Actual and illusory differences in constant speed influence the perception of animacy similarly

Paul A. Szego
Department of Psychology, Neuroscience & Behaviour, McMaster University, Hamilton, Ontario, Canada

M. D. Rutherford
Department of Psychology, Neuroscience & Behaviour, McMaster University, Hamilton, Ontario, Canada

The ability to perceive objects as alive is the first step in social cognition. When the status of an object is ambiguous—if far away or fast moving—animacy is best perceived using motion cues. Previous studies have revealed that acceleration is a robust cue to animacy. The current study tests the prediction that, in the absence of acceleration, an object traveling at a relatively faster constant speed is more likely to be perceived as animate. Experiment 1 confirmed this hypothesis. Experiment 2 investigated the robustness of this finding by employing an illusory speed difference: Participants viewed dots moving at the same speed across apparently smaller and apparently larger central circles that were actually equally sized. Two thirds of participants perceived a dot traveling across an apparently larger circle to be faster or alive. Experiment 3 showed that participants' responses were not due to response bias. Together, these results suggest that our perceptions of animacy are influenced by constant speed differences, and that the perceptual association of speed and animacy is influenced by actual and illusory speed differences similarly.

Keywords: animate motion, motion perception, social cognition, illusory perceptions

Citation: Szego, P. A., & Rutherford, M. D. (2007). Actual and illusory differences in constant speed influence the perception of animacy similarly. *Journal of Vision, 7*(12):5, 1–7, http://journalofvision.org/7/12/5/, doi:10.1167/7.12.5.

Introduction

Humans have evolved specialized cognitive mechanisms designed to solve social problems because of having evolved in large social groups (Cosmides & Tooby, 1992; Dunbar, 1998). From early infancy, humans show preferences for, and orient selectively to, social stimuli (Mondloch et al., 1999). Very young infants have specialized cognitive processes that allow them to interpret, to use, and to anticipate social information (Csibra, Gergely, Bíró, Koós, & Brockbank, 1999; Gergely, Nádasdy, Csibra, & Bíró, 1995; Kuhlmeier, Wynn, & Bloom, 2003; Premack & Premack, 1995; Woodward, 1998). Perhaps the earliest and most fundamental of these social skills is the ability to discriminate which objects belong to the class of social stimuli, thus warranting further processing by social cognitive mechanisms. We propose that this perception of animacy underlies all other social cognitive abilities.

The perception of animacy has been primarily studied using two different approaches: First, by varying the features of an object such as whether it has eyes, faces, or limbs (e.g., Guajardo & Woodward, 2004), and second, by varying the motion of simple objects that have no such morphological features, typically using basic geometric shapes (see Gelman & Opfer, 2002; Rutherford, Pennington, & Rogers, 2006; for a review, see Scholl & Tremoulet, 2000). Heider and Simmel's (1944) seminal research revealed that people can and do interpret the motions of simple shapes in terms of mental states. When shown animations of two triangles and a circle moving in specific ways, people interpreted the motions as social behaviors, including chasing, fighting, cowering, and protecting. Perceptual sensitivity to even such simple displays begins very early in infancy (Luo & Baillargeon, 2005; Rochat, Morgan, & Carpenter, 1997) relies on dedicated neural areas for interpreting social stimuli (Giese & Poggio, 2003; Martin & Weisberg, 2003), appears stable cross-culturally (Barrett, Todd, Miller, & Blythe, 2005), and differs between typically developed children and those with autism (Rutherford et al., 2006). However, this research has relied on relatively complex and overtly social or intentional motions (e.g., circles chasing each other, Rochat et al., 1997; objects appearing to avoid other obstacles, Gergely et al., 1995; Kuhlmeier et al., 2003) and therefore may exploit participants' knowledge of intentionality and mental states more than their perception of motions indicative of animate objects. Attempting to examine fundamental perceptions of animacy requires stimuli that do not explicitly suggest or induce perceptions of intentionality. This is perhaps best accomplished by using not only visually simple stimuli, but also simpler motion displays than previously used.

Tremoulet and Feldman (2000) conducted a study examining people's perceptions of animacy based on the motion of simple geometric shapes. In their study, participants responded, using a Likert scale, to displays of solitary objects moving across an otherwise empty

doi: 10.1167/7.12.5 Received November 22, 2006; published September 18, 2007 ISSN 1534-7362 © ARVO

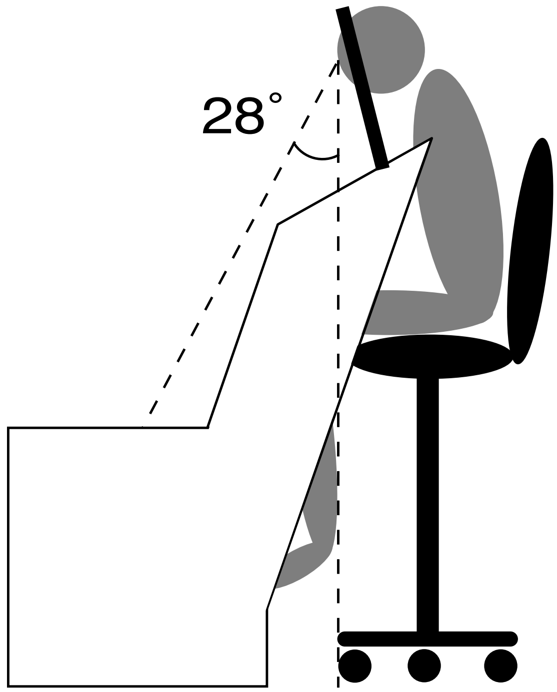

Figure 1. Presentation apparatus containing a monitor oriented horizontally. All participants sat on a stool, looking down at the screen at an angle of 28° off perpendicular, using a chin rest.

circular background. On each trial, either a dot or a line segment would enter the circle from one of twelve points (distributed clocklike around the perimeter) and travel at a constant speed toward the center of the circle, at which point it could change speed and direction relative to its initial motion. Their experiments revealed that even very simple motions are effective cues of people's perceptions of animacy; the most robust finding was that acceleration is a particularly salient cue for animacy: Increased acceleration resulted in higher ratings of animacy. We have replicated their results in our laboratory using a Likert scale and a two-interval forced choice procedure and have confirmed their findings. It appears that acceleration is a reliable visual cue for animacy, and that objects accelerating greatly appear alive more often than objects accelerating relatively less.

Current study

Given that our social perceptual systems appear to be sensitive to a change in speed, we wondered whether our perceptual systems were similarly sensitive to differences in constant speed. Two experiments were designed to investigate whether differences in constant speed would influence our perceptions of animacy, such that the association of faster objects appearing animate would be maintained. We adapted the stimuli from Tremoulet and Feldman (2000) but simplified the motions even further by having the objects travel at a constant speed, with no change in trajectory. Objects traveled across two circles of the same size, either at different speeds (Experiment 1) or at speeds only appearing to differ (Experiment 2). We predicted that in both experiments, people would perceive animacy more often when objects appeared to travel at faster constant speeds.

Experiment 1

Experiment 1 was designed to expand upon the general findings of Tremoulet and Feldman (2000) by examining objects traveling at constant speeds. We tested the hypothesis that of two objects traveling at different speeds, the relatively faster object would be perceived as animate more often than a relatively slower object, consistent with the trend found in previous studies.

Method

Participants

Seventeen undergraduate psychology students participated for credit (13 female, 4 male; mean age = 24.1 years, range = 19–44 years). All participants had normal or corrected-to-normal vision.

Stimuli

Two circles, outlined in black and subtending 3.8°, were shown centered on an otherwise empty grey screen. A white dot subtending 0.13° appeared and traveled across each circle, one circle at a time. The entire display subtended 17.8° by 23.5°. Each dot in a given trial traveled at one of three constant speeds: 1.8, 2.6, or 3.4 deg/s; speeds were randomized within and across trials. Each dot traveled for 753 ms and was separated within a trial by a blank screen presented for 400 ms. The display was presented using a Macintosh G4 running Matlab and the Psychophysics Toolbox (Brainard, 1997; Pelli, 1997). Stimuli were viewed on a 21-in. CRT monitor at a distance of 95 cm.

Procedure

Participants sat in front of a monitor oriented horizontally (with the screen pointing to the ceiling) to prevent any biasing effects of gravity (see Figure 1). Participants were given a two-interval forced choice task. On every trial, participants viewed a dot moving across each of the two circles, one after another. The dots started from one of twelve points distributed clocklike around the circle's perimeter and traveled through the center of the circle to a point at the opposite end of the circle. All displays began with dots in motion to prevent the perception of self-propulsion. Participants were asked to identify "Which dot looks alive?" and were instructed to respond "as quickly as possible" by pressing one of two buttons on a joystick. Each participant completed 192 trials in a darkened room.

Results and conclusions

Seventy-six percent of the participants reported that the faster dot appeared alive most of the time (13 vs. 4). On average, participants rated the faster dot as animate on two thirds of the trials. A difference of proportions test (Blalock, 1972) revealed that significantly more participants judged the faster object as animate ($z = 2.9$, $p < .01$). It appears that constant speed differences are a robust cue to the perception of animacy, confirming the association of faster objects appearing animate. As an objects' speed increases, so does the perception that it is alive, for the speeds tested.

Experiment 2

The previous experiment showed that relatively faster objects are perceived as animate more often than relatively slower objects. Experiment 2 was designed to test this perceptual association by displaying objects that appeared to move at different speeds but in actuality did not. We began with the stimuli used in Experiment 1 and surrounded the two circles with relatively smaller and relatively larger circles, thus recreating the Ebbinghaus illusion. This created the impression that dots were traveling across an apparently larger and an apparently smaller circle that were, in actuality, the same size. Although there were no actual speed differences, we predicted that people would exhibit a similar trend to Experiment 1 and perceive an object appearing to move at a relatively faster constant speed (in the larger circle) to be animate. We predicted that dots traveling across the apparently larger circle would be perceived as moving faster than dots traveling across the apparently smaller circle because they would appear to travel a greater distance in the same amount of time. Following the results of Experiment 1, we also predicted that people would perceive the dots traveling across the apparently larger circle as animate more often than dots traveling across the apparently smaller circle because these dots would appear to be traveling faster.

Method

Participants

Fifty undergraduate psychology students participated for credit (37 female, 13 male; mean age = 19.6 years, range = 18–44 years.). Twenty-five individuals participated in the "speed" condition and 25 individuals participated in the "animacy" condition. All participants had normal or corrected-to-normal vision.

Stimuli

The Ebbinghaus illusion consists of two identical circles, each surrounded by a number of relatively smaller or relatively larger circles, creating the illusion of an apparently larger and apparently smaller central circle when presented simultaneously (Haffenden, Schiff, & Goodale, 2001; see Figure 2). The central circles were the same size as displayed in Experiment 1 but were now each surrounded by six circles. The relatively smaller surrounding circles subtended 1.6° each; the relatively larger surrounding circles subtended 5.5° each. All circles were black outlines 2 mm thick against a solid grey background. The dots and their motion were identical to Experiment 1, as was the equipment used to create and present them.

Procedure

The use of a horizontal monitor (see Figure 1), a two-interval forced choice task, and the motions of the dots were identical to Experiment 1. The Ebbinghaus display was mirror-reversed randomly such that either the left or the right central circle would appear larger (i.e., as in Figure 2 or its mirror image). Whether the dot first appeared on the left or the right side of the display was also randomized across trials. Each trial began with a fixation cross, presented where the first dot would appear, to ensure that participants saw the first motion display in its entirety (as each display began with the dot already in motion).

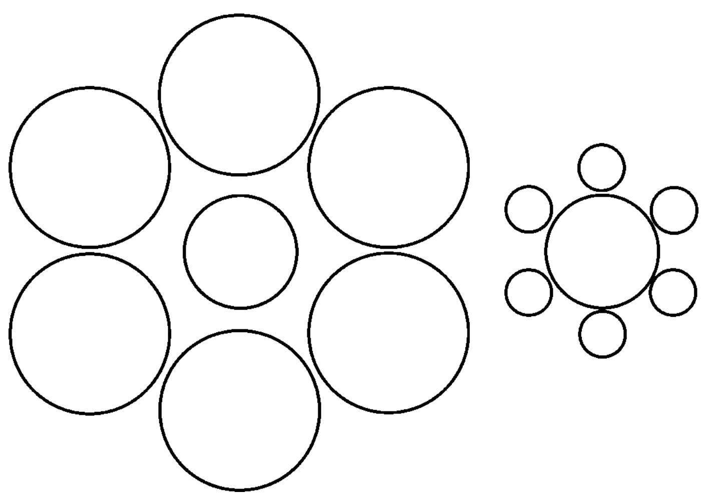

Figure 2. The Ebbinghaus illusion. Participants viewed dots traveling across the apparently larger central circle on the right and the apparently smaller central circle on the left. The central circles were the same size as in Experiment 1.

Subjects were informed that they would see a configuration of circles on the monitor resembling two flowers side-by-side, and that a dot would travel across the middle circle of each flower, one after the other. Subjects in the speed condition were told to report "Which dot is faster?" Subjects in the animacy condition were told to imagine that one of the dots was a bug and the other was a piece of dirt, and they were to report "Which one is the bug?" All subjects were instructed to respond "as quickly as possible" via a button press on a joystick. Each participant completed 384 trials in a darkened room.

Results and conclusions

Responses were not significantly different for the three speeds tested in either condition, so speed was collapsed for analyses. Results of a difference of proportions test (Blalock, 1972) revealed that significantly more people reported perceiving a dot traveling across the apparently larger area as faster than a dot traveling across the apparently smaller area (68% vs. 32%: $z = 2.55$, $p < .01$; Figure 3, left). In the animacy condition, a difference of proportions test revealed that significantly more people reported a dot traveling across an apparently larger area as alive than a dot traveling across an apparently smaller area (64% vs. 36%: $z = 1.98$, $p = .02$; Figure 3, right). The pattern of results in the animacy condition did not differ significantly from those of Experiment 1 ($z = 0.83$, *ns*), suggesting that animacy perception is influenced by illusory and actual speed differences similarly.

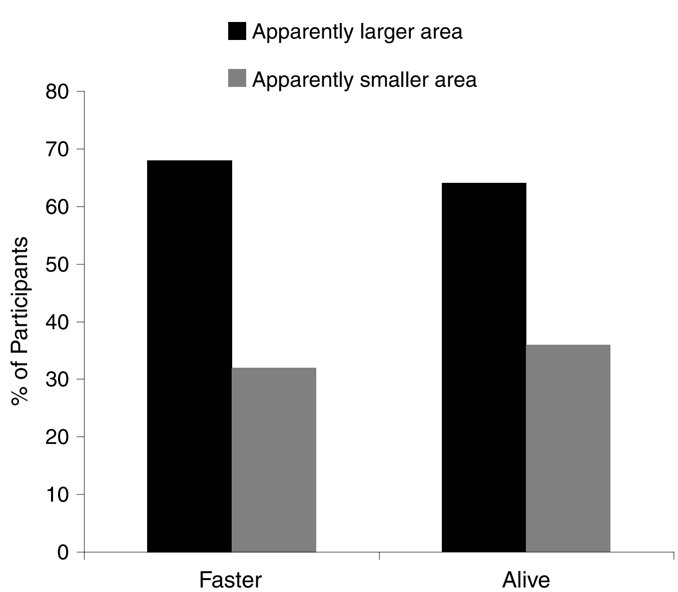

Figure 3. Percentage of people who judged a dot as faster (left, speed condition) or alive (right, animacy condition). More people said a dot was faster or alive when it traveled across an apparently larger area versus an apparently smaller area.

A significant majority of the participants reported a dot traveling across an apparently larger area as appearing faster despite there being no difference in speed. That the majority also perceived the same dot as alive most often appears to confirm the association of speed and animacy and suggests that the strength of this association is great, given the illusory perception of speed.

We argue that this perception of animacy was driven by a perception of speed; that is, people judged the dot traveling across the apparently larger area as animate because it appeared to be traveling faster. However, as we predicted that participants would choose dots moving across an apparently larger circle as both faster and animate, a follow-up experiment sought to determine whether the predicted results were due to actual perceptual judgments and not simply participants' response bias.

Experiment 3

If the findings of Experiment 2 were not due to an association between people's perceptions of speed and animacy, but rather a response bias or demand characteristic elicited by some aspect of the experiment (i.e., participants choose the apparently larger circle regardless of the quality they are asked to judge), then other presumably unrelated judgments of the same stimuli should elicit similar responses. However, if the results of Experiment 2 do address the qualities of speed and animacy—and not a generalized response bias—then unrelated judgments should show a different pattern of response. To examine this, we showed participants the same stimuli as in Experiment 2 but asked them to judge the motions based on any one of six qualities that we predicted should have no relation to the concept of animacy, and thus should not elicit a similar pattern of response as in Experiment 2.

Method

Participants

Twenty-four undergraduate students participated for credit (21 female, 3 male; mean age = 18.4 years, range = 17–25). All participants had normal or corrected-to-normal vision.

Stimuli

Each trial began with one of six words presented in the center of the monitor for 1000 ms. The words were "stronger," "sharper," "softer," "kinder," "smoother," and "louder." Each word was presented 90 times over 540 trials; the order of word presentation was randomized. During the last 200 ms of the word's presentation, a fixation point was presented on either side of the word, indicating where the first dot would appear, after which point both the word and the fixation point would disappear. The Ebbinghaus illusion and motion displays were presented exactly as they were in Experiment 2.

Procedure

Participants were informed that a word would be presented on the screen, after which they would see two groups of circles, one on either side of the screen, and that a dot would travel across the center circle, one at a time. They were instructed to "choose the dot—the one on the left or the one on the right—that is best described by the word presented." All judgments were to be made "as quickly as possible" by pressing a button on a joystick. The experiment was conducted in a darkened room, and the stimuli were presented horizontally (see Figure 1).

Results and conclusions

Difference of proportions tests (Blalock, 1972) were conducted on the number of participants choosing either the apparently larger area or the apparently smaller area, for each of the six words presented. People only differed significantly when responding to "stronger" and "louder" trials, and in both cases they chose the apparently smaller area, associated with the slower object ("stronger": z = 3.46; "louder": z = 2.91; both $p < .01$). On all other trials, people did not significantly favor one circle over another (see Figure 4). The patterns of response in Experiment 3 suggest that the alternative explanations for the findings of Experiment 2 do not appear to be valid, and that the earlier data are neither the result of participant's response bias nor the demand characteristics of the task. Participants were significantly different from chance for only two of six stimulus words and chose the apparently smaller area for both, which contradicts the pattern of responses in either condition of Experiment 2. Therefore, we conclude that the results of Experiment 2 are not due to demand characteristics and likely due to a perceptual association of speed and animacy.

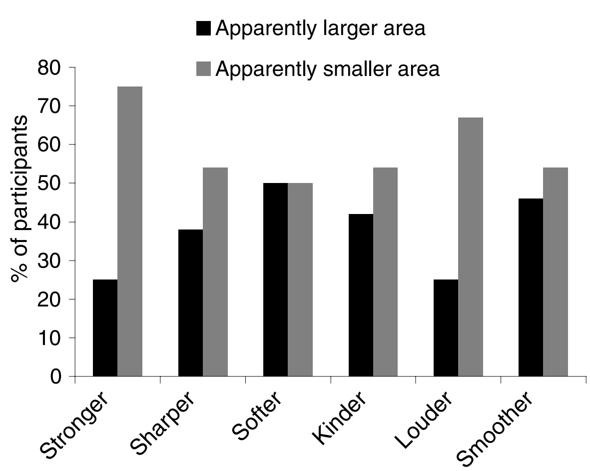

Figure 4. Percentages of people choosing the dot moving across the apparently smaller area or apparently larger area for six qualities predicted to be unrelated to animacy.

Discussion

This research suggests that constant speed differences are a cue for determining whether an ambiguous object is alive or not. Furthermore, it appears that actual differences are no more necessary than perceived differences in speed for judgments of animacy. These results do not appear to be driven by response bias or demand characteristics, but rather that more people perceive an object that appears to be moving faster as alive, all else equal.

Two new findings contribute to our understanding of the relation between the perception of speed and the perception of animacy. First, unlike previous research in this field, the objects in our displays did not change speed or direction at any time. This illustrates for the first time that our visual system can use constant velocities and trajectories to categorize objects as animate or not. Experiments 1 and 2 replicate this finding. It appears that our perceptual systems may be more sensitive to motion cues triggering animacy than previously reported in studies displaying speed increases and changes of trajectory (Tremoulet and Feldman, 2000). From an evolutionary approach, this makes good sense: Barrett (2005) argues that we should be sensitive to motion cues predicting the presence of a predator or prey animal. Any fast-moving objects would likely best be identified by motion cues, as their morphological features would not be visually discernable. (It is entirely likely that objects traveling at extremely high speeds may not be perceived as animate if they appear irreconcilable with our ideals of the speed of animate creatures.) Being sensitive to constant velocities and trajectories is presumably more advantageous than only being made aware of an animate presence through changes in velocity or trajectory, as it allows for discriminations using less information, and importantly allows for a more instantaneous percept.

Second, we have shown that the requisite speed differences between two objects need not be actual differences at all, but that illusory speed differences also trigger the perception of animacy, for the speeds tested. In the speed and the animacy conditions of Experiment 2, people reported the dots traveling across the apparently larger area as faster and alive, respectively. The results of the animacy condition are apparently due to the corresponding perception of greater speed, given that the same dots were perceived as faster as in the speed condition. This conforms to the aforementioned perceptual association of speed and animacy and suggests evidence of its apparent strength. As our social perceptions are often experienced as immediate and irresistible, there may be a payoff in the accuracy of identification, leading to some erroneous encoding of motion information, especially considering such simple and ambiguous displays as was presented. Although the motion information presented in Experiment 2 may be interpreted erroneously, it is nonetheless consistent and reliable information and thus is useful to a degree. From an evolutionary point of view, it would be advantageous to use any information (indeed, the least information) concerning the possible presence of a predator or a prey. Identifying the factors of visual perception informing this illusory perception and the relation between speed processing and social perceptions requires more detailed investigation.

Experiment 3 revealed that these results do not seem to be due to a response bias or demand characteristics but rather appear to capture actual discrepancies in perceptual judgments. There was a subtle difference between the animacy condition and all other conditions, where participants were asked to make relative judgments (e.g., "faster," "sharper"). Despite this, participants' responses appear to indicate their understanding of animacy as being a mutually exclusive property and not a relative one, as indicated by the consistency of responses across Experiments 1 and 2, and the different pattern of responses observed in Experiment 3.

Understanding how our visual system perceives animacy is a necessary step in understanding how we perceive the social world. The perception of animacy is an automatic process that begins in early infancy (Gergely et al., 1995; Leslie, 1994; Luo & Baillargeon, 2005; Premack, 1990; Rakison & Poulin-Dubois, 2001). In contrast, in cases of some developmental disorders such as autism, these sorts of perceptions develop atypically, leading to difficulties in perceiving animacy easily and automatically (Rutherford et al., 2006). Knowing more about the quality of motions that trigger such a fundamental perceptual ability is vital to understanding how our social cognitions work in both typical and atypical individuals. Additionally, the perception of animacy is an area of research that can increase our knowledge of how different neural systems (such as motion perception and social cognition) inform and interact with one another to create a social world.

Acknowledgments

This research was supported by a Natural Sciences and Engineering Research Council grant to MDR.

Commercial relationships: none.
Corresponding author: Paul A. Szego.
Email: szegopa@mcmaster.ca.
Address: 1280 Main St. West, Hamilton, Ontario L8S4K1.

References

Barrett, H. C. (2005). Adaptations to predators and prey. In D. M. Buss (Ed.), *The handbook of evolutionary psychology* (pp. 200–223). New York: Wiley & Sons, Inc.

Barrett, H. C., Todd, P. M., Miller, G., F., & Blythe, P. W. (2005). Accurate judgments of intention from motion cues alone: A cross-cultural study. *Evolution and Human Behavior, 26,* 313–331.

Blalock, H. M. (1972). *Social statistics* (Second ed.). New York: McGraw-Hill.

Brainard, D. H. (1997). The Psychophysics Toolbox. *Spatial Vision, 10,* 443–446. [PubMed]

Cosmides, L., & Tooby, J. (1992). Cognitive adaptations for social exchange. In J. H. Barkow, L. Cosmides, & J. Tooby (Eds.), *The adapted mind: Evolutionary psychology and the generation of culture* (1st ed., pp. 163–228). New York: Oxford University Press.

Csibra, G., Gergely, G., Bíró, S., Koós, O., & Brockbank, M. (1999). Goal attribution without agency cues: The perception of 'pure reason' in infancy. *Cognition, 72,* 237–267. [PubMed]

Dunbar, R. A. (1998). The social brain hypothesis. *Evolutionary Anthropology, 6*(5), 178–190.

Gelman, S. A., & Opfer, J. E. (2002). Development of the animate–inanimate distinction. In U. Goswami (Ed.), *Blackwell handbook of childhood cognitive development* (pp. 151–166). Oxford, UK: Blackwell Publishing.

Gergely, G., Nádasdy, Z., Csibra, G., & Bíró, S. (1995). Taking the intentional stance at 12 months of age. *Cognition, 56,* 165–193. [PubMed]

Giese, M. A., & Poggio, T. (2003). Neural mechanisms for the recognition of biological movements. *Nature Reviews, Neuroscience, 4,* 179–192. [PubMed]

Guajardo, J. J., & Woodward, A. L. (2004). Is agency skin deep? Surface attributes influence infants' sensitivity to goal-directed action. *Infancy, 6,* 361–384.

Haffenden, A. M., Schiff, K. C., & Goodale, M. A. (2001). The dissociation between perception and action in the Ebbinghaus illusion: Nonillusory effects of pictorial cues on grasp. *Current Biology, 11,* 177–181. [PubMed][Article]

Heider, F., & Simmel, M. (1944). An experimental study of apparent motion. *American Journal of Psychology, 57,* 243–259.

Kuhlmeier, V., Wynn, K., & Bloom, P. (2003). Attribution of dispositional states by 12-month-olds. *Psychological Science, 14,* 402–408. [PubMed]

Leslie, A. M. (1994). Tomm, toby, and agency: Core architecture and domain specificity. In L. Hirschfeld, A., & S. A. Gelman (Eds.), *Mapping the mind: Domain* *specificity in cognition and culture* (pp. 119–148). Cambridge: Cambridge University Press.

Luo, Y., & Baillargeon, R. (2005). Can a self-propelled box have a goal? Psychological reasoning in 5-month-old infants. *Psychological Science, 16,* 601–608. [PubMed]

Martin, A., & Weisberg, J. (2003). Neural foundations for understanding social and mechanical concepts. *Cognitive Neuropsychology, 20,* 575–587. [PubMed] [Article]

Mondloch, C. J., Lewis, T. L., Budreau, D. R., Maurer, D., Dannemiller, J. L., Stephens, B. R., et al. (1999). Face perception during early infancy. *Psychological Science, 10,* 419–422.

Pelli, D. G. (1997). The VideoToolbox software for visual psychophysics: Transforming numbers into movies. *Spatial Vision, 10,* 437–442. [PubMed]

Premack, D. (1990). The infant's theory of self-propelled objects. *Cognition, 36,* 1–16. [PubMed]

Premack, D., & Premack, A. J. (1995). Intention as psychological cause. In D. Sperber, D. Premack, & A. J. Premack (Eds.), *Causal cognition: A multidisciplinary debate* (pp. 185–199). New York: Oxford University Press.

Rakison, D. H., & Poulin-Dubois, D. (2001). Developmental origin of the animate–inanimate distinction. *Psychological Bulletin, 127,* 209–228. [PubMed]

Rochat, P., Morgan, R., & Carpenter, M. (1997). Young infants' sensitivity to movement information specifying social causality. *Cognitive Development, 12,* 537–561.

Rutherford, M. D., Pennington, B. F., & Rogers, S. J. (2006). The perception of animacy in young children with autism. *Journal of Autism and Developmental Disorders, 36,* 983–992 [PubMed]

Scholl, B. J., & Tremoulet, P. D. (2000). Perceptual causality and animacy. *Trends in Cognitive Sciences, 4,* 299–309. [PubMed]

Tremoulet, P. D., & Feldman, J. (2000). Perception of animacy from the motion of a single object. *Perception, 29,* 943–951. [PubMed]

Woodward, A. L. (1998). Infants selectively encode the goal object of an actor's reach. *Cognition, 69,* 1–34. [PubMed]