher recording every trial.

Procedure

Participants were randomly assigned to either the "KR," the "KR-precision 1," or the "KR-precision 2" group. All participants were informed that the task goal was to toss the hacky sack with their dominant arm to the center of the target, which was placed on the floor in front of them. All participants performed five-blocks of 10-trials for a total of 50 acquisition trials. After every trial, participants in the “KR” group received KR consisting of either “Hit” or “Miss.” This feedback indicated if the thrown hacky sack had hit or missed the center of the target. The participants in the “KR-precision 1” group received KR consisting of “Hit” or “Missed” in addition to being told if the toss had landed to the right, left, beyond, or short or short of the center of the target. The participants in the “KR-precision 2” group received KR consisting of “Hit” or “Missed” plus the direction and how many cm the hacky sack landed away from the center of the target. For example an individual who hit the 50 cm circle on the right received the feedback statement of “Missed to the right by 50 cm.” All participants returned after 24 hours and performed a 10 trial retention test, blindfolded, without KR. Participants also performed a 10 trial transfer test with no KR provided. During the transfer test participants performed the same task but with their non-dominant arm. So if a participant completed the practice trial with their left hand the transfer test was completed with their right hand. The transfer test was performed without a blindfold.

Data Analysis

Throwing accuracy during practice was analyzed in a 3 (Group: KR, KR-precision 1, KR-precision 2) x 5 (Trial Blocks) analysis of variance (ANOVA) with repeated measures on the last factor. Retention and transfer test scores were analyzed with separate one-way ANOVAs.

Results

Practice

The results of the 3 (Condition) x 5 (Trial Block) ANOVA indicated that there was a significant main effect for Condition, $F\ (2, 27) = 50.351$, $p < 0.001$. Post-hoc analysis (LSD) indicated that the KR-precision 2 condition was significantly more accurate than both the KR, and KR-precision 1 conditions. Additionally, the follow-up analysis revealed that the KR-precision 1 condition was significantly more accurate than the KR condition. The ANOVA also revealed a main effect for Trail Block, $F\ (4, 108) = 17.326, p < 0.001$. Post-hoc testing (LSD) indicated that all three groups showed improvements in throwing accuracy during the acquisition phase. The Condition x Trial Block interaction was also significant, $F\ (8, 108) = 2.526, p < 0.015$. Follow-up testing revealed that the interaction was the result of the KR-precision 2 group having a much more rapid gain in accuracy compared to the KR and KR-precision 1 groups. The practice performances of each condition are displayed in Figure 1.

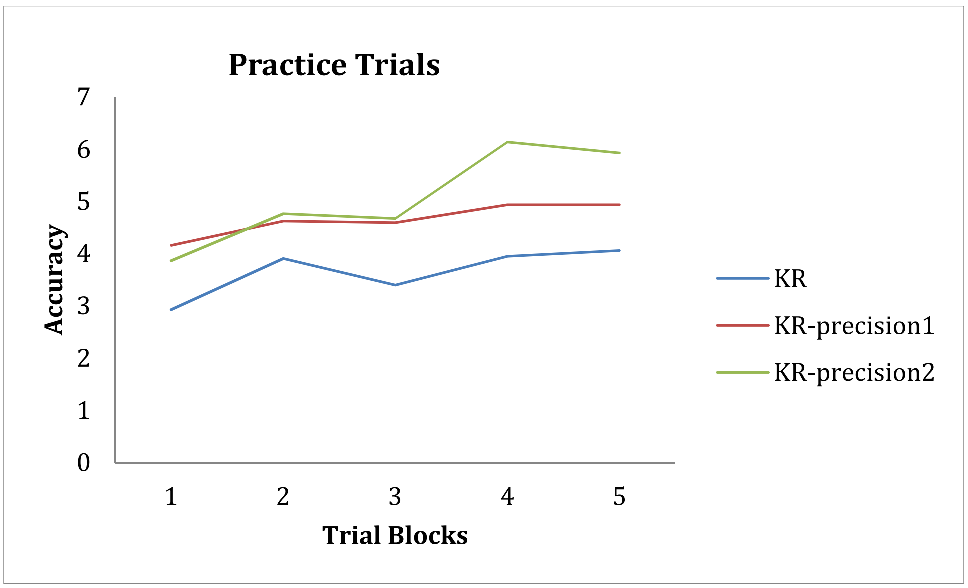

Figure 1: Mean accuracy scores for each condition through 5 trial blocks.

Post-tests

Retention. The one-way ANOVA used to analyze retention test scores indicated there was a marginally significant main effect, $F\ (2, 357) = 2.78, p = 0.065$. Follow-up testing revealed that the KR-precision 2 group was significantly more accurate on the retention test compared to the KR-precision 1 group. No other group differences were found. The average retention test scores for each condition are displayed in Figure 2.

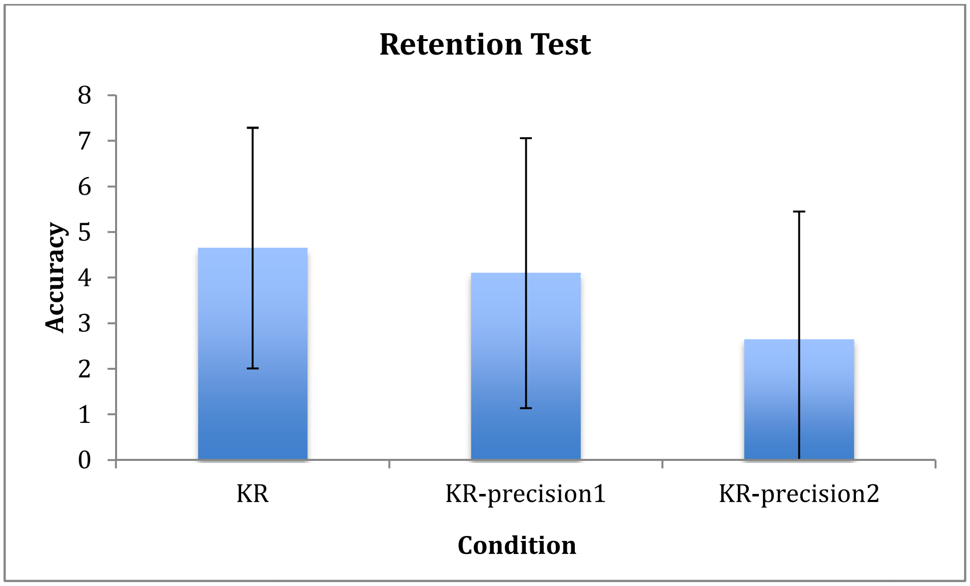

Figure 2: Mean accuracy scores for the retention test for each condition. Error bars represent standard deviation.

Transfer. The ANOVA used to compare transfer test scores indicated that the three groups did not significantly differ from each other, F (2, 357) = 2.325, p = 0.099. The average transfer test scores for each condition are displayed in Figure 3.

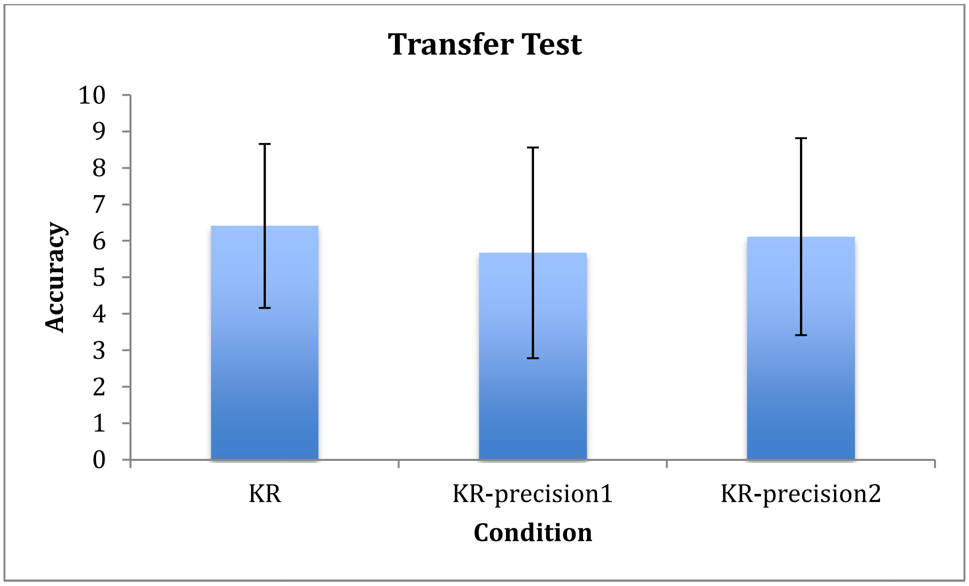

Figure 3: Mean accuracy scores for the transfer test for each condition. Error bars represent standard deviation.

Discussion

It has been established that KR has an important role in acquiring motor skills (Young & Schmidt, 1992). However, this study was designed to determine whether providing more precise, or specific, feedback to an individual was detrimental to the learning process compared to providing feedback that was more general. There has been very little research done to establish whether precision of feedback has an effect on learning.

The task used in the present study required participants to toss a hacky sack with their dominant arm to a target that was placed on the ground three meters away. During the performance of all practice and retention test trails participants were blindfolded in order to prevent them from observing the outcome of their toss. All participants performed five-blocks of 10-trials for a total of 50 practice trials. After every trial, participants received KR of varying precision depending on their randomly assigned group. All participants returned after 24-hours and performed a 10-trial retention test, blindfolded, with no KR provided. Participants also performed a 10-trial transfer test without any KR.

As hypothesized, each group became more accurate throughout the practice session. This was to be expected based on studies that show that individuals tend to become better or produce less error as they practice (Badets & Blandin, 2004; Guadagnoli & Kojl, 2001; Rice & Hernandez, 2006). Additionally, there were differences in accuracy between all groups during practice. Specifically, the KR-precision 2 condition was significantly more accurate than both the KR, and KR-precision 1 conditions; and the KR-precision 1 condition was significantly more accurate than the KR condition. The group that was most accurate, KR-precision 2, received the most precise feedback during practice. This finding is consistent with previous research which showed that individuals who received more precise KR had more accurate results during the practice trials (Guadagnoli & Kojl, 2001).

Results showed that during the retention test there was a marginally significant (p = .065) difference between the KR-precision 2 group and the KR-precision 1 group. However, there were no significant differences when comparing the KR group to the other two groups. These findings suggest that, after a 24-hour of no practice, individuals in the KR-precision 2 group were marginally more accurate than participants in the KR-precision 1 group, but not significantly different than participants in the KR group. This finding is not consistent with the hypothesis that the KR-precision 1 group would be the most accurate during the retention test compared to the other two conditions.

Transfer test findings suggest that there were no significant differences between any of the groups during the transfer test. This result suggests that the precision of the feedback provided during practice did not influence the participant’s ability to adapt to different performance characteristics (i.e., throwing with their other limb without a blindfold). This finding does not support the hypothesis that if an individual is given too much precision in feedback the learning process will be disrupted.

In the present study it was predicted that the KR-precision1 group would be more accurate than both the KR-precision 2 and the KR group during the transfer test. This lack of group differences could be because the transfer task was conducted while the participants were not blindfolded, which allowed them to be provided ample visual (i.e., task-intrinsic) feedback. Additionally, when participants performed the task during the transfer test everyone received the same task-intrinsic feedback. Regardless of the feedback the participants received during practice, everyone was able to see the outcome of their toss during the transfer test. They were then able to determine what to change based on their naturally available visual feedback. In retrospect, the transfer test should have been conducted with the participants blindfolded to inhibit the participants from receiving task-intrinsic feedback.

There are some limitations to the present study; many of these limitations offer avenues for future research on this topic. One limitation is that the present study used a 100% feedback method, which previous research has established may not be optimal for motor learning (Chen, Kaufman, & Chung, 2001; Gillespie, 2003; Young & Schmidt, 1992). Those authors suggested that less frequent KR is more beneficial for learning motor skills than providing KR after every trial. It is said that when participants are provided a lower (i.e., less than 100%) frequency of KR it encourages an increase in cognitive effort in the working memory system and therefore increases the capabilities of the learner (Guadagnoli & Kojl, 2001). It's possible that since participants in the present study were given some form of KR after every trial during practice, and not presented any KR during the retention and transfer test, that they were unable to determine what to change in their process. It is also possible that the present study did not give feedback that was *too* precise. There could be a way to add more precision to the task in future studies. For example, the researcher could give instruction on throwing techniques as well as letting the participants know where the hacky sack landed.

A second limitation is that the hacky sack may have landed long and to the right of the target, and the researcher had to decide whether to tell the participants if the location was long or right, depending on their own subjective view. This is a limitation because with a different researcher the feedback may have been different, which would have provided the participant with different augmented feedback that may have altered their performance. Future studies should quadrant the target off in sections where it would be easier to determine which location would provide the most accurate feedback.

Another limitation of the present study was that there was a difference in the sound that the hacky sack made when it hit the target versus when it completely missed the target. This noise provided auditory augmented feedback to the participant that was in addition to the feedback provided from the researcher. This may have created a confound within the design of the study because it provided additional feedback in addition to the prescribed feedback delivered by the researcher. In a future study the surface surrounding the target should be the same type of material as the target, or the target should be drawn on the floor so there is no extra auditory feedback.

A final limitation of this study is that participants performed a relatively low number of practice trials (i.e., 50) throughout the experiment. Some other feedback studies have had participants complete many more practice trials (i.e., 100+). This could have influenced the results of the present study. Future studies should increase the number of practice trials to better investigate this issue. This study also contained a relatively low number of participants. There were marginal group differences, and theoretically, with a larger sample size there would be more statistical power resulting in more meaningful group differences.

In conclusion, the results of this study supported the hypothesis that the group that received the most precise feedback would be the most accurate during practice compared to the groups that received less precise feedback. However, the hypothesis that the group with only magnitude feedback would be more accurate in the transfer and retention trials was not supported. The most precise group, KR-precision 2, was more accurate during the practice trials and there were no differences between any of the groups when comparing the transfer test performances. This study is unique because there have not been many published reports regarding the precision of feedback and whether or not it has negative effects on motor learning. The present study confirmed previous findings on increasing accuracy during practice trials, however the findings indicate that this effect may be temporary and not carry over into retention and transfer testing.

Further research on the topic of KR precision will benefit coaches and teachers in helping them determine the best type of feedback needed to promote an optimal learning environment. If it turns out that giving an individual more precise feedback has a positive effect on motor learning, practitioners will be able to use that to their advantage when teaching. For example, a coach trying to get an athlete to run a certain time in the 40-yard dash will be able to know the right amount of feedback that should be given. Meaning if an athlete is working towards a 4.50 second 40-yard dash, there is a big difference between the coach measuring the time from the tenths place and measuring from the hundredths place. For example, a coach might tell the athlete they ran a 4.6 second run and they actually ran a 4.69 second run. They are further away from their goal than they may think, but what does the difference in precision mean?

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Research Paper Title:
THE EFFECTS OF APPLYING INCREASING PRECISION IN KNOWLEDGE OF RESULTS WHEN PRACTICING A NOVEL MOTOR SKILL

Major Professor: Jared Porter