This article appeared in a journal published by Elsevier. The attached copy is furnished to the author for internal non-commercial research and education use, including for instruction at the authors institution and sharing with colleagues.

Other uses, including reproduction and distribution, or selling or licensing copies, or posting to personal, institutional or third party websites are prohibited.

In most cases authors are permitted to post their version of the article (e.g. in Word or Tex form) to their personal website or institutional repository. Authors requiring further information regarding Elsevier’s archiving and manuscript policies are encouraged to visit:

http://www.elsevier.com/copyright
Does action affect perception or memory?

Adam D. Cooper * , Cassidy P. Sterling, Michael P. Bacon, Bruce Bridgeman

Department of Psychology, University of California, Santa Cruz, California 95064, United States

A R T I C L E   I N F O

Article history:
Received 20 September 2011
Received in revised form 12 April 2012
Available online 24 April 2012

Keywords:
Action
Perception
Memory

A B S T R A C T

Current literature maintains that success or failure in the performance of an action can modify perception of the objects of that action. The tests of that modification, however, may have measured memory rather than perception. To address this issue, the current experiment had observers throw a marble into various sized holes and assess their size through either a haptic or verbal measure. They respond either before the throw while the hole is visible (control condition), after the throw while the hole is visible (perception condition), or after the throw while the hole is not visible (memory condition). It was found that observers judged the hole size to be different depending on their throwing success only during the memory condition. This casts doubt on the conclusion of an action-specific perception account (Witt, 2011), and instead we propose an action-specific memory account.

1. Introduction

This paper investigates the effect of action on cognitive processes. While previous research has found support for such an effect (e.g., Witt et al., 2008b; Witt & Proffitt, 2005), none has attempted to tease apart two main components of cognition (perception and memory), either of which may be responsible for some of the reported findings.

An explanation of how the modification of perception and memory is possible is provided by the theory of embodied cognition. Under this view cognition arises from the interaction of brain, body, and environment as the organism engages in action (Gibson, 1979), and thus can be altered by a change to any of them.

The emphasis on action in theories of cognition was pioneered by Fitts and Seeger (1953). By comparing reaction time, speed, and errors between differently related stimuli and responses, they demonstrated that the link between environment and organism affects action. Because this link is dependent upon environment and organism characteristics, different opportunities for action arise as either is changed. Gibson (1979) referred to these opportunities as affordances, and was interested in how they informed cognition.

Because one’s abilities are dependent upon the physical and mental ability to conduct motor action, affordances are not static. Instead they can be altered due to mental outlook and physical modifications, which have the potential to result in perceptual changes. For example chronic pain is a detriment to ability. Participants in a study by Witt et al. (2008a) were patients with chronic back pain and controls without such pain. When their task was to estimate distances, the patients estimated them as significantly farther than did the controls, thereby tying one’s condition to distance perception. The authors believe that this modification of perception is correlated with the specific task (in this case walking) instead of tasks in general. In other words these patients would not be predicted to overestimate reaching judgments. Although a follow up study was never carried out to test this, Witt, Proffitt, and Epstein (2004) found that distance perception in normal people is affected by holding heavy balls only when they intend to throw them, as opposed to when they intend to walk (without the ball). Therefore it appears that one’s ability to act affects the corresponding perception, instead of perception in general.

Differences in ability also arise in organized sports. After a baseball game players were asked to choose from a number of ball sizes as to the one they believed was used in the game. Those with a high batting average (high ability) choose a larger ball than those with a poor batting average (low ability) (Witt & Proffitt, 2005). Similar results were found for golf in terms of perceived hole size. This effect was not related to overall ability but instead to performance during a specific game. This concept was tested further in the lab where golf putting distance was manipulated. After putting, people in both the close and distant conditions were placed at the same distance from the hole they were putting to, and were asked to judge the hole size by manipulating a circle on a computer screen. Those in the closer condition (easier task, resulting in greater ability) responded with a larger circle than did those in the far condition (harder task, resulting in lower ability) (Witt et al., 2008b).

This effect of ability on size perception has been investigated further by studies correlating the perceived width of doors with the width of people (Stefanucci & Geuss, 2009), the size of goal...
posts with ability to kick (Witt & Dorsch, 2009), the size of a bulls-eye with ability to throw darts (Wesp et al., 2004), the height of walls with ability to climb them (Taylor, Witt, & Sugovic, 2010), the size of target with children’s performance throwing and catching a ball (Cañaíl-Bruland & Van der Kamp, 2009), and the height of a tennis net with ability to play (Witt & Sugovic, 2010). In all of these, and previously reported size perception studies, perception was assessed with a visual matching task or a slight variant of such a task, which means memory may have confounded the results. These and all other findings demonstrating the effect of action on perception are categorized by Witt (2011) as action-specific perception accounts.

While most of these action effects are truly perceptual in nature (e.g., attention increasing spatial discrimination) and intuitively seem to convey an evolutionary advantage (e.g., a predator grabbing one’s attention leading to an enhancement of visual processing thereby increasing one’s chance of survival), some effects that have been labeled perceptual would seem to be disadvantageous and may simply be memory masquerading as perception.

One such claim, dealing with the perceived size of objects being altered by one’s ability to act (Witt, 2011; Witt & Proffitt, 2005; Witt et al., 2008b), postulates that this effect has an evolutionary advantage: a hunter who often fails will perceive prey as smaller than a hunter who is usually successful, and so will move closer to get a better shot. This action-specific (size) perception account, however, means that a successful hunter would perceive the prey as larger, and may therefore aim wide of the actual target and miss.

It would seem, then, that size perception should be relatively stable in order to avoid such problems. An alternative explanation for the reported size effects is that the better hunter merely remembers the prey as being larger and the worse hunter remembers it as smaller simply as a means of subconsciously accounting for their respective success or failure. In this case both actually perceive the prey as equal in size during the hunt. Therefore this effect, and possibly many others, is in need of a more rigorous scientific exploration that distinguishes between memory and perceptual processes in order to get at the issue of what is being affected by action.

Witt and Proffitt (2005) conclude that perception of size is influenced by one’s ability to successfully perform some act with the object in question. Size judgements, however, were conducted while the object was no longer visible. In every experiment perception was assessed while participants were looking away from the goal object. Evidence that both could look back and forth as often as they wished from goal object to response area, and in the case of Witt and Dorsch (2009) the visual distance from goal object to response area was small, only a very small area of the visual field can be perceived in any amount of detail at any one time (Gregory, 1997).

Because participants never looked directly at the object in question while making their size responses, it is possible that the outcome of an action merely affects how one stores the object in memory, and subsequently describes it. The exact process of this action-dependent visual memory effect is beyond the scope of this paper, but based on the work of Cañaíl-Bruland et al. (2011) we know that the mere knowledge of success or failure at a given task is insufficient. What is required is that attention be paid to the goal object during the action combined with the knowledge of success or failure. This combination, therefore, may change how one thinks about the object after the fact, as opposed to how one actually perceives it during the time of action. For example, at the moment of action, a professional baseball player perceives the ball to be the same size as does an amateur. Only after the action occurs do the professional and the amateur’s thoughts concerning the size of the ball differ.

Memory is not infallible, and evidence for memory distortion has been found in a number of studies including the recollection of stories over time (Bartlett, 1932), the report of experienced events after receiving misleading information (Loftus & Pickrell, 1995; Nourkova, Bernstein, & Loftus, 2004; Sacchi, Agnoli, & Loftus, 2007), the illusory recollection of words that were never presented (Payne et al., 1996; Read, 1996), and the illusory recollection of performing an action that was never performed (Goff & Roediger, 1998). Visual details of a scene are subject to a similar fate. Evidence of poorly remembered scene details comes from studies on change blindness: participants rarely notice changes to a scene after a real or implied saccade (Rensink, O’Regan, & Clark, 1997) when gist is held constant (Sampanes, Tseng, & Bridgeman, 2008).

In order to determine whether action affects size perception or visual memory, the present study assigns both as independent variables when reporting the size of objects. Perception is assessed when a participant is looking at the object in question while giving their report, and visual memory is assessed when the participant can no longer see the object while giving their report. The experimental design is between subjects, with participants randomly assigned to Experiment and Condition. Two types of reports are used, haptic and verbal.

### 2. Experiment 1: Haptic measure

Participants threw a marble into one of three different sized holes presented in a random order. They were asked to indicate how large they perceived the hole to be, using their non-dominant hand. The purpose of this experiment was to determine whether perceived hole size reported haptically can be altered by success in completing an action.

#### 2.1. Method

##### 2.1.1. Participants

One-hundred and four (52 males, 52 females) undergraduate students volunteered in exchange for course credit. Thirty-four (15 females, 19 males) were assigned to the control condition, 35 (20 females, 15 males) to the perception condition, and 35 (17 females, 18 males) to the memory condition. They all threw with their dominant hand, had normal or corrected-to-normal vision, and, as assessed by a questionnaire at the conclusion of the study asking for their technique in reporting hole size, were unaware of the purpose of the experiment.

##### 2.1.2. Apparatus and stimuli

Participants sat in a chair facing the hole they were throwing to. The distance between their eyes and the hole was 1.38 m. Each hole was drilled into the center of a 390 mm by 110 mm by 12.7 mm wood board. The board slid into the front of a box sitting on a 77 cm tall table. A black curtain hung 16 cm in front of the box and covered it completely when down. An X was marked in white tape on the curtain, directly behind which the hole in the board appeared when the curtain was raised. Three boards, with hole diameters of 53 mm, 56 mm, and 59 mm, were used. All boards were painted flat white, while the box that holds the boards in place was covered in white duct tape.

Participants threw a marble with their dominant hand at each hole when it was presented. Immediately before or after their throw (depending on the condition), they indicated with their non-dominant hand how large they perceived the hole to be. To aid in the assessment of this measurement, their forefinger and thumb were marked with a black dot from a Sharpie pen at the point on their skin next to the inside corner of their nails. During the experiment, the participant’s hand was placed on a 20 cm by 25 cm measuring board, on a table 60 cm high. On one side of the board, the participant’s thumb and forefinger were placed...
along a measuring tape. In the middle of the tape a thumbtack served as their starting position. On the opposite side of the measuring board a camera was mounted to record participants' hand measurements. The perceived hole size was computed by noting the distance between the black dot on the participant's forefinger and thumb with respect to the measuring tape.

2.1.3. Procedure

After participants were seated they underwent a Pre-Practice to show them how the measurement part of the experiment worked. They were shown ten different sized circles drawn on paper, which ranged from 20 mm to 90 mm in diameter. When the circle was presented, they were to extend their forefinger and thumb apart from each other on the measuring device until the perceived diameter of the circle shown was reached. This distance was assessed by the experimenter, who then informed the participant of their measurement, and the actual size of the circle. This was done for every circle presented for a total of ten trials.

Next participants underwent Practice, which was designed to get them accustomed to the procedure of the experiment. Participants were presented with the boards to be used in the actual experiment (1–3). No feedback was given concerning the correct size of the hole. Instead feedback was given about the correct mechanics of each throw and measurement.

Before each board was revealed, participants were to hold the marble in their dominant hand while gripping the thumbtack on the measuring board with their non-dominant hand. Their marble holding arm was outstretched towards the white X on the curtain. When the hole was revealed the participants cocked back their arm and threw the marble towards the hole (Fig. 1). In the control condition they measured with their non-dominant hand once the hole was revealed, and threw immediately afterwards. In the memory condition they measured immediately after they threw but while the hole was still revealed. In the perception condition they measured immediately after they threw but while the hole was still revealed. In the memory condition they measured after they threw and immediately after the hole was covered by the curtain. After 10 practice trials and the subjects felt comfortable with the procedure they moved onto the actual experiment, which did not differ in instruction from the practice. Here each board was presented 10 times in random order for a total of 30 trials per participant.

To code the results, two raters watched the video of every measurement on a Mac desktop computer and assessed the distance between thumb and forefinger based on the ruler upon which the participant's hand rested. The observers were blind as to condition and whether the throw was a make or a miss.

2.2. Results/discussion

Anyone who was successful with less than 20% of their throws was eliminated due to a lack of comparison data between makes and misses. This accounted for one person in the perception condition. One person was also removed in the control condition due to the experimenters' inability to view their fingers during recording.

The average of the three holes used was 56 mm, and the average reported hole size of all three holes (overall average) was 47.89 mm in the control condition, 50.0 mm in the perception condition, and 50.2 mm in the memory condition. The overall average percentage of successful throws for the control condition was 58.2%, perception condition was 53.1%, and memory was 52.6%.

The overall percentage of successful throws and the overall average reported hole size were both analyzed between conditions to test for possible confounds. No significant differences were found between conditions for overall percentage of successful throws (F(2, 99) = 1.659, p = .196, η² = .032) or overall reported hole size (F(2, 99) = .593, p = .555, η² = .012).

A between-subjects correlation of average reported hole size with percentage of successful throws for each condition was calculated. There was no significant correlation in the control condition (Pearson's Correlation (2-tailed) = .181, N = 34, p = .306), perception condition (Pearson's Correlation (2-tailed) = .108, N = 34, p = .542), or memory condition (Pearson's Correlation (2-tailed) = .082, N = 34, p = .043).

To compare reported hole size between the control, perception, and memory conditions when a throw was successful versus when it failed on a trial by trial basis we analyzed each participant's successful minus failed throws for holes 1, 2, and 3. The overall average response for successful versus unsuccessful throws in the control condition was 47.6 mm and 48.2 mm respectively, the perception condition was 50.2 mm and 49.7 mm respectively, and the memory condition was 51.2 mm and 48.8 mm respectively. There was a significant effect of success minus failure
between conditions \((F(2, 99) = 7.53, p = .001, \eta^2 = .132)\). Post hoc comparisons using the Tukey HSD test indicated that the mean score of success minus failure for the memory condition \((M = .237, SE = .055)\) was significantly different from the perception condition \((M = .043, SE = .055)\) \((p = .036)\) and control condition \((M = -.058, SE = .055)\) \((p = .001)\) (Fig. 2).

We found no relationship between overall performance during a throwing task and the resulting perception or visual memory of the target object when the response was haptic. We did find evidence that visual memory for the target was altered on a trial by trial basis in a manner dependent upon successful or failed action, but we found no evidence that this was the case for perception. Furthermore, the memory effect was not due to an inherent confound between conditions, but was instead due to differences between successful and failed actions on a trial by trial basis.

3. Experiment 2: Verbal measure

Participants threw a marble into one of seven holes of differing size presented randomly. They measured how large they perceived the hole to be with verbal report. The purpose of this experiment was to determine whether perceived hole size reported verbally can be altered by one's successful versus unsuccessful completion of an action, based on evidence that under some conditions verbal and motor measures of the same stimulus situation can yield different results (Bridgeman, Peery, & Anand, 1997).

3.1. Method

3.1.1. Participants

One-hundred and fifteen undergraduate students (32 males, 83 females) volunteered in exchange for course credit. 38 (27 females, 11 males) were assigned to the control condition, 38 (27 females, 11 males) to the perception condition, and 39 (27 females, 12 males) to the memory condition. They all threw with their dominant hand, had normal or corrected-to-normal vision, and, as assessed by a questionnaire at the end of the study asking for their technique in reporting hole size, were unaware of the purpose of the experiment.

3.1.2. Apparatus and stimuli

Apparatus and stimuli were the same as in experiment one except that we used seven boards with hole diameters of 47 mm, 50 mm, 53 mm, 56 mm, 59 mm, 62 mm, and 65 mm. Participants threw a marble with their dominant hand at each hole when it was presented. Immediately before or after their throw (depending on condition), they verbally reported how large they perceived the hole to be, where #1 was the smallest and #7 was the largest possible hole size.

3.1.3. Procedure

Participants were first shown seven drawn circles of the same sizes as the seven holes to be used in the actual experiment, and inside each circle was the number that corresponded to it (1–7). They were presented on a 75 cm by 39 cm paper, with the largest (7) on top and the smallest (1) on the bottom. Participants were then seated and underwent Pre-Practice, analogous to that in Experiment 1. They were presented with a board with one of the seven hole sizes, and were asked to report its size on a 1–7 scale. Each hole was presented once. Participants were given feedback as to the correctness of their assessment.

Next participants underwent Practice, where they learned how to throw the marble and verbally report the hole size. No feedback was given concerning the correct size of the hole. Instead feedback was given about the correct mechanics of each throw and verbal measurement.

The motor practice and experimental procedures were the same as in experiment 1, with the exception that each board was presented seven times in random order for a total of 49 trials per participant.

3.2. Results/discussion

Anyone who was successful with less than 20% of their throws was eliminated due to a lack of comparison data between makes and misses. This accounted for one person in the perception condition and two people in the memory condition. Also anyone who was never successful or always successful when hole 4 was presented (the hole of interest in this experiment) was eliminated due to a lack of data for subsequent analyses. This accounted for eight people in the control condition, four in the perception condition, and two in the memory condition. Holes 1–3 and 5–7 were used to provide a range of possible verbal responses, but their analysis in this study is confounded with their respective closeness to the edge of this range. When presented, these holes do not have an equal probability of being reported as larger or smaller than they actually are, but instead carry with them an initial confound of being closer to the higher end of the range (holes 5–7) or to the lower end of the range (holes 1–3). For example, a hole of size 6 has five possibilities of being reported as smaller than it is, and only one possibility of being reported as larger than it is. This issue is even more apparent with
hole sizes 7 and 1. Because only hole number 4 lacks an initial bias of available smaller or larger size possibilities (being in the middle of the range), it is the only one that will be analyzed here. This was not an issue with Experiment 1 because each participant’s response to a particular hole (indicated by thumb and forefinger) was not dependent upon a predetermined range.

Hole number 4 is 56 mm in diameter. After all hole size reports were translated to an actual diameter, the average for reported hole size in the control condition was 55.9 mm, perception was 56.0 mm, and memory was 56.2 mm. The average percentage success for the control condition was 37.6%, perception condition was 37.2%, and memory condition was 42.9%.

The overall percentage of successful throws and the average reported hole size were both compared between conditions to test for possible confounds. No significant differences between conditions for overall percentage of successful throws \((F(2, 95) = .826, p = .441, \eta^2 = .017)\) or reported hole size \((F(2, 95) = .130, p = .878, \eta^2 = .003)\) were found.

A between-subjects correlation of average reported hole size with percentage of successful throws for each condition was calculated. There was no significant correlation in the control condition (Pearson’s Correlation (2-tailed) = -.297, \(N = 30, p = .111\)), perception condition (Pearson’s Correlation (2-tailed) = .065, \(N = 33, p = .72\)), or memory condition (Pearson’s Correlation (2-tailed) = .047, \(N = 35, p = .789\)).

To compare reported hole size between the control, perception, and memory conditions when a throw was successful versus when it failed on a trial by trial basis we analyzed each participant’s successful minus failed throws. The average response for successful versus unsuccessful throws in the control condition was 55.7 mm and 56.0 mm respectively, the perception condition was 55.7 mm and 56.0 mm respectively, and the memory condition was 56.7 mm and 55.8 mm respectively. There was a significant effect of success minus failure between conditions \((F(2, 95) = 4.385, p = .015, \eta^2 = .085)\). Post hoc comparisons using the Tukey HSD test indicated that the mean score of success minus failure for the memory condition \((M = .981, SD = 1.84)\) was significantly different from the perception condition \((M = -.339, SD = 2.08) (p = .025)\) and control condition \((- .257, SD = 2.26) (p = .045)\) (Fig. 3).

We found no relationship between a person’s overall performance during a throwing task and their resulting perception or memory of the target object when the response was verbal. We did find evidence that memory for the target was altered on a trial by trial basis in a manner dependent upon the successful or failed action, but found no evidence that this was the case for perception. Furthermore, the memory effect found was not due to an inherent confound between conditions, but was instead due to differences between successful and failed actions on a trial by trial basis.

4. General discussion

According to Witt (2011) the high ability participants in their studies perceived the goal object to be larger at the time of successfully performing the respective action for each experiment. This would predict that high ability participants as assessed by performance in the present study would perceive a larger hole than those of low ability, and this would be reflected in their size judgments.

In both experiments one and two, perception and memory were not found to correlate with overall ability as assessed by the percentage of successful throws made by each participant. This demonstrates that overall performance of a series of actions does not have an effect on the perception or memory of the goal object being used. An explanation as to why we found no effect at all for this analysis is given below.

Because of our experimental setup, we were also able to investigate ability’s effect on size perception and memory on a trial-by-trial basis across all participants. Here it was found that ability affects the memory, but not the perception, of each individual action in a manner dependent upon success or failure. This explains why we found no effect of overall performance on participant responses while Witt and Proffitt (2005), Witt et al. (2008b), and Witt and Dorsch (2009) did. In conditions where an effect was found they had participants respond only after all of the action was completed. Those who performed better would therefore be more likely to have successfully completed their last action, and so would respond with a larger size judgment than those who performed worse, who were more likely to have failed their last action. In accordance with the present study, those experiments were effectivity testing only the last action performance instead of the overall performance. Therefore our results do not conflict in this regard.

It must be noted, however, that Wesp et al. (2004) found an effect for overall performance and reported hole size after the participant’s first make. Because of their experimental setup, those who were poor at the task would be more likely to miss many shots before finally making it and reporting. Therefore it’s possible that these multiple failures in the beginning of the task affect memory more profoundly than the one success. Perhaps the act of responding after every shot, as was done in the present experiment, wipes the emotional slate clean, and participants can act and respond in a fresh way every time. This emotional baggage theory may provide a more satisfactory explanation for Witt and Proffitt (2005), Witt et al. (2008b), and Witt and Dorsch (2009) findings as well. Cañal-Bruland et al. (2011), however, also tested size perception after the first make and did not find a correlation between number of attempts and reported size. The reason for this discrepancy between Wesp et al. (2004) and Cañal-Bruland et al. (2011) is not...
clear, and more research on the effect of response frequency is needed to verify the emotional baggage theory.

The fact that we did not find evidence for an effect on perception in either the overall or trial-by-trial ability analysis goes counter to the action-specific perception account proposed by Witt (2011). Her theory that perception is shaped by one’s ability to act is not supported by the present findings. What is supported, is an action-specific visual memory account, where one’s successful versus unsuccessful action alters the memory for the objects used during the action.

More research is needed to determine whether the stored representation of the goal object is altered by (1) the success or failure of the action, (2) the transfer of stored information from memory to size report, or (3) some other response bias or demand characteristic is the cause of the size effect found. It should also be noted that the conclusions reached in the present paper only concern size reports in regards to objects in near space. Experiments by Witt (2011) concerning distance perception being affected by ability, for example, are quite robust, even when participants are looking directly at the goal object while giving their reports. Woods, Philbeck, and Danoff (2009) and Durgin et al. (2009) have found, however, that distance reports in some of Witt’s (2011) studies appear to be influenced by verbal instruction instead of perception. This contradiction between distance and size perception and the possible confound of response bias remains unclear, and should be further investigated.

In summary, because all research claiming to find evidence for the malleability of size perception suffers from the possible confound of memory, the more parsimonious conclusion from those studies and the present study is that action affects memory and/ or the reporting of goal objects on an action-by-action basis. An effect of action on memory rather than perception remains a significant insight into human action planning, however, and does not diminish the importance of earlier experiments finding effects of action on subsequent psychophysical measures. This conclusion adds further evidence to our understanding of just how dynamic memory really is, and how perception reliably delivers size properties of the world regardless of motor ability. Future research is needed to investigate the specifics of this size memory effect to answer lingering uncertainties, such as where along the route from encoding to reporting it occurs, and why some perceptual properties of the world seem to be flexible (e.g., distance) while others do not (e.g., size).

References


