Perception, Cognition, and Action in the Execution of a Motor Skill

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Abstract

Perception, cognition, and action are the three components required to execute a motor action. However, research combining all three facets of action is scarce. The current research aims to combine all three components of perception, cognition, and action and study each component within individuals. It was predicted that perception, cognition, and action are related, but are primarily separate entities and function as such. This was expected to be manifested in inconsistencies of skill between perception, cognition, and action within each individual participant. The current study used billiards to gauge the three components of action. Specifically, a bank shot in billiards was used to frame the study. It was found that perceptual cognitive error was significantly greater than motoric error when shooting a shot in billiards.
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The completion of motor tasks occurs often in our daily lives, but we know little about the process as a whole. The current research aims to bridge the gap in the research between the components of perception, cognition, and action. This gap in the research is so prominent that Rosenbaum (2005) refers to motor control as "the Cinderella of psychology," claiming that textbooks and journals have failed to present this relationship. Intuitively, the subject matter of perception, cognition, and action in the execution of motor tasks ought to be a topic of great interest to psychologists, who are very broadly interested in the physical manifestations or behaviors following mental processes. Therefore, in attempt to supplement the literature, the current research will isolate the three components (perception, cognition, and action) of a motor skill. This is expected to provide a better understanding of the relationships among the three components of a motor skill, whereas much of the previous research focuses on a single component or the relationship. We examined two hypotheses in the current research. First, perceptual cognitive error constitutes significantly more of the total error than motoric error. Second, cognitive load will significantly increase perceptual cognitive error whereas cognitive facilitation will significantly decrease perceptual cognitive error.

The research used billiards as a means of studying perception, cognition, and action. Billiards provides an appropriate frame for this research due to the facility of separating a shot into the three components of perception, cognition, and action. Does the participant perceive the ideal shot when researchers manipulate the table to encourage the bank shot? Does the participant have an understanding of where they ideally would like to hit the ball off of the rail to make a shot? Finally, can the participant execute the shot that they planned using the cognitive decision they have made? For the purposes of our experiment, executing a successful shot in
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billiards necessitates that participants have adequate skills in the two components of perception and cognition and in action.

We will first explain perception, cognition, and action independently of one another. The distinction between perception and cognition is vague; it is sometimes difficult to determine where perception ends and cognition begins. Perception, for example, could be recognizing a flaw on the billiards table that would alter the course of a shot whereas cognition would represent the planning involved in calculating an alternative. Visual perception is the primary source of information participants will use in determining the ideal shot and is to be understood as the process of absorbing information from the environment which instills forms of objects, surfaces, and patterns within the perceiver (Williams, Davids, & Williams, 1999). Perception applies in billiards in the sense that a participant can perceive the ideal shot on the table. That is, participants in billiards generally shoot the shot that has the greatest probability of being successful. For the purpose of this research, the billiards table was always fixed to have one ideal shot, which was the bank shot.

In billiards, it is necessary for participants to plan the ideal shot. They utilize cognitive processes to find a suitable shot with the highest likelihood of success. The structure of these cognitive processes was explained by Montgomery and Svenson (1989). They describe cognition in action in terms of the dominance-search model. This model views the decision making process as a search for the dominance structure, as a stand out alternative that can be justifiably used over the other alternatives. According to Montgomery and Svenson, there are four phases in the decision making process including the pre-editing phase, finding a promising alternative, the dominance-testing phase, and the dominance-structuring phase. In the pre-editing phase, the participant considers alternatives that pertain to the problem, discarding those that are unlikely to
become the dominant structure. This is followed by finding a promising alternative, where a participant will search for an alternative that appears more dominant than the previously considered options. In this phase an option will be chosen after consideration. Next, in the dominance-testing phase, the participants will test whether there is an alternative with more potential than the preliminarily chosen option. Participants evaluate whether there are debilitating disadvantages to the option in the lead. If they have reevaluated and found that their choice is ideal, then the dominant structure has been chosen and the process ends. However, if there is a fault with the option that the participant has chosen, then he or she progresses into the dominance-structuring phase where the information is restructured in order to obtain a dominance structure. This process is characterized by offsetting the perceived disadvantages. This can be accomplished through de-emphasizing the importance of a fault or exaggerating and emphasizing the advantages of the dominance structure.

This cognitive model is applicable in the current research. Participants must make decisions in the cognitive tasks that involve assessing and choosing the ideal location to direct the cue ball to successfully execute the shot. Participants are not intended to have feedback based on their actions, so they must repeatedly engage in the previously described dominance structure search to execute what they believe is the ideal shot. In this study, participants will utilize this structure several times, under baseline conditions, conditions designed to impair the participants with cognitive load, and facilitation conditions.

Once cognition has been accomplished, one must complete the physical component of the action. Keele (1968) outlines three possible ways in which motor actions can be controlled. First, slow movements can be corrected with visual feedback. For instance if a billiards player sees the cue stick slowly coming in at the wrong angle, he or she can change the angle to rectify
the shot. Second, kinesthetic feedback can inform a participant completing a motor action that he or she is executing the shot inadequately. However, this would seemingly apply to someone who was not a novice at the skill of taking a shot in pool. Finally, the motions involved in executing a shot may be preprogrammed in the individual, meaning that they will have a sense of the ideal timing and muscle movements required to produce a successful result.

Despite a lack of psychological research on perception, cognition, and action, one model does exist. Hurley (2001) comments that historically, the three components of an action are viewed in the following way: perception and action are distinct and peripheral entities that sandwich cognition between them. She refers to this idea as “the classical sandwich.” Her critique of this model advocates for its avoidance. Hurley posits that the belief that cognition and motor control are separate and distinct entities should be discarded. She also believes that perception and action should be considered less peripherally and that cognition should be viewed as arising out of the two. However, the basis of the current research is in opposition to Hurley’s theory. Cognition and motor control are separate entities and we anticipate providing evidence in support of this separation. Additionally, it is hypothesized that perceptual cognition and motor control play distinctive roles rather than cognition arising out of perception and action. The current research can examine this because we are isolating perceptual cognition and action and measuring them as separate entities. Significantly different errors will suggest that cognition does not arise from perception and action, but rather that it is a distinctive component of the execution of a motor skill. It is hypothesized that perceptual cognitive error will be significantly greater than motoric error.

The basis of the current research is that the mechanisms of perception, cognition, and action are distinctively separate, but interworking. In daily practice, the way in which a motor
action occurs inarguably requires the three components. Progression through the stages is not possible without the previous determinant. In motor planning and action, perception precedes cognition and cognition precedes action. Hurley’s critiques may reflect more accuracy in generalized action, whereas the current research has an inclination toward the planned actions specifically involved in sports with meticulous strategy. The current research is expected to provide evidentiary support for the notion that perception and cognition are predictive of the overall performance on a task while action may not have such strong linkages in the accuracy of performance of a motor skill.

For comparison, the current research studies the relationships of cognition and action when debilitated and facilitated. Cognitive load will complicate the planning and action components of motor skill execution. Performance under cognitive load is intriguing in the sense that people are frequently under varying conditions of stress and distraction during their activities. Whether one is in a “normal” cognitive condition or in a distracted or poor cognitive condition, the same expectations are placed on individuals for performance. Lopresti-Goodman, Richardson, Baron, Carello, and Marsh (2009) studied the effects of cognitive load on the simple task of grasping and moving wooden planks. A cognitive load condition was implemented, resulting in what researchers describe as hysteresis, or a lag in action, indicating that cognitive load can cause interference with one’s primary goal even in a simple task. Beilock and Carr (2001) found evidence that cognitive load reduces performance on a putting task. Participants in the cognitive load condition were instructed to monitor a list of spoken words for the word, “cognition” while they were executing their shots. The reduced performance of these participants suggests that having this distraction influences the execution of the putt through affecting perceptual cognitive mechanism or the action mechanism.
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By discovering how debilitating conditions influence people, perhaps we can begin to solidify methods of reducing the impact of cognitive debilitation in action performance. The facilitation condition has the potential to provide insight onto whether cognitive facilitation can effectively reduce human error in perception and cognition, action, or both. Such interventions may improve the performance of all people who use planned movement from elite athletes to rehabilitation patients. By improving cognitions that plan the actions required for advancement toward their goals, people can experience more efficient and effective movement in spite of cognitive load ideally.

The current research aims to answer the questions of whether there are relationships between the components of action and if so the research will determine what types. We are specifically interested in whether performance can be predicted by perception and cognition, action, or both, which of these predictors is stronger, and do the trends withstand in states of facilitation and debilitation. It is predicted that perception and cognition will better predict overall performance than action. That is to say, participants that have cognitive abilities are unlikely to fail to execute a successful shot, whereas participants who merely have mastery of action will be likely to fail more often. Secondly, the current research is concerned with whether any existing relationships will be sustained even when cognition and action are facilitated and debilitated. It is hypothesized that perception and cognition will worsen in the cognitive debilitation condition, but that action will remain intact. Likewise, it is expected that the cognitive facilitation condition will improve perceptual cognitive performance, while action is unchanged.

Method

Participants
Participants were either enrolled in an introductory psychology course at a medium sized Midwestern university or recruited from the individuals present in the student center at the university. There were 30 total participants. 3 participants were disregarded, 2 of which were due to incomplete data and 1 participant had already completed the experiment, but failed to inform the researcher until after the data were collected. Participants enrolled in the introductory psychology course completed the experiment in exchange for experimental credit. Participants recruited from the student center completed the experiment in exchange for $5. Participants were recruited regardless of their billiards experience. A set of practice shots (described in the procedure) was used to determine whether recruited participants would be able to contribute to the study. Four scratches, or the inability to execute the shot with adequate velocity or accuracy, were grounds for dismissal from the study. 1 participant was dismissed on the basis of the practice shots due to having made four scratches.

Procedure

Table Preparation An illustration of the table preparation can be found in Figure 1. This experiment was conducted with permission on the billiards table at the student center of the university. The eight ball was positioned on the edge of the center pocket on the same side of the length of the table as the cue ball. Between the eight ball and the cue ball was a wall of billiards balls extending from the wall. The wall was four balls deep spaced approximately equal distances apart designed to barricade the direct pathway from the cue ball to the eight ball.

Tape measures were taped to the opposite walls of the cue ball starting points running from the corner pocket to the center pocket. Located against the table was a camera mounted on a stand. The camera functioned to record the exact location of when the cue ball hit where the
participant had the intention of sinking the eight ball in the center pocket by means of a bank shot.

**Task** Participants were greeted when they arrived or were recruited by the researcher. They were asked to read and sign an informed consent sheet prior to beginning the study. Afterward, participants were instructed to begin their practice shots. Practice shots consisted of three shots of striking the cue ball from one of the table’s starting points so that it moved straight forward toward the opposite diamond on the width of the table, back past the starting point to the diamond behind it, then finally coming to rest on the respective starting point. The three practice shots were designed as an acclimation period and for participants to gauge the velocity at which they would most likely be striking the shot during the experiment. Practice shots also served as a method to determine whether participants had an adequate skill level to complete the experiment.

To begin the actual experiment, participants were asked what they perceived to be the ideal shot, or which shot that they thought would have the best chance of sinking the eight ball in the center pocket. Participants were then assigned into one of two alternating conditions. Either they completed the baseline task set first followed by the cognitive impairment task set or cognitive impairment task set first followed by the baseline task set for counterbalancing purposes. The baseline, cognitive impairment, and cognitive facilitation task sets all involve three distinct tasks.

The procedure hereafter will be written as the procedure for participants in the baseline task set as the initial set of the experiment. For the first task (task 1), the participants were simply asked to sink the eight ball in the center pocket by means of the bank shot, which was shown to them. If possible to do so without risking injury or because the velocity was too fast, the researcher intercepted the cue ball immediately after it had struck the wall. The purpose of
this interception was to avoid giving participants feedback about their shot. The camera recorded where the shot hit on the wall. The second task of the baseline condition was for the participants to show the researcher where they intended to shoot the cue ball off of the wall in order to sink the eight ball in the center pocket. This procedure was conducted with the researcher slowly and consistently moving a pen down the rail along the tape measure. Participants were instructed to say, “Stop” when the researcher’s pen arrived at the point on the rail that they felt would be the ideal spot to hit the cue ball. This location was recorded, but the distance on the tape measure was not revealed to participants. For the third and final task in this set (task 3), participants were instructed to attempt to hit the cue ball where they had previously mentioned was the perceived ideal spot. The researcher placed his or her pen on the rail where participants had previously said and began recording, instructing the participants to aim for that mark. At this point, participants shot the cue ball when they were ready. Following this shot, the researcher moved the cue ball to a new starting point and moved the wall, eight ball, and camera to their new locations according to the new starting spot.

For the cognitive impairment task set (task set 2), participants were under cognitive load. For each of the three tasks, they were instructed to count backwards out loud by threes from various starting points. All three tasks in the cognitive impairment set mirrored those of the first task in the baseline set. The camera recorded tasks 4 and 6. Following the final shot of the task set, the researcher moved the cue ball to the third and final starting location and changed the table layout to correspond with the new location.

For the final task set, the researcher used a laser to line up participants’ shots and show them the ideal shot. For the first task in this section (task 7), participants were instructed to line up their shot as if they were about to shoot, but not actually shoot. The researcher would line up
their shot by directing a laser attached to a stand to fall across the center of the cue ball and align with the participants cue stick. Participants were allowed to make adjustments to their stance when they saw their path. Where the laser crossed the tape measure on the edge of the rail was recorded. In the next task, participants were instructed to make that shot (task 8). The researcher highlighted the laser that could be viewed on the table. The camera recorded where their shot hit the rail. Finally, for the final task (task 9), the researcher set up the laser so that it crossed the tape measure at 65 centimeters and went over the center of the cue ball. This was considered the "ideal shot" that if this line were followed with a suitable velocity and without spin, the cue ball would strike the eight ball and it would be sunk in the center pocket. Participants executed this shot to the best of their ability and the location on the rail where the cue ball struck was recorded by the camera.

Following the experiment, the participants were all debriefed and either given credit or payment in exchange for their participation. They were then dismissed.

**Video analysis** After the data collection, two researchers coded the videos. The shots that needed to be recorded from the camera were tasks 1, 3, 4, 6, 8, and 9. Researchers used *Windows Movie Maker* to view the videos frame by frame to see the exact location that the cue ball hit the rail. All shots were viewed by two researchers, recorded, and averaged. Any disagreements where the difference between the two raters' was greater than 1 inch were discussed and reconciled. Those deviances less than one inch were averaged. All measurements were made to the nearest half inch and then converted to centimeters. The videos were coded in inches due to the quality making it difficult to distinguish the numbers of the centimeter measures.

**Results**
The variable of perceptual error was calculated using the absolute value of the participants' perception and cognition relative to the ideal point. This was obtained by calculating the difference between the ideal point and the location specified in task 2 (or task 5 for working memory), where participants told the researcher where the ideal point was when the researcher ran their pen along the tape measure. The motoric error was isolated by using the participants' execution placement relative to their perception and cognition. This was calculated using the difference between the values found in task 3 and task 2 or for working memory, tasks 6 and 5. This is the difference between where the participant said was the ideal point (task 2) and where the participant actually executed the shot (task 3). A paired-samples t-test was conducted to compare the perceptual and cognitive error and the motoric error within participants. There was a significant difference between perceptual and cognitive error ($M = 8.87, SD = 5.72$) and motoric error ($M = 3.55, SD = 5.24$); $t(26) = 4.18, p < .01$. Results indicate that there is a significant difference in perceptual/cognitive error and motoric error. Specifically, when people are engaging the execution of a motor skill like a shot in billiards, they have a tendency to err significantly more on perceptual cognition skills than on motoric skills.

It was hypothesized that any relationships that existed would be intensified in the cognitive impairment and facilitation to be worse or better, respectively. However, this was not the case. Significant results were not found for cognitive impairment and facilitation conditions.

**Discussion**

Results showed that error was significantly greater for perceptual cognition skills than action skills in all conditions. These findings indicate that most error that occurs during the execution of a motor skill can be attributed to perceptual and cognitive error in billiards,
suggesting that motoric error in similar activities can also be attributed to perceptual and
cognitive error.

Unfortunately, we did not collect data that supported our hypotheses. This could be due
to a number of confounds or limitations described later. However, if this type of study could be
repeated with more appropriate methodology, the implications could be extremely beneficial for
athletes and physical rehabilitation purposes. Athletes often focus attention on improving their
cognitive skills with the hope of improving the execution of these skills. Techniques such as
visualization and imagery are examples of thought techniques used for performance
enhancement. The current research aims to perhaps generalize these ideas to populations outside
of athletes. It is predicted that cognition and action will not be predictive of one another,
implying these skills may need to be taught or that they are more effective in “sport” realms
rather than an experiment.

There may be implications for skill learning and acquisition as well. If in fact cognition
and action are positively related, even weakly, it would suggest that cognitive rehearsal and
strategy could improve skill. This may be particularly beneficial for novice populations. Further
research will be able to expand upon these implications. It would be appropriate to next explore
some of the differences in expertise when participants of varying experience levels are placed
under cognitive load or facilitation.

Particularly for individuals undergoing rehabilitation, these findings can be interesting.
People in physical therapy are generally individuals who have lost or experienced a deficit in a
motor skill that they have previously mastered. These individuals may maintain their cognitive
skills, but experience difficulty in performing the action similarly. If cognition and action are
not strongly positively related, as predicted, this would provide some insight as to what makes physical recovery from injury difficult.

The data collection of cognitive facilitation and debilitation manipulations can also be applied in the sport and motor control domains. The presence of cognitive load in the debilitation is expected to weaken the relationship between cognition and action. This can be a problem particularly for athletes in the sense that peak performances are expected without regard to personal problems that an athlete faces. Excessive pressure can be perceived by athletes, which can be a particularly harmful problem for younger more impressionable athletes.

While this research is theoretically and practically valuable, there are several limitations that may have hindered the ability to find patterns and relationships between perception, cognition, and action. For example, previous research indicates that working memory should have an effect on perception and cognition of a motor skill, no significant results were found in this study. This was due to an inability to find the true deviation of the motoric component from the perceptual and cognitive component. Ideally, subtracting the absolute values of the motoric error from the perceptual and cognitive error would yield the data points necessary to properly analyze the data. However, when participants err perceptually and cognitively or motorically, they do not necessarily err consistently. That is to say the performance of one component may compensate for the other by having a different relationship to the ideal point. A participant may perceive that the ideal point to bank the cue ball off of the wall is several inches greater than what the ideal point is, yet they may strike the cue ball so that it actually hits beyond that point.

Further limitations include the notion that expertise was not controlled. It is possible that individuals high in expertise have different relationships between cognitive knowledge of the ideal shot and their ability to execute actions than novices. While the original intent of the
experiment was to obtain data that could be generalized to all levels of expertise, it was later thought that expertise may be a moderator of the relationships between perception, cognition, and action.

An additional limitation is the methodology for gauging competency in the aspect of perception. Participants are merely asked to acknowledge the ideal shot. Their answer was either correct or incorrect. After their statement of the perceived ideal shot, the researcher either accepted or corrected their response and ran the duration of the experiment accordingly. Therefore, perception was detached from the remainder of the experiment in the sense that an individual’s correct or incorrect identification of the ideal shot did not influence the subsequent tasks.

Regardless of the limitations, this type of research that combines the components of perception, cognition, and action in motor skills has numerous advantages when the research can be done in a manner that accurately measures error and isolates the three components. Supplementation of the literature on perception, cognition, and action is greatly needed. The potential implications are also promising. Additionally, the current research has the capacity to be expanded upon by looking at potential moderators of the relationship between perception, cognition, and action and variations between different populations.

Perception, cognition, and action are suggested by the current research to be distinctive in spite of Hurley’s claim that this idea should be discarded. Perceptual cognition and action can be isolated and measured accordingly, suggesting that cognition does not arise out of perception and cognition as thought by Hurley. Instead, the research supports “the classical sandwich” model. Regardless, additional research must be conducted in order to fully understand the three components involved in the execution of a motor skill.
References


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