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It's Alive! Animate Motion Captures Visual Attention

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Abstract

Across humans' evolutionary history, detecting animate entities in the visual field (such as prey and predators) has been critical for survival. One of the defining features of animals is their motion—self-propelled and self-directed. Does such animate motion capture visual attention? To answer this question, we compared the time to detect targets involving objects that were moving predictably as a result of collisions (inanimate motion) with the time to detect targets involving objects that were moving unpredictably, having been in no such collisions (animate motion). Across six experiments, we consistently found that targets involving objects that underwent animate motion were responded to more quickly than targets involving objects that underwent inanimate motion. Moreover, these speeded responses appeared to be due to the perceived animacy of the objects, rather than due to their uniqueness in the display or involvement of a top-down strategy. We conclude that animate motion does indeed capture visual attention.

Keywords

attention, animacy, attentional capture, motion

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For most of humans' evolutionary history, detecting potential prey and predators in the environment was crucial for survival. Ancestors that failed to find the protein-rich food sources supplied by animals, or became that food source for other animals, would cease to be part of the family tree. Indeed, if one assumes that the ability to rapidly detect animals in the visual field is advantageous to survival, modern humans should be extremely good at detecting animals even though most people have little reason to fear predation and most likely find their prey in decidedly un-animal-like forms in highly structured supermarkets. Moreover, the modern world still has potential dangers from animate creatures (certain insects and animals, vehicles operated animatedly by humans), and detecting animate objects has always had an important social function in enabling observers to find people in complex visual scenes. In the study reported here, we looked for evidence of this evolutionary imperative by asking the following question: Does the motion associated with animate objects capture visual attention?

Three distinct lines of research provide indirect evidence supporting the possibility that animate motion capture visual attention. First, research utilizing static images has shown that humans prioritize the visual processing of animate objects over inanimate ones. For example, Kirchner and Thorpe (2006) found that people initiate saccades more quickly to pictures of animals than to pictures of other objects, and New, Cosmides, and Tooby (2007) used a change-detection paradigm to show that changes in animals are detected more rapidly than changes in inanimate objects. Second, another line of research has shown that people are capable of extracting a great deal of information from very sparse displays of moving humans known as point-light walkers (e.g., Johansson, 1973). Even infants can extract surprising amounts of information about the actors in extremely degraded perceptual displays (Kuhlmeier, Troje, & Lee, in press), revealing an exquisite sensitivity to animate motion. Third, research has shown that the onset of motion captures attention better than objects that are static, that are continuously moving, or that have stopped suddenly (Abrams & Christ, 2003). Moreover, this attentional capture by motion onset is not due to low-level luminance-based motion detectors (Guo, Abrams, Moscovitch, & Pratt, in press) and is not modulated by attentional control settings (Al-Aidroos, Guo, & Pratt, 2010). Abrams and Christ speculated that the reason motion onsets capture attention is that they may signal a biologically significant event because

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objects that undergo a motion onset must have their own internal energy source.

Each of these lines of research (prioritization of animal pictures, sensitivity to point-light walkers, and capture of attention by motion onset) provides one piece of evidence supporting the prediction that motion characteristic of animate entities will capture attention. Such a finding would provide a bridge from the evolutionary past to the processes that drive the allocation of attention in modern humans. In order to directly test the prediction that animate motion per se captures attention, it is necessary to create a situation in which the animacy of motion can be directly manipulated and in which other factors related to animacy, such as the depiction of actual animals (as in Kirchner & Thorpe, 2006) and the presence of motion onsets (as in Abrams & Christ, 2003), can be eliminated. One of the defining attributes of animate motion is that it involves movement that appears to be self-produced, as animate objects move without requiring external forces and the motion can vary in predictability. Furthermore, it has been shown that even simple geometric figures can be perceived as animate by virtue of their motion, a phenomenon known as perceptual animacy (Scholl & Tremoulet, 2000). The advantage of such simple displays is that they permit the study of perceptual animacy without contamination from other factors that might come into play with images of animals or objects undergoing motion onsets.

To test the notion that perceptual animacy per se can capture attention, we had participants view scenes in which simple geometric objects changed in the direction or speed of their motion (or both), either because of collisions with other objects (inanimate motion) or because of a hidden, presumably internal, source of power (animate motion). We found that it is indeed the case that motion changes that imply an internal energy source also attract attention.

Experiments 1a and 1b

In the first two experiments, each trial presented four objects that moved pseudorandomly around the display, periodically colliding with themselves and with a surrounding frame, and rebounding in predictable ways (inanimate motion). At some point, one of the objects suddenly changed direction without any visible collision (animate motion). Soon after this event, a target that involved one of the objects was presented. If perceptual animacy captures attention, participants should respond more quickly to targets that involve an animate-motion object than to targets that involve inanimate-motion objects.

Subjects and apparatus

Twelve University of Toronto undergraduates (mean age = 19.6 years; 8 women, 4 men) participated in Experiment 1a, and 14 others (mean age = 19.3 years; 11 women, 3 men) participated in Experiment 1b. Subjects received course credit for their participation. All subjects reported normal or corrected-to-normal vision, and none were aware of the hypotheses being tested.

The experiment was conducted in a dimly lit, sound-attenuated testing room. Visual stimuli were presented on a CRT with a refresh rate of 85 Hz. A chin and head rest maintained a viewing distance of 48 cm. Eye movements were monitored using a closed-circuit TV camera to ensure compliance with the instructions.

Procedure and design

The display was black with a white border, and contained a fixation cross (0.5° × 0.5°) in the center. Subjects were instructed to remain fixated on the cross during the experiment and to allocate attention evenly across the display.

In Experiment 1a, each trial began with four solid white squares (3° × 3°) positioned randomly on the screen, each moving with a constant speed of 0.2 pixels per millisecond in a random direction. Occasionally a square would collide with the border of the screen, at which point it would rebound without any change in speed. Two squares would also sometimes collide. In that case, not only did the squares rebound (i.e., change direction), but the velocity of each square changed randomly, with the combined velocities remaining constant. The display thus represented an environment with constant energy.

The squares always moved along straight-line paths, and bounces against other objects were specular (the angle of incidence before the collision was equal to the angle of reflection after the collision), so that the motion was highly predictable. After 6.0, 6.5, 7.0, or 7.5 s, a randomly selected square underwent animate motion—that is, an unanticipated change in direction and speed that did not follow a collision with any object or the screen border. The changes consisted of a 50% increase in speed and a reversal of the sign of the horizontal or vertical component of the square's motion vector, whichever was larger. In other words, these changes were exactly the same kind that occurred when an object collided with another object or the border, but for this animate motion, no such collision took place.

After the animate motion, the four squares continued moving for another 200 ms, and then a randomly selected square vanished from the screen. Subjects were instructed to press the space bar on a keyboard as soon as they noticed one of the squares vanish. After the selected square vanished, the remaining objects kept moving for another 2,000 ms or until the subject responded, whichever occurred first. If the subject did not respond within 2,000 ms of the square vanishing, or if a different key was pressed, a brief error tone was sounded. After an intertrial interval of 750 ms, the next trial began.

Experiment 1b used the same apparatus and procedure except that (a) the objects were four circles with a diameter of 3°, (b) the target was the appearance of either "X" or "+" in one of the circles, and (c) subjects were instructed to identify the target (by pressing one of two designated keys) as quickly as possible.

In each experiment, there were 256 trials, including 64 in which the target (offset or symbol) occurred in the object that underwent animate motion.

Results and discussion

Trials with reaction times (RTs) less than 100 ms or greater than 1,500 ms and trials on which the wrong key was pressed were removed prior to analysis (less than 2% of the trials in Experiment 1a and less than 3% in Experiment 1b). The RTs for both experiments (see Fig. 1) were analyzed with t tests comparing targets involving animate-motion objects with targets involving inanimate-motion objects). In Experiment 1a, offsets were detected 45 ms faster for animate-motion objects than for inanimate-motion objects, $t(11) = 6.15$, $p < .001$. In Experiment 1b, targets were identified 21 ms faster in animate-motion objects than in inanimate-motion objects, $t(13) = 5.10$, $p < .001$.

In both experiments, subjects were faster to respond to targets (offset or symbol) involving objects that underwent a change in motion consistent with the movement of an animate object. These experiments are the first empirical demonstration that perceptual animacy (i.e., the appearance of motion not due to an external event) can capture attention. Moreover, the attentional capture was not dependent on the judgment required: It occurred for both the detection of offset and the discrimination of symbols. Finally, in interviews following the experiments, none of the subjects reported having noticed the animate motion; that is, no one was aware that on each trial one of the objects changed speed and direction without hitting another object or the screen border.

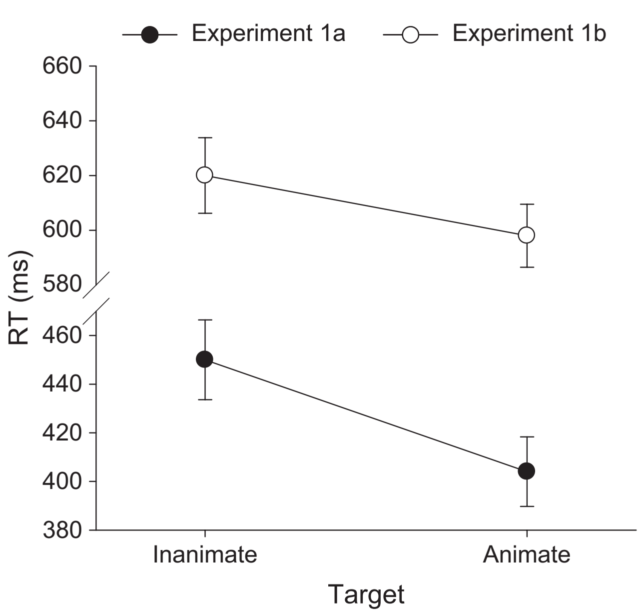

Fig. 1. Mean reaction times (RTs) for detecting the offset of an object (Experiment 1a) and identifying a symbol in an object (Experiment 1b) as a function of whether the object had undergone animate motion or only inanimate motion. Error bars represent 95% confidence intervals.

Experiments 2a and 2b

Experiments 1a and 1b strongly supported the conclusion that perceptual animacy can capture attention, but we also considered two potential alternative explanations of the results. One alternative explanation was that because only one animate-motion event occurred amid a multitude of nonanimate-motion events in each trial, the animate-motion event captured attention because it was unique—a perceptual singleton—and not because it signaled animacy per se. Indeed, other types of perceptual singletons have long been known to capture attention (e.g., Treisman & Gelade, 1980). To examine this possibility, in Experiment 2a we used the same stimuli as in Experiment 1a but inverted the motion probabilities: All four objects performed animate motion as their default motion, and 200 ms before one of them disappeared, an inanimate-motion event occurred (making the inanimate motion the singleton). If uniqueness drove the effect in the initial experiments, then the inanimate-motion event in Experiment 2a would be expected to produce attentional capture.

The other alternative explanation arose from the fact that the occurrence of the offset or appearance of the target symbol was always 200 ms after the animate-motion event in the initial two experiments. Subjects may have learned that animate motion always predicted the arrival of the target, and they may have attended to that motion in a strategic, top-down manner. Experiment 2a provided a test of this possibility, as in this experiment the inanimate-motion event could be used to predict the arrival of the upcoming target. We further examined the possibility of a top-down-driven allocation of attention in Experiment 2b, by making the animate-motion event nonpredictive of the occurrence of the target. To accomplish this, we used three types of trials with different probabilities of occurrence. On neutral trials (25%), no animate-motion event ever occurred, and after some time, one of the objects disappeared. On delayed trials (50%), an animate-motion event did occur in one object, but the offset occurred (in any of the four objects) after two to seven intervening inanimate-motion events involving the animate-motion object. Only on immediate trials (25%) did the target offset immediately follow (200 ms) the occurrence of an animate-motion event. In this experiment, it would not be strategic to attend to the animate-motion event, as it predicted the timing of a target offset on only one quarter of the trials overall and one third of the trials containing animate motion.

Subjects

Sixteen University of Toronto undergraduates (mean age = 18.6 years; 9 women, 7 men) participated in Experiment 2a, and 15 new undergraduate subjects (mean age = 18.9 years; 7 women, 8 men) participated in Experiment 2b. All subjects reported normal or corrected-to-normal vision, and all were naive to the purpose of the study and had not participated in any previous experiments in this study.

Apparatus, procedure, and design

The apparatus and basic experimental procedure were identical to those used in Experiment 1a except that the circle objects from Experiment 1b were used. In Experiment 2a, the four objects moved around the display as before but did not contact each other or the screen border. After 6.0, 6.5, 7.0, or 7.5 s, one of the circles underwent inanimate motion after a collision with another object or the screen border. Then, after 200 ms, one of the four objects disappeared. As before, this experiment had 256 trials, but in this case the sole circle that underwent inanimate motion disappeared on 72 of those trials.

Experiment 2b used a procedure similar to that used in Experiment 1a; indeed, on 25% of the trials, the target offset followed the animate-motion event by 200 ms (immediate condition), exactly as in the earlier experiment. In addition, on another 25% of the trials, no animate motion preceded the target offset (neutral condition). Finally, on 50% of the trials, the target offset occurred after the animate object underwent two to seven subsequent inanimate-motion events (delayed condition). In other words, after the animate-motion event, the animate object collided with the screen border and other objects two to seven times (about 1.5 to 7 s) before one of the objects disappeared (the three inanimate objects continued their collision-associated trajectories during the delay period). This experiment had 576 trials, and as before, the circle that vanished could be any of the four objects.

Results and discussion

For Experiment 2a, the trimmed RTs (see Fig. 2) were analyzed with a t test, and no difference was found between RTs to offsets of objects that underwent inanimate motion and RTs to offsets of objects that did not undergo inanimate motion, $t(15) < 1$. To compare these findings with those from Experiment 1a, we conducted a 2 (experiment: 1a or 2a) × 2 (motion: singleton or nonsingleton) analysis of variance (ANOVA). Although there was a significant main effect for motion, $F(1, 26) = 35.31$, $p < .001$ (RTs to singleton motion targets were faster than RTs to nonsingleton motion targets), no effect of experiment was found, $F(1, 26) < 1$. There was an interaction between experiment and motion, $F(1, 26) = 41.74$, $p < .001$, as differences in RTs between singleton and nonsingleton targets occurred only in Experiment 1a. In other words, unique animate motion captured attention, but unique inanimate motion did not. These results suggest that animacy, not uniqueness, was the reason for the capture in Experiment 1a.

For Experiment 2b, the trimmed RTs (see Fig. 2) were first analyzed with a 2 (condition: delayed or immediate) × 2 (motion: animate or inanimate) ANOVA. Although there were definite trends, neither the main effect of condition, $F(1, 14) = 3.53$, $p < .09$, nor the main effect of motion, $F(1, 14) = 3.43$, $p < .09$, reached significance. The critical interaction, however, was significant, $F(1, 14) = 7.26$, $p < .02$, as offsets of animate-motion objects were detected faster than offsets of

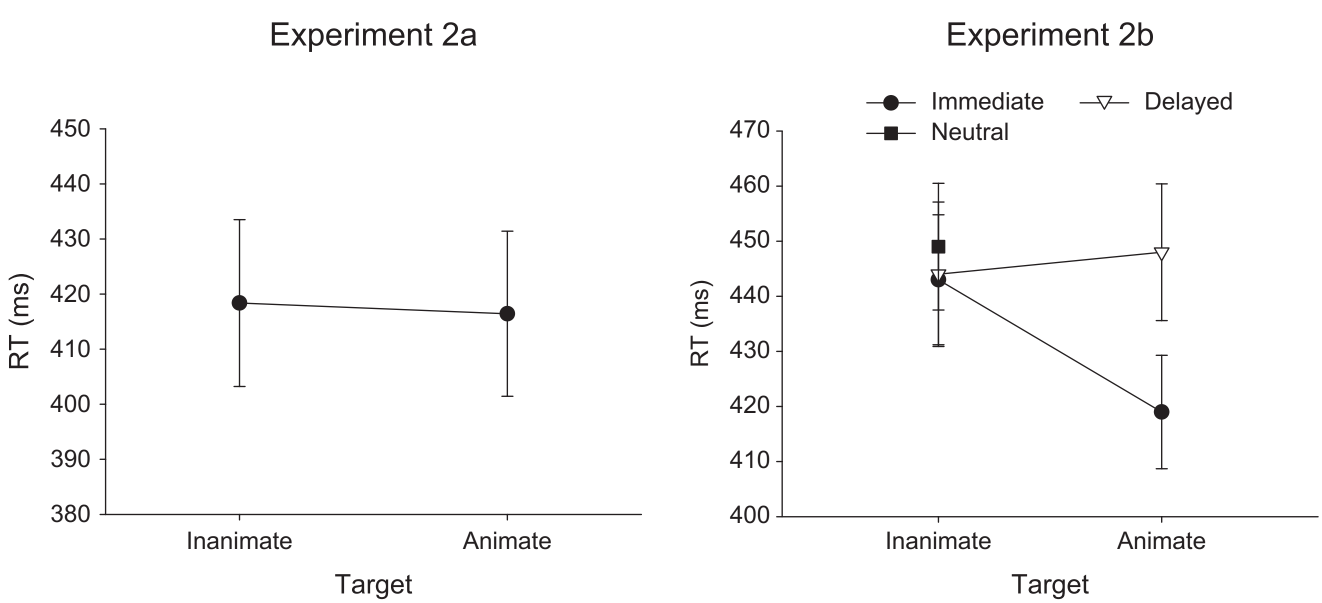

Fig. 2. Results from Experiments 2a and 2b: mean reaction times (RTs) for detecting the offset of an object as a function of the movement of that object. In Experiment 2a (left panel), inanimate targets were offsets of an object that underwent a unique inanimate-motion event just prior to the offset, and animate targets were offsets of an object that underwent only animate-motion events. In Experiment 2b (right panel), animate targets were offsets of an object that underwent a unique animate-motion event prior to the offset, and inanimate targets were offsets of an object that underwent only inanimate-motion events. On immediate trials, the target offset occurred just after the unique animate-motion event, and on delayed trials, it occurred after two to seven intervening inanimate-motion events. On neutral trials, there was no animate-motion event. Error bars represent 95% confidence intervals.

inanimate-motion objects in the immediate condition, but not in the delayed condition. There was an advantage for animate-motion objects despite the fact that animate motion was not predictive of the timing of the target offset in this experiment. The difference between RTs to animate targets and RTs to inanimate targets in the immediate condition was confirmed by a *t* test, $t(14) = 3.57$, $p < .005$. A *t* test confirmed that offsets of animate objects in the immediate condition were detected faster than offsets in the neutral condition, $t(14) = 3.82$, $p < .005$. Moreover, a one-way ANOVA comparing RTs in the animate delayed, inanimate delayed, inanimate immediate, and neutral conditions found no differences, $F(3, 42) < 1$.

Together, these two experiments indicate that the attentional capture found in Experiments 1a and 1b was not due to singleton capture (as no such capture was found when the inanimate motion was the singleton) nor to a top-down allocation of attention (as animate motion still captured attention even when the event was not predictive of the timing of the target offset). Instead, attention was captured by perceptual animacy.

Experiments 3a and 3b

If animate motion does indeed capture attention by virtue of its animacy, then it should be possible to modulate the magnitude of the attentional capture by altering the extent to which the motion is perceived to be animate. In a series of psychophysical experiments, Tremoulet and Feldman (2000, 2006) asked observers to assess the animacy of a small moving dot that changed its direction and speed of movement. Dots that underwent larger direction or speed changes were perceived to be more animate than dots that underwent smaller changes. If the attentional effects found in our previous experiments were in fact due to animate motion, then we should find stronger attentional capture with greater changes in direction or speed because such events are more likely to be perceived as indicative of animacy.

Subjects

Twenty University of Toronto undergraduates (mean age = 20.1 years; 9 women, 11 men) participated in Experiment 3a, and 21 new student subjects (mean age = 19.2 years; 9 women, 12 men) participated in Experiment 3b. All subjects reported normal or corrected-to-normal vision, and all were naive to the purpose of the study and had not participated in any previous experiments in this study.

Apparatus, procedure, and design

The apparatus and basic experimental procedure were identical to those used in Experiment 1a except that the circle objects from Experiment 1b were used. In Experiment 3a, the animate motion consisted only of a change in direction of motion: 10°, 40°, or 70°. In the case of offset of an inanimate-motion object, one of the same three direction changes occurred just prior to the offset. In Experiment 3b, the animate motion consisted only of a change in speed; the speed after the change was a multiple of that before the change. The multipliers used were 1 (default speed of all objects; no change), 2 (twice the initial speed), and 4 (quadruple the initial speed). In the case of offset of an inanimate-motion object, one of the same three speed changes occurred just prior to the offset. Across trials, the different directional changes (Experiment 2a) or speed changes (Experiment 2b) for the animate motion were equally likely.

Each experiment consisted of 288 trials, with a short break after every 48 trials. In 72 trials, the circle that performed the animate motion was also the circle that vanished. Hence, the animate-motion event was not informative.

Results and discussion

For each experiment, the RTs were analyzed with a 2 (motion: animate vs. inanimate) × 3 (change magnitude: angular deviation of 10°, 40°, or 70° in Experiment 3a; speed-change multiplier of 1, 2, or 4 in Experiment 3b) ANOVA. In Experiment 3a (see Fig. 3), there was a main effect of motion, $F(1, 19) = 13.15$, $p = .002$ (detection latencies were shorter for animate-motion targets than for inanimate-motion targets), and change magnitude, $F(2, 38) = 16.98$, $p < .001$ (RT decreased as the angular deviation increased). There was also a significant interaction between motion and change magnitude, $F(2, 38) = 14.47$, $p < .001$, as the magnitude of the angular change affected offset detection only for the animate-motion objects.

In Experiment 3b (see Fig. 3), there were also significant main effects of motion, $F(1, 20) = 16.25$, $p = .001$ (RTs were shorter for animate-motion targets than for inanimate-motion targets) and change magnitude, $F(2, 40) = 108.42$, $p < .001$ (RT decreased as the speed change increased). The interaction between motion and change magnitude was also significant, $F(2, 40) = 3.73$, $p = .033$. In this case, although both types of motion yielded reductions in RT with increases in speed, the effect was greater for animate-motion objects.

The findings of greater attentional capture with greater changes in direction and speed support the notion that perceptual animacy captures attention, because greater changes in direction and speed are associated with stronger perceptions of animacy (Tremoulet & Feldman, 2000, 2006). As before, in a postexperiment interview, the subjects gave no indication that they were aware of the animate motion.

General Discussion

The question addressed in this study was whether or not animate motion, the motion associated with animate entities, captures attention. The six experiments provide a clear answer: yes. In Experiments 1a and 1b, targets that involved objects that had undergone animate motion (i.e., a change in direction and speed not attributable to an external source) were detected and discriminated more quickly than targets that involved

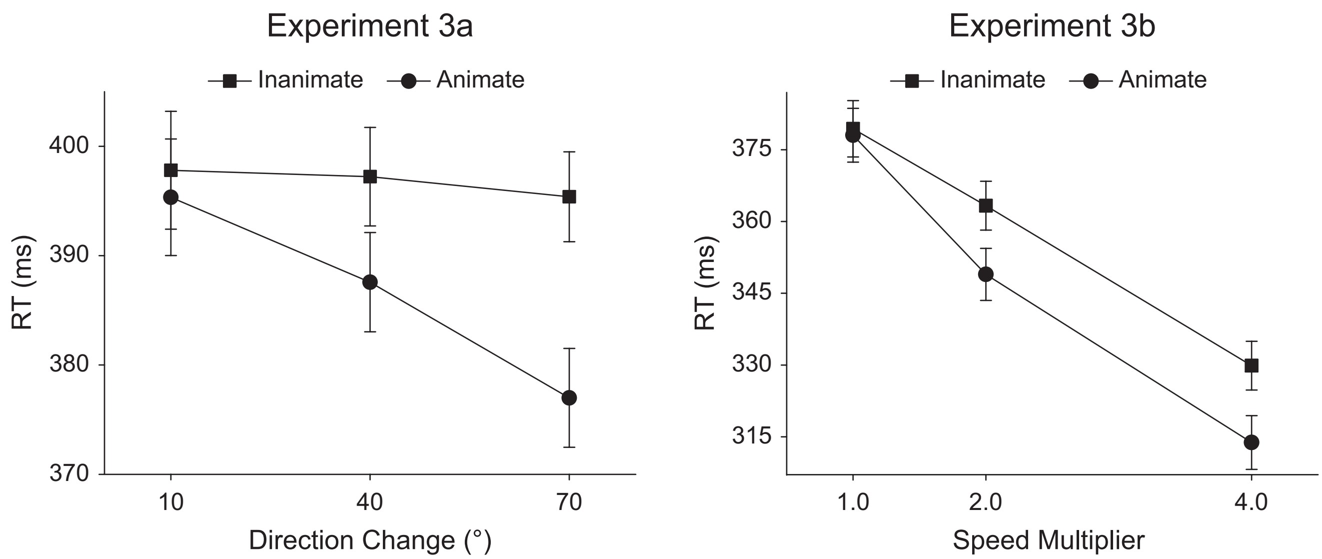

Fig. 3. Mean reaction times (RTs) for detecting the offset of an object that underwent animate or inanimate motion, as a function of the magnitude of the object's motion change immediately prior to its offset. In Experiment 3a (left panel), the magnitude of the object's angular change varied across trials, and in Experiment 3b, the magnitude of the object's change in speed varied across trials. Error bars represent 95% confidence intervals.

objects that had undergone the same motion changes after collisions with other objects or the surrounding frame (i.e., inanimate motion). In Experiments 2a and 2b, no evidence of attentional capture was found when inanimate motion was the unique (singleton) event, but animate motion captured attention even when that motion did not predict the timing of the upcoming target (i.e., capture was not due to a top-down strategy). In Experiments 3a and 3b, offsets of moving objects were easier to detect the more likely the movement was to reflect animacy. Taken together, the results demonstrate that animate motion captures attention. Moreover, this capture appears to have occurred without awareness of the perceptual animacy that generated the orienting of attention.

One of the interesting aspects of this study is that although the magnitude of the direction change in Experiment 3a affected RTs to animate but not inanimate targets, in Experiment 3b, the magnitude of the speed change affected RTs to both animate and inanimate targets (although RTs to animate targets were affected to a greater extent). It may be that changes in speed are more salient events and induce a general alerting function across the display, whereas directional changes remain localized to the object in question. Thus, it appears that the various aspects of animate motion differ in saliency. In addition, there are most likely limits to when certain visual events will capture attention. For example, Cosman and Vecera (in press) recently reported that motion onset does not capture attention under conditions of high perceptual load.

Another interesting aspect of the study is the seemingly unavoidable confound between predictability and animacy. The aspect of animate motion that we focused on in this study was the self-generated, or self-propelled, nature of the motion. Objects that are animate can move where and when they want, and this makes their movement unpredictable; in contrast, inanimate objects are at the mercy of the forces acting on them, which makes their motion much more predictable (although, granted, some forces are not immediately obvious). Disentangling predictability from animacy will be an important next step in determining what it is about animate motion that attracts attention.

The present findings add to the growing literature indicating that the human attentional system has been finely tuned by evolution. It is very likely that undergraduate students at major universities, the population from which most research subjects are recruited for these sorts of studies, have more experience with automobiles than with nonhuman animals. Despite their personal history, however, this population of subjects initiates saccades to (Kirchner & Thorpe, 2006), and detects changes in (New et al., 2007), static pictures more rapidly if the pictures depict animals rather than other objects. And there still are important reasons to attend to "biological" entities, such as cars (operated animatedly) and people, in visually dense and complex environments. The present study shows that simple geometric objects whose movement is animate in nature receive priority in the attentional system. Why should observers prioritize static, two-dimensional representations of animals they have never encountered, or selectively attend to decidedly inanimate geometric objects whose motion, ever so briefly, is consistent with that of a biological entity? It seems that the evolutionary past, during which detecting animate objects was critical to survival, and the selection pressures exerted by modern environments have a profound impact on the way in which people extract information from the visual field.

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Declaration of Conflicting Interests

The authors declared that they had no conflicts of interest with respect to their authorship or the publication of this article.

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