The perception and memory of object properties: The role of attention, intention, and information detection

Brandon J. Thomas (thomab9@mail.uc.edu)
Department of Psychology, 47 Corry Blvd
Cincinnati, OH 45219-0376 USA

Michael A. Riley (rileym@ucmail.uc.edu)
Department of Psychology, 47 Corry Blvd
Cincinnati, OH 45219-0376 USA

Abstract

The current study sought to investigate the relationship between attention, perception and memory in the perception and recall of attended and unattended properties of objects. Two experiments tested whether the intention to perceive maximum overhead reaching height with the use of handheld rods with different mass and rotational inertia yielded information for participants to remember the rods' heaviness after they were removed from view. Participants remembered the difference in heaviness of rods but only when haptic information was solely available during the earlier perception of overhead reaching height and vision was occluded. The results support an ecological approach to perception, attention and memory, and suggest that information detected for perception can be later used to remember other object properties that have a correlated informational basis.

Keywords: remembered affordances, direct perception, ecological psychology, information, attention

The ecological approach defines attention as an active process of detecting goal-relevant information about the environment (E. J. Gibson, 1969; E. J. Gibson & Pick, 2000; J. J. Gibson, 1966, 1979). Michaels and Carello (1981) consider attention as the *control of information detection*, which proposes that an organism's intention is a driving force of attention and subsequent information detection (e.g., Arzamarski, Isenhower, Kay, Turvey, and Michaels, 2010; Carello & Turvey, 2004; Michaels & Isenhower, 2011; Riley, Wagman, Santana, Carello, & Turvey, 2002; Stephen, Arzamarski, & Michaels, 2010).

Consonant with this explication, Michaels, Weier, and Harrison (2007) found that when participants perceived the affordances (action capabilities) of multiple tools in a number of different behavioral tasks, perception of tool suitability was accomplished by attending to task-specific properties of the tools and information about each tool was generated by differential exploratory movement patterns for different tools and tasks. Participants tended to rely on visual information when it was available, even when concurrently available dynamic touch information could have supported the perception of affordances. Information that specified the environmental property necessary to fulfill the task was attended, detected, and constrained the perception of tool suitability.

The ecological approach also suggests that information within ambient energy arrays lawfully specifies (i.e., relates in a 1:1 fashion to) intentionally perceived properties of the environment (J. J. Gibson, 1966, 1979). However, a number of studies suggest that individuals can use variables that correlate with specifying variables—*nonspecifying variables* (Gilden & Proffitt, 1994; Jacobs & Michaels, 2001; Jacobs, Runeson, & Michaels, 2001; Runeson & Vedelar, 1993) to perceive properties of the environment. The degree of perceptual accuracy with the use of nonspecifying variables depends on the magnitude of the correlation between the nonspecifying variable and the property in question. If a perceiver intends to perceive a certain property, such as the length of a handheld rod, then the perceiver might have incidentally obtained nonspecifying information of properties that merely correlate with the information detected about length.

Research on dynamic touch has provided an understanding of the different informational variables used to perceive both the length and heaviness of handheld rods. Perceived length is a power function of the rods' first moment of inertia (I_1) raised to a positive value and the third moment of inertia (I_3) raised to a negative value (Fitzpatrick, Carello, & Turvey, 1994). Perceived heaviness is a function of the object's mass, inertia ellipsoid volume, and inertia ellipsoid symmetry (Shockley, Grocki, Carello, & Turvey, 2001). For a review on dynamic touch see Carello & Turvey, 2000) The variables I_1 and I_3 influence both the perceived length and heaviness of a wielded object. If perceivers detect information that expresses the influence of those mechanical quantities, then the intention to perceive the length of an unseen rod by dynamic touch might incidentally enable rod heaviness perception. In other words, the correlated informational bases of perceived length and heaviness by dynamic touch might permit people to incidentally perceive one by detecting the other.

We hypothesized that the intention to perceive a property will partially support the memory of properties that share an informational basis with the intended property. Other informational variables that do not correlate with that of the intended property should not be remembered. We tested this hypothesis using the remembered affordance paradigm (Wagman, Thomas, Day, & McBride, 2013), which has previously been used to uncover specific aspects of the environment that people detect (Thomas & Riley, 2014). It is possible that individuals can incidentally remember object properties that differ from the properties they initially intended to perceive if the informational variable detected correlates with the "unintended" object property (i.e., if the detected information acts as a nonspecifying variable). This should, however, depend on the salience and availability of the type of information available to the perceiver. We therefore manipulated the availability of different perceptual modalities during the task.

Experiment 1

In Experiment 1, visual and dynamic touch information were available concurrently to participants while they reported their maximum ability to reach overhead with a rod. We predicted that perceived reach-ability would not differ between the two wielded rods, since they differed in weight but not length. Participants should use geometric visual information in this context, consistent with Michaels et al. (2007). We also expected that participants would not report differences in heaviness between the two rods once the rods had been removed from view, even though one of the rods had more mass than the other. We expected this because the visual information detected to perceive reach-ability does not correlate with rod heaviness information.

Method

Participants

Thirty-seven undergraduates from the University of Cincinnati participated in this experiment for course credit. Written informed consent was obtained prior to data collection. Given the height constraints of the laboratory and apparatus, participants were required to be no taller than 173 cm. The average height of participants was 164.4 cm (*SD* = 5.1 cm). The sample consisted of 32 females and 5 males, and their average age was 20.0 yrs (*SD* = 3.9 yrs).

Materials & Apparatus

When providing reaching height reports, participants instructed an experimenter to use a pulley and string to raise or lower a marker consisting of 11 stacked washers (11 g mass, 3 cm diameter, 2 cm tall) until they felt it was at their maximum reaching height. The marker was suspended via the pulley system attached to the top of a planar surface (264 cm tall × 165 cm wide). To create a uniform background behind the marker, grey sheets were draped over the surface. A tape measure affixed to the back of the vertical surface was used to measure the height of the suspended marker once participants finalized their perceptual reports. The tape measure was not visible to participants.

Two 46 cm long aluminum rods were used. Both rods had a 50 g circular weight (5.2 cm diameter and 1.9 cm tall) attached 13.9 cm from the bottom. The rod's "handle" was the length of the rod that extended below this weight resulting in an effective rod length of 32.1 cm (i.e., given the length of the handle, the rod could have extended reach by a maximum of 32.1 cm). Brown construction paper was wrapped around the distal portion of rod, covering it from the top of the handle to the end of the rod, and red duct tape covered the distal end of the rod. In addition to the 50 g weight at the top of the handle, which was attached to rods, the heavy rod had an additional 50 g weight attached to the distal end. The properties of the rod set are listed in Table 1.

Table 1: Metric rod properties for Experiments 1 and 2.

Property	Light Rod	Heavy rod	Standard rod
Length	46 cm	46 cm	46 cm
Mass	111.4 g	163.1 g	50.5 g
I_1 (g × cm$^{2)}$	36,766	126,657	28,971
I_2 (g × cm$^{2)}$	35,739	125,183	28,401
I_3 (g × cm$^{2)}$	1,780	2,945	604

Procedure

Each participant stood 285 cm from the vertical surface in a viewing area (50 × 50 cm) that was centered relative to the vertical surface. In each perceptual report condition, participants completed three ascending trials (in which the marker was initially set at its lowest position and then raised during reporting) and three descending trials (in which the marker was initially set at its highest position and then lowered during reporting). Ascending and descending trials alternated.

All participants completed the conditions in blocked fashion in the same order (rod present trials must necessarily precede rod absent trials). There were two sets of trial blocks. Each set began with a block of *reach-with-rod-present* trials. Half of the participants wielded the *light rod* in this block, and half wielded the *heavy rod*. Participants held out their right arm so that it was parallel to their body and the rod was placed in their hand, aligned with the distal end of the handle. Participants were instructed to wield the rod comfortably in their hand about their wrist, elbow, or shoulder as long as they did not explicitly practice reaching upward with the rod or raise their elbow above shoulder height. Participants reported the maximum height they would be able reach if they were to walk over to the front of the vertical surface and use the rod to reach for the marker. The reports were provided by instructing the experimenter to raise or lower the marker until it was at the maximum height that the participant believed he or she could reach. The experimenter adjusted the height of the marker from behind the vertical surface and was not visible to the participant. Participants were able to fine-tune the height of the marker on a given trial until they were satisfied with the report. After each trial, participants were asked to close their eyes while the marker was set for the next trial.

At the conclusion of this condition, participants closed their eyes and the rod was placed behind the vertical surface and out of view. They then performed the *reach-with-hand* condition, in which participants reported the maximum height they could reach if they were to walk over to the front of the vertical surface and reach up with the fingertips of their right hand[1].

Next, in the *reach-with-rod-absent* conditions, participants performed the same perceptual task as in the *reach-with-rod-present* conditions except the rod remained out of view. Participants were instructed to imagine that they were still holding the rod and report the maximum height they would be able to reach if they were to walk over to the vertical surface, and use it to reach for the marker. The order of conditions resulted in a delay of a few minutes (i.e., the duration of the trial block for the *reach-with-hand* condition) between the *reach-with-rod-present* and the *reach-with-rod-absent* conditions.

In the *heaviness* conditions, a magnitude estimation strategy was used to obtain reports in which the participant was handed the standard rod in their right hand and told that they would refer to it to report the heaviness of the rod that they wielded in the first block of trials. The participant was told that the standard rod was assigned a value of 100 that did not correspond to any actual units of heaviness, and that if they thought the rod held earlier was twice as heavy as the standard, to give it a value of 200 or a value of 50 if they thought it was half as heavy. However, they were told that they could give the rod any value. Prior to this point in the experiment, participants had no knowledge that they were to report the heaviness of the rod.

Participants then repeated those four conditions in the second set of trial blocks. Participants made reach-ability and heaviness reports with the other rod in the second set of trial blocks[2]. The second set continued with *reach-with-rod-absent, reach-with-hand*, *reach-with-rod-absent*, and *heaviness* blocks. The experimental design is schematized in Figure 1. After completing the first set of trial blocks, it is likely that participants expected to be instructed to report heaviness in the second set of trial blocks, and thus may have attended explicitly to rod heaviness. Our primary hypothesis about whether attending to rod length would support perception of rod heaviness was most appropriately evaluated using the data from the first set of trial blocks. For these reasons we included the set as a factor in analyses of heaviness reports. There were six trials per condition, yielding a total of 48 trials in the experiment (not including the two heaviness reports in sets 1 and 2).

After the completion of all trials, the experimenter measured participants' standing height and maximum reaching heights when reaching with their right hand and when reaching with the *heavy* and *light rods* held in their right hand. At no prior point in the experiment did any participant approach the surface or attempt to reach for the marker.

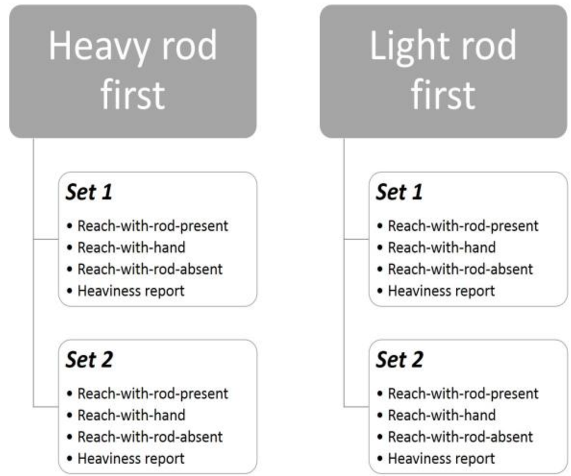

Figure 1: A schematic of the experimental design and procedure for Experiments 1 and 2.

Results & Discussion

Each participant's perceptual reports were averaged across the six trials per condition. Those data were screened for outliers that were 2.5 *SD* less or greater than the median. One outlier was found and that participant's data were excluded from any further analyses. The significance of the main effects and interaction did not change by removing this participant.

Mean perceived maximum reaching height reports were compared in a two-way, repeated-measures analysis of variance (ANOVA) with the factors of rod (light and heavy) and condition (reach-with-rod-present, reach-with-hand, and reach-with-rod-absent). There was a significant effect of condition, $F(1, 66) = 243.8$, $p < .001$, $\eta_p^2 = .88$. According to Bonferroni-corrected post-hoc *t*-tests, the reach-with-rod-present (M = 219.0 cm) and reach-with-rod-absent (M = 219.8 cm) conditions did not significantly differ ($p = .972$), but both were significantly greater than the reach-with-hand condition (M = 201.9 cm), both $p < .001$. The main effect of rod ($F(1, 66) = 0.014$, $p = .906$, $\eta_p^2 = .01$) and rod × condition interaction ($F(2, 66) = 2.14$, $p = .216$, $\eta_p^2 = .06$) were not significant. There was no difference between the mean reach-with-hand reports when participants reported the reach-ability of the light rod (M = 201.5) compared to the heavy rod (M = 202.2), $t(33) = 0.62$, $p = .542$ (see Figure 2).

[1] The *reach-with-hand* condition was included to introduce a delay between rod present and absent conditions and to replicate the method of Thomas and Riley (2014).

[2] Participants made reports for the heavy rod in set 2 if they reported on the light rod in set 1 and vice versa.

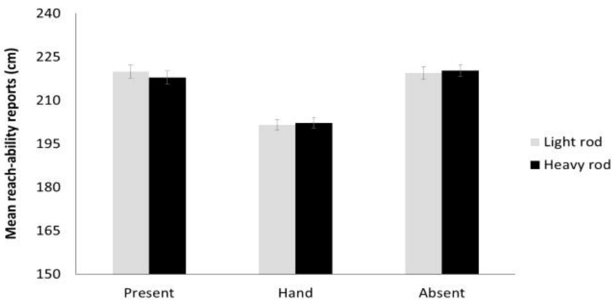

Figure 2: Mean perceptual reports (cm) for the *reach-with-rod-present*, *reach-with-hand*, and *reach-with-rod-absent* conditions × *heavy* and *light rods* in Experiment 1. Error bars represent within-subjects standard errors.

Because of the carryover effects that were anticipated when participants reported the heaviness of the rod in the set 2, we compared mean heaviness reports in a two-way ANOVA with a between-subjects factor of rod (light and heavy) and a within-subjects factor of set (set 1 and set 2). There was a significant main effect of rod $F(1, 32) = 10.08$, $p = .003$, $\eta_p^2 = .24$, with the heavy rod ($M = 201.3$) eliciting greater reports than the light rod ($M = 142.5$). There was a significant main effect of set, $F(1, 32) = 6.39$, $p = .017$, $\eta_p^2 = .17$, with greater reports in set 2 ($M = 187.6$) than set 1 ($M = 156.2$). There was also a significant interaction, $F(1, 32) = 7.23$, $p = .017$, $\eta_p^2 = .18$. A simple-effects test revealed that the set 1 heavy condition ($M = 168.8$) did not differ from the set 1 light condition ($M = 143.5$), $p = .263$. However, the set 2 heavy condition ($M = 233.8$) significantly differed from the set 2 light condition ($M = 141.5$), $p < .001$. A second set of simple effects tests revealed that the set 1 heavy rod condition differed from the set 2 heavy rod condition, $p = .001$. The set 1 light rod condition did not differ from the set 2 light rod condition, $p = .910$ (see Figure 3).

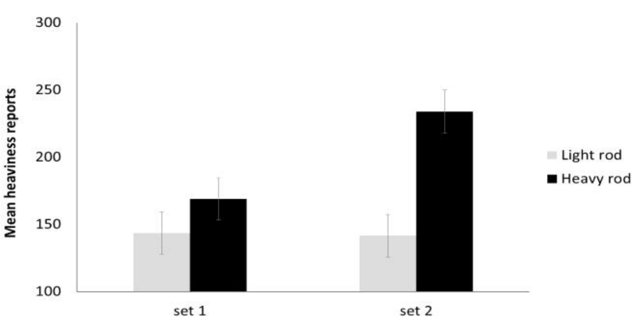

Figure 3: Mean magnitude estimated heaviness reports for *set 1* and *set 2* × *heavy* and *light rods* in Experiment 1. Error bars represent within-subjects (set) and between-subjects (rod) standard errors.

There was no difference in perceived reach-ability between the light and heavy rods, and the reach-with-rod-present and -absent conditions were different from the reach-with-hand condition. Participants did not detect the available dynamic touch information about the rods' length, even though participants actively wielded the rods. There was no difference in remembered heaviness between the light and heavy rods when participants reported the rods' heaviness in set 1. Though, participants were sensitive to the rods' difference in mass and rotational inertia in set 2 once they became aware that they would be asked to report heaviness.

Experiment 2

In Experiment 2, the rods were occluded from view in the reach-with-rod-present conditions. We expected participants to perceive that they could reach higher with the heavy rod because of its difference in mass and mass distribution. We also expected that attention to dynamic touch information about length would support accurate discrimination of the two rods' heaviness in set 1.

Method

Participants

Thirty-nine undergraduates from the University of Cincinnati participated in this experiment for course credit. Written informed consent was obtained prior to data collection. Participants were required to be no taller than 173 cm for the same reasons as Experiment 1. The average height of participants was 166.4 cm (*SD* = 6.4 cm). The sample consisted of 38 females and 1 male, and their average age was 19.9 yrs (*SD* = 4.3 yrs).

Materials, Apparatus, & Procedure

The materials and apparatus from Experiment 1 were reused in Experiment 2. A grey curtain that fully occluded the wielded rods was also utilized. The curtain was hung from the ceiling and had a slit that participants put their hand through.

The procedure was the same as Experiment 1, except for in the *reach-with-rod-present* conditions, in which participants put their hand through the slit in the curtain. The rod was placed in the participant's hand so that the distal end of the handle was even with the bottom of the hand.

Results & Discussion

Mean perceived maximum reaching height reports were compared in a two-way, repeated-measures ANOVA with the factors of rod (light and heavy) and condition (reach-with-rod-present, reach-with-hand, and reach-with-rod-absent). There was a main effect of rod, $F(1, 41) = 18.36$, $p < .001$, $\eta_p^2 = .31$; heavy rod reports ($M = 209.5$ cm) were greater than the light rod reports ($M = 205.1$ cm). There was a significant effect of condition, $F(2, 82) = 108.98$, $p < .001$, $\eta_p^2 = .73$. According to Bonferroni-corrected post-hoc *t*-tests, all conditions significantly differed. The reach-with-rod-absent condition (*M* = 214.2 cm) was greater than the reach-with-rod-present condition (*M* = 210.2 cm), and both of those were greater than the reach-with-hand condition (*M* = 197.5 cm), all $p < .001$. There was a significant rod × condition interaction, $F(2, 82) = 5.24$, $p = .007$, $\eta_p^2 = .11$ (see Figure 4). Post-hoc simple-effects tests revealed that the light and heavy rod conditions differed in the reach-with-present and -absent conditions (all $p < .003$), but the rod conditions did not differ in the reach-with-hand conditions ($p = .276$); this was expected because the rod variable was essentially undefined during reach-with-hand reports).

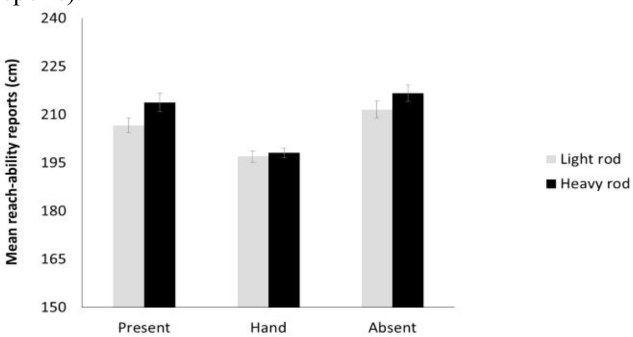

Figure 4: Mean perceptual reports (cm) for the *reach-with-rod-present*, *reach-with-hand*, and *reach-with-rod-absent* conditions × *heavy* and *light rods* in Experiment 2. Error bars represent within-subjects standard errors.

Mean heaviness reports were compared in a two-way ANOVA, with the between-subjects factor of rod (heavy and light) and the within-subjects factor of set (set 1 and set 2). There was a significant main effect of rod $F(1, 40) = 25.67$, $p < .001$, $\eta_p^2 = .39$, with greater heavy rod reports ($M = 239.9$) than light rod reports ($M = 158.9$). Neither the main effect of set, $F(1, 40) = .69$, $p = .412$, $\eta_p^2 = .02$ or the set × rod interaction were significant, $F(1, 40) = 2.22$, $p = .144$, $\eta_p^2 = .05$ (see Figure 5).

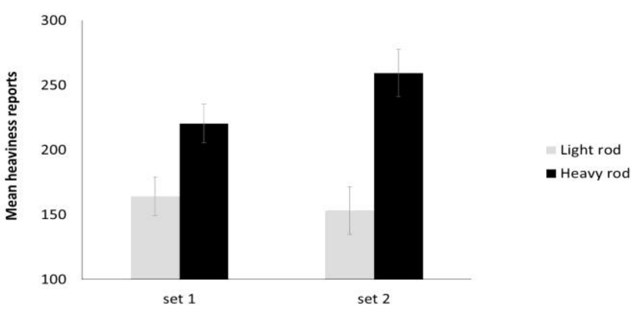

Figure 5: Mean magnitude estimated heaviness reports for *set 1* and *set 2* × *heavy* and *light rods* in Experiment 2. Error bars represent within-subjects (set) and between-subjects (rod) standard errors.

Reach-ability reports with the heavy rod were greater than reports with the light rod in both the present and absent conditions. Both present and absent reach-ability reports with the rod were greater than reports in the reach-with-hand condition. Also, reports of remembered heaviness were significantly greater for the heavy than the light rod in both set 1 and set 2. The set 1 heaviness results indicate that perceived reach-ability with the rods by dynamic touch supported the memory of the rods' heaviness by dynamic touch, because of the correlation in the variables that determine both perceived heaviness and perceived reach-ability.

General Discussion

In Experiment 1, we predicted that participants would detect visual, geometric information when perceiving reach-ability and that reports would not be affected by the difference in mass and mass distribution of the two rods, consistent with Michaels et al. (2007). In Experiment 2, when vision was occluded, we predicted that participants would detect dynamic touch information when perceiving reach-ability and that reports would be constrained by the specification of length based on the rods' rotational inertia, with greater reports for the heavy rod than the light rod. Both of these hypotheses were confirmed.

We also predicted that the detection of information to perceive reach-ability would support the memory of heaviness when the information detected about rod length correlates with that of heaviness. We expected this would be the case in Experiment 2, since the informational bases of perceived length and heaviness by dynamic touch correlate, which was the only information about the rods available to participants. However, we expected that the intention to perceive reach-ability would not support the memory of heaviness when the informational bases were uncorrelated as they were in Experiment 1 (where participants attended to visual, geometric information about rod length). Both of these hypotheses were also confirmed. The results suggest that nonspecifying informational variables can be used to *remember* properties of objects that are not intentionally perceived while the object is present.

The results are consistent with Craik's (2002) claim that retrieval is largely determined by the nature of processing during encoding and the relationship between the retrieval cue and the encoded stimulus. While we do not invoke processing depth or elaboration during encoding in our explanation, our results also suggest that the informational variables detected during perception are a constraint on remembering. The results of the current study also contribute to the concept of implicit learning or implicit knowledge. A. Reber (2003) defines implicit learning as situation-neutral processing of stimuli beyond a person's awareness of the process or acquisition of the knowledge obtained (for a review of implicit learning see Kihlstrom, Dorfman, & Park, 2007; P. Reber, 2013). The results of the current study add to this literature and suggest that implicit perception and memory of object properties are constrained by the information detected to fulfill perception-action goals while the object is present.

The current study highlights the constraints imposed on experience by a perceiver-actors intention and the information detected for fulfilling that intention. The current study also demonstrates the potential utility of nonspecifying variables for understanding the attention to, and perception and memory of object properties. Future investigations into the relationship between information detected for perceiving and remembering might prove insightful in understanding attention, perception, and memory.

References

Arzamarski, R., Isenhower, R. W., Kay, B. A., Turvey, M. T., & Michaels, C. F. (2010). Effects of intention switching and feedback on attunement in dynamic touch. *Attention, Perception, & Psychophysics, 72*, 721–735.

Carello, C., & Turvey, M. T. (2000). Rotational invariants and dynamic touch. In M. Heller (Eds.), *Touch, representation and blindness* (pp. 27-66), New York: Oxford University Press.

Craik, (2002). Levels of processing: Past, present…and future? *Memory, 10*, 305-318.

Fitzpatrick, P., Carello, C., & Turvey, M. T. (1994). Eigenvalues of the inertia tensor and exteroception by the “muscular sense”. *Neuroscience*, *60*, 551-568.

Gibson, E. J., & Pick, A. D. (2000). *An ecological approach to perceptual learning and development*. New York: Oxford University Press.

Gibson, E. J. (1969). *Principles of perceptual learning and development*. New York: Appleton-Century-Crofts.

Gibson, J. J. (1979). *The ecological approach to visual perception.* Boston, MA: Houghton Mifflin.

Gibson, J. J. (1966). *The senses considered as perceptual systems*. Boston, MA: Houghton Mifflin.

Gilden, D. L., & Proffitt, D. R. (1994). Heuristic judgment of mass ratio in two-body collisions. *Perception & Psychophysics*, *56*, 708-720.

Jacobs, D. M., & Michaels, C. F. (2001). Individual differences and the use of nonspecifying variables in learning to perceive distance and size: Comments on McConnell, Muchisky, and Bingham (1998). *Perception & Psychophysics, 63*, 563-571.

Kihlstrom, J.F., Dorfman, J, & Park, L. (2007). Implicit and explicit learning and memory. In M. Velmans & S. Schneider (Eds.), A companion to consciousness (pp. 525-539). Oxford, U.K.: Blackwell.

Jacobs, D. M., Runeson, S., & Michaels, C. F. (2001). Learning to visually perceive the relative mass of colliding balls in globally and locally constrained task ecologies. *Journal of Experimental Psychology: Human Perception and Performance, 27,* 1019-1038.

Michaels, C. F., & Isenhower, R. W. (2011). Information space as action space: perceiving the partial lengths of rods rotated on an axle. *Attention, Perception, & Psychophysics, 73*, 160-171.

Michaels, C. F., & Carello, C. (1981). *Direct perception*. Englewood Cliffs, NJ: Prentice Hall.

Michaels, C. F., Weier, Z., & Harrison, S. J. (2007). Using vision and dynamic touch to perceive the affordances of tools. *Perception, 36*, 750-772.

Reber, A.S. (1993). Implicit learning and tacit knowledge: An essay on the cognitive unconscious. New York, NY: Oxford University Press.

Reber, P. J. (2013). The neural basis of implicit learning and memory: A review of neuropsychological and neuroimaging research. Neuropsychologia, 51, 2026-2042.

Riley, M. A., Wagman, J. B., Santana, M. V., Carello, C., & Turvey, M. T. (2002). Perceptual behavior: Recurrence analysis of a haptic exploratory procedure. *Perception, 31*, 481-510.

Runeson, S., & Vedeler, D. (1993). The indispensability of pre-collision kinematics in the visual perception of relative mass. *Perception & Psychophysics, 53*, 617-633.

Shockley, K., Grocki, M., Carello, C., & Turvey, M. T. (2001). Somatosensory attunement to the rigid body laws. *Experimental Brain Research, 136*, 133-137.

Stephen, D. G., Arzamarski, R., & Michaels, C. F. (2010). The role of fractality in perceptual learning: Exploration in dynamic touch. *Journal of Experimental Psychology: Human Perception and Performance*, *36*, 1161-1173.

Thomas B. T., & Riley, M. A. (2014). Remembered affordances reflect the fundamentally action-relevant, context-specific nature of visual perception. *Journal of Experimental Psychology: Human Perception and Performance, 40*, 2361-2371.

Wagman, J. B., Thomas, B. J., McBride, D. M., & Day, B. M. (2013). Perception of maximum reaching height when the means of reaching are no longer in view. *Ecological Psychology, 25*, 63-80.