INVESTIGATIONS INTO THE MOTION CUES ELICITING A PERCEPTION OF ANIMACY

AN INVESTIGATION INTO THE MOTION CUES ELICITING A PERCEPTION OF ANIMACY

By

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Abstract

The perception of animacy – judging an object as appearing alive – is a fundamental social perception dating back to Piaget. The present research investigates motion to examine how and when people will perceive an ambiguous moving object as appearing alive.

Chapter 1 uses a number of methods to illustrate that people will judge a relatively faster-moving object as appearing alive more often than an identical but relatively slower-moving object. Chapter 2 demonstrates that people are more likely to perceive an object moving at a constant speed if it appears to move relatively faster than a similar object. Further, people will make this judgement even if the differences in speed are not real, but merely illusory.

Chapter 3 describes a specific case where the association of greater speed and animacy is not perceptually maintained. By showing people objects that appear to fall or rise – thereby obeying or violating gravity – it is shown that our perceptions of animacy are not fixed, but rather are functionally adapted to at least one regular and predictable feature of the visual environment; namely gravity. This suggests that some aspects of our perceptions of animacy have been shaped over evolutionary time.

The following chapter examines whether our perceptions of animacy are structured – like our perceptions of colours – categorically, such that there is an identifiable boundary between the velocities that elicit a perception of animacy and the velocities that do not. Results suggest that people do not perceive animacy categorically.

The final empirical chapter illustrates that experience over the lifespan also influences our perceptions of animacy and of speed. Monolingual readers of a language read from left-to-right (viz., English) were biased to judge an object moving in that direction as appearing faster and more alive than an object moving at the same speed in the opposite direction. However, bilingual readers of both English and a language read from right-to-left did not exhibit this bias.

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Chapter 1

General Introduction

Visual Perception, Specialized Adaptations, and Survival

William James famously described the world of the newborn as "one great blooming, buzzing confusion" (James, 1890/1950). Although researchers now disagree with this oft-quoted claim, it remains tantalizingly thought provoking, likely because it touches on intuition. The visual world made up of electromagnetic wavelengths and particles of light bombarding our retina at unimaginable speeds *is* a "great blooming, buzzing confusion" and would remain that way if our visual system didn't interpret it in meaningful ways. Thankfully, the visual system *does* interpret these signals in meaningful ways, because of specialized adaptations that have evolved to solve particular problems concerning survival, such as how to find food and detect the presence of a predator.

Our visual system can solve these problems because it has been shaped by visual input that was present in our ancestral environment, commonly referred to as the environment of evolutionary adaptedness (EEA) (Bowlby, 1971; see also Shepard, 2001; Palmer, 1999). The EEA is the set of regular, systematic, and predictable features of the physical and social environment that existed during our prehistory, when humans were transitioning from earlier forms to modern ones. Aspects such as social group size, social status, types and locations of food sources available, and mating patterns are examples of features present in our EEA (and not necessarily present today) that have shaped our cognitive and perceptual abilities. With regards to the perception of animacy, one example of systematic and predictable input present in the terrestrial environment is the energy contained in the electromagnetic spectrum and how this energy gets reflected and dissipated (or not) by objects under different circumstances (e.g., shade, direct light). For example, humans consistently see wavelengths from ~650 to ~760 nm as red, and wavelengths from ~500 to ~650 nm as green. These wavelengths will also appear a particular, but consistent, way under varying amounts of reduced lighting such as moonlight or cloudy shade. Our visual system has been shaped by these systematic regularities over time to provide a consistent and predictable result: a red object generally maintains its red appearance across different lighting conditions. Humans have this specialized adaptation to detect red and green because it has proved beneficial to our species' survival: it helps us find red berries against a sea of green leaves and grasses. Other species may not benefit from this particular specialized adaptation. The visual system of a bee, for instance, is maximally sensitive to detect wavelengths in the ultraviolet range of the electromagnetic spectrum, because this allows them to detect the presence of pollen amongst myriad flowers. Humans cannot even detect these signals, but we don't need to. Each organism uses what has proven in the EEA to be useful for its survival. Evolutionary pressures have shaped the visual system in these particular ways because of the benefits conferred on the system's owner (or, in the case of humans, the survival of our ancestors in the Pleistocene). By converting visual input into perceptions that are meaningful and informative, bees and humans are better able to solve the problems presented by survival. From this fact, we can glean two important features regarding how our visual processing helps us from being overwhelmed by the barrage of otherwise meaningless visual input.

First, not all of the input reaching our retina is even processed. As mentioned, there are regions of the electromagnetic spectrum such as ultraviolet and infrared light that cannot be detected by our visual system. The wavelengths hit our eyes, but we do not have the physiological mechanisms for processing them; the rods and cones in our retina are maximally sensitive to other regions of the spectrum. This limits the amount of input that our visual system needs to be concerned with, allowing it to focus only on the parts of the spectrum that have been beneficial to our ancestors' survival. Second, the visual information that gets processed to the point of coming into our perceptual awareness is processed with little or no conscious effort. This is why red objects simply *look red* in many different lighting conditions, rather than requiring us to perseverate on whether the object is truly red or not before coming to a decision. Both of these features help us because they allow us to expend less energy and reserve our cognitive resources (Cosmides & Tooby, 1994). This also allows us to have mostly accurate perceptions computed in very little time – allowing us to react speedily according to the information communicated by these perceptions. This seemingly effortless and fairly accurate visual processing is a major accomplishment of the brain, one which experimental psychologists have being studying, beginning with the classic work of Fechner and Holtz.

Theory of Mind: A set of specialized adaptations for social perceptions

There are other realms where the visual system – again using specialized adaptations – creates perceptions based on what is viewed. In the social domain we have a wealth of perceptions that allow us to infer a persons' current physical state such as their height, gender, approximate age and general health, and do so quickly and accurately. The advantage of these social visual perceptions helps us to make better decisions when choosing a mate. Other specialized adaptations allow us to make quick and accurate perceptions about a persons' mental state. When we see a person smile, we infer (via our perceptions) that she is happy. Seeing a person cross their arms tightly makes us believe (via our perceptions) that they are angry. The same can be said of people's desires and goals: when we see someone reaching for a cup, we infer that they desire the cup and its contents and have the goal of grabbing it, bringing it to their mouth, and drinking from it.

As with the visual processes described above, our social perceptions have been shaped over evolutionary time because they confer an advantage onto us. In the social realm, these advantages not only allow us to choose a better mate, they also allow us to better facilitate child-rearing, to avoid conflict, and to solve other social challenges such as exchanges of goods and information (referred to as the *Social Contract Theory* (Cosmides, 1989; Cosmides & Tooby, 1992; see also Dunbar, 1998; Humphrey, 1983). There are many psychological adaptations within the social realm, some even contrary to James' famous observation: In the first few minutes of life, a newborn will turn his head to view faces and face-like stimuli more than similar but meaningless displays of scrambled faces (Mondloch et al., 1999; Goren, Sarty & Wu).

All of these perceptions come to us immediately and irresistibly because of a suite of specialized adaptations that allow us to make inferences about people's mental states (including their emotions, desires, beliefs, goals and intentions). Collectively, this suite of perceptual and cognitive mechanisms is referred to as Theory of Mind (ToM) (Baron-Cohen, 1995). ToM emerges in the first year of life, and continues to develop through the early adulthood (Diamond & Kirkham, 2005; Keysar, Lin & Barr, 2003). Beginning around nine months of age, a child will begin to detect that another person is looking at the same object as they are, by gauging the direction of the head and eyes. This ability creates the perception that the other person has a particular attentional state, informing the infant that both parties are involved in a shared experience (Tomasello, 1999). The process of "reading" the internal states of others gets more complex over the next few years, culminating in a Theory of Mind (ToM) (Baron-Cohen, 1995). Ultimately, this ability allows us to perceive that other people have emotions, beliefs, desires and intentions, which can differ from our own, and which we can use to predict and explain behaviours (Baron-Cohen, 1995).

One of the precursors to ToM is the ability to interpret actions as being meaningful, non-random, and directed towards a goal. Goals can be as simple as a hand grasping a mug, indicating that the hand's owner *wants* the mug. The goal, however, is nothing more than a particular end state of the action: grasping the mug. The end state is what the visual system has as input; the output of the visual processing is the perception of a goal. Note the simultaneous perception of a goal (grasping the mug) and a mental state (desiring the mug and its contents), which is interpreted as an intentional action (that the person was merely stretching her arm in the direction of the mug seems highly unlikely to an observer, even before the person has *grasped* the mug). Actions appear to us as intentional goals so immediately and effortlessness that Michotte famously referred to the perception of intentionality as "automatic and irresistible" (Michotte, 1963). This same perceptual bias is what Daniel Dennett refers to as *the intentional stance*: a ubiquitous interpretation of the world in terms of meaningful actions, goals, and the underlying mental states such as desires that appear to drive them (Dennett, 1987).

Objects that have emotions, intentions, and other mental states have one important quality in common: they are alive. Therefore, to be able to detect the presence of a mental state, one must first be able to perceive the presence of an animate object. However, the object need not be an animal, or even real. This is because the perceptual system has, over time, evolved to be maximally sensitive to particular visual cues that create a perception of animacy even in the absence of a living object. Identifying some of the motion cues that elicit this perception of animacy is the goal of this dissertation.

The Perception of Animacy

Detecting objects that appear alive from those that do not is a fundamental component of ToM (Gelman & Opfer, 2002) and "the first step toward recognizing its intentions" (Blythe, Todd & Miller, 1999, p. 260). The perception of animacy emerges early in life, around the middle of the first year (Rakison & Poulin-Dubois, 2001; Hamlin, Wynn & Bloom, 2007). Detecting animacy produces activation in specific neurophysiological locations, even beyond visual areas in the occipital lobe (Blakemore et al., 2003). Individual with severe autism show deficits in this ability, differing in their perception and processing of animate stimuli (Klin, 2000; Rutherford, Pennington, Rogers, 2006) and their neurophysiological activation in response to displays of animacy (Castelli et al., 2002).

People are able to detect if an object appears alive or not using a variety of cues, many of which are visual. Some cues are based on surface, or external, features of an object. Gelman and Opfer (2002) call these "featural cues", referring to components such as eyes, mouths, and limbs. These components can be combined in various ways to create the perception of emotional expressions such as happiness or anger. Even whole-body postures can elicit perceptions of mental states: tightly crossed arms indicate anger, while slumped shoulders communicate sadness or defeat – the opposite of which is "holding your head high" (Pollick, Lestou, Ryu, Cho, 2002; Attkinson, Dittrich, Gemmel, Young, 1996).

Another way that visual cues can elicit a perception of animacy is through an objects' motion. Gelman and Opfer (2002) call this second class of cues "dynamic cues", which are independent of objects' featural cues. Dynamic cues refer to motion qualities such as speed and direction. Perhaps the most striking and well-documented example of motion creating the perception of an animate object comes in the form of point-light walkers. When shown as a static image of a point-light walker, it appears to be a collection of seemingly random dots. However, when shown in motion, the dots clearly represent the head, shoulders, elbows, hands, hips, knees and feet of a person walking on the spot (which is, in fact, where the data to create a point-light walker is gathered from). The perception of a walking person is created because the various dots move in predictable and reliable ways, mimicking a person's joints as they complete strides (Johannson, 1973). These displays can also produce accurate perception of actions such as gender (Troje, 2001; Pollick 2002) and emotional states

(Attkinson, Dittrich, Gemmell & Young, 2004) simply from viewing the motion of a moving arm (Pollick, Paterson, Bruderlin & Sanford, 2001).

These examples all mimic some property of a person's appearance, but the visual system does need these resemblances to create a perception of animacy. Showing people simple geometric shapes such as solid circles and triangles is sufficient to create a perception of animacy so long as the shapes are moving in particular ways. In the 1940's, Heider and Simmel (1944) showed people short animations of a large and small triangle and a small circle, and asked viewers to describe what they saw. People overwhelmingly described the scene using mental states such as fear, joy and anger. This seminal experiment revealed that people willingly attribute human-like mental states to decidedly non-human and impoverished displays. Piaget commented on the perception of animacy being elicited from non-animate sources decades earlier when he observed that his daughter described the sun as being "alive" because it appeared to be following her throughout the day (Piaget, 1934/1973).

Other researchers have since expanded on Heider and Simmel's findings, elucidating a variety of motion cues that elicit a perception of animacy. Notably, Michotte (1963) showed participants animations of a circle moving towards a second, stationary, circle as if it had been "launched" from some unseen origin. If the stationary circle moved when the first circle came into contact with it, viewers described the objects as "colliding" like billiard balls. However, if the stationary circle moved *before* the first circle came into contact with it, viewers described the interaction using terms such as "avoiding" or "chasing"; terms that denote the presence of a mind, and thus, an animate agent (see also Scholl & Tremoulet, 2000 for review).

More recently, Rochat and colleagues (1997) utilized a slightly more complex version of this display, in order to determine if infants could differentiate between movements that suggested sociality or not. Three- to six-year-olds and adults viewed two pairs of circles. One pair's movements suggested that a circle was "chasing" the other; the other pair's movements were similar in speed and distance from one another, but did not suggest the occurrence of a chase. Adults and older infants looked for longer periods of time at the non-chasing dots. This, Rochat argues, is because the chasing display was easily understood, while the unrelated motion was not so easily explained and thus captivated the viewers' attention. Conversely, younger infants spent longer periods of time looking at the chasing objects, suggesting that they perhaps detected a relation, but were captivated by trying to discern the nature of the interaction. Rochat (1997) concluded that the difference in looking behaviours between the older and younger viewers was evidence of a perceptual sensitivity to social motions, present even in the younger infants. Rutherford (2009) has replicated this finding in very young infants.

Other researchers have revealed similar findings relating to the detection of animacy and mental states in infants as young as six months of age, including attributions of mental states such as "helping" and "hindering" (Kuhlmeier, Wynn, Bloom, 2003; Hamlin, Wynn, Bloom, 2007). Similar experiments have revealed that adults and infants will commonly attribute the motions of simple geometric shapes as appearing goal-directed (Opfer, 2002), purposeful (Dittrich & Lea, 1994), intentional (Luo & Baillargeon, 2005; Shimizu & Johnson, 2004), or rational (Csibra et al., 1999), despite the absence of any featural cues such as faces or limbs. Barrett and colleagues have shown that both German and Shuar (in Amazonian Ecuador) adults will offer similar descriptions of animated ants appearing to "chase," "fight," "court," or "play" with each other (Barrett, Todd, Miller, Blythe, 2005). In fact, these animations were created by a separate group of participants instructed to mimic the various behaviours while controlling the ants using a computer. This research suggests that we not only recognize the presence of mental states, but can also produce them – even in artificial forms – well enough to be accurately identified reliably even across vastly different cultures.

It is now widely accepted that our visual system is able to detect and interpret which objects appear alive when presented with particular motions even in the absence of surface resemblances to humans or other animals (Scholl & Tremoulet, 2000). However, the motions described thus far depict intricate choreographies and interactions, leading some researchers to investigate if decidedly simpler motions are sufficient to elicit perceptions of animacy in adults.

The Perception of Animacy Elicited from Simple Motions

In the early 1980's, a doctoral student of Gelman's named Judith Stewart began the modern resurgence of interest in animate motions. Stewart wanted to investigate the nature of the motions themselves. Her Ph.D. dissertation (discussed in Gelman, Durgin & Kaufman, 1995) rested on they hypothesis that any motion violating Newtonian principles would be perceived as animate. This hypothesis has been restated by David Premack (1990; Premack & Premack, 1995) and Alan Leslie (1994). These researchers argue that possession of an internal power source is a defining feature of living organisms, which can move of their volition regardless (to some degree) of Newtonian principles such as friction and inertia. Therefore, the argument goes, when a person intuits the presence of an internal power source – based on the way the object moves – they would accordingly perceive the object to be animate. (The three researchers differ in regards to their claims of the underlying cause and origins of this perceptual deduction in development.)

To test her hypothesis, Stewart's original studies and the follow-up studies conducted by Gelman presented typically-developed adult with a series of animations consisting of a circle moving along various linear and curvilinear paths. Some motions cohered with Newtonian mechanics, such as objects colliding with one another (hypothesized to be perceived as inanimate), objects moving in linear and curvilinear trajectories at constant speeds with no interactions of stationary or moving objects (believed to elicit a neutral perception of neither decidedly animate nor inanimate judgements). A third group of motions displayed objects moving in ways that violated Newton's Laws of Motions, such as objects rising into the air in non-linear trajectories; these motions were hypothesized to elicit perceptions of animacy. Unfortunately, much of the data is ambiguous with regards to reliable perceptions of animacy. Partly, this is due to the many variations of motion paths displayed (including various curves, parallel motions of two objects moving simultaneously, and a miscellany of interactions with stationary objects); partly it is due to the complicated instructions employed in the studies (Gelman, Durgin & Kaufman, 1995). Because of these shortcomings, the underlying question of whether very simple motions – absent of interactions with other objects – can elicit perceptions of animacy remains unanswered.

Overview of the Current Research Programme

In 2000, Tremoulet and Feldman attempted to avoid the issue of motion complexity by controlling the speed, direction, and orientation of a solitary dot moving against an empty background. The aim of their study was to determine if the motion of a solitary object – in the absence of any interactions – was sufficient to create a perception of animacy. They revealed that in some cases, depending on the features of the motions, it was possible.

Participants in their study gazed down a large cardboard tube, which they were instructed to think of as an oversized microscope, corresponding to the cover story of their trying to detect which microscopic particles are alive and which are not. At the end of the tube was a monitor displaying a blank grey screen, across which small dots or line segments (subtending 0.123°) would travel. On each trial, a single object would travel towards the centre of the empty screen at a constant velocity, at which point the objects' motion would change by a predetermined speed and angle. Speed changes were a decrease by half of the current speed, a two-fold or four-fold increase, or no change. Coincident with these was a change in direction of 0°, 10°, 20°, 40° or 80° from the initial trajectory. Line segments would either change orientation to remain aligned with the direction of travel (aligned condition) or remain in their initial orientation, thus becoming misaligned after a change in direction (misaligned condition). After viewing each trial, participants were instructed to judge whether the object appeared alive or not, using a 7-point Likert scale ranging from "definitely not alive" to "definitely alive." To assist in their judgements, participants were told to give low ratings to any motions appearing "artificial, mechanical, or strange" (p. 945).

Tremoulet and Feldman's (2000) hypothesis was based on Gelman, Durgin, and Kaufman (1995): any object which appeared to have an internal power source – evidenced by the ability to turn and/or speed up with no obvious, visible cause – would appear animate and receive higher ratings by participants. To create an ambiguous perception regarding the cause of an object's motion, all displays began with the objects already in motion. The researchers hypothesized that the greater the magnitude of speed and angular change, especially when occurring simultaneously, the greater the corresponding perception of animacy would be. Additionally, they predicted that line segments which rotated to remain aligned with the new direction of travel would be perceived as more animate than line segments that did not turn. This was predicted since the aligned segments would have a secondary indicator of an internal power source, while the misaligned segments would appear as possibly lacking this source of power; dots would appear ambiguous in this regard. The results of their experiment proved this to be the case: generally, as the magnitude of change increased for the simultaneous events, so too did the ratings of how animate the object appeared to be. Tremoulet and Feldman found that misaligned lines were judged as appearing significantly less animate than dots or aligned lines; aligned lines were rated significantly higher than both other objects (Tremoulet & Feldman, 2000).

The findings of Tremoulet and Feldman (2000) revealed that solitary ambiguous objects travelling along simple motion trajectories could elicit a perception of animacy. As the purpose of the present research programme is to investigate the perception of animacy as elicited by simple motion cues, Tremoulet and Feldman's methods appeared to be a fruitful starting point from which many important related questions could be examined. However there are ambiguities in their design and their findings, relating to the extra motion cue that is the rotation of the aligned lines. By orienting to the (new) direction of travel, the perception of a "head" and "tail" was created. This additional cue, while apparently very persuasive, is more similar to Gelman and Opfer's featural cues than to the other cues examined such as speed and direction change. Additionally, this rotation introduces a second, and non-ambiguous instance of the presence or absence of an internal power source, in contrast to the first ambiguous instance occurring when each object appears on screen already in motion. As these attributes did not fit the focus of the present research programme, modifications were made to avoid them and their corresponding perceptions.

Before expanding into new research, it was necessary to replicate Tremoulet and Feldmans' (2000) findings, to ensure that we were starting with a reliable finding and methodology. We began by replicating the stimuli and Likert response method from the original study. Beyond these similarities, differences in the presentation of the stimuli were introduced. Instead of having participants look down a cardboard tube, we built a viewing station that allowed participants to sit in a high stool while looking down at a monitor facing upwards (refer to Chapter 2, Figure 2.1). Participants could sit upright while resting on a chinrest and viewing the monitor at an angle of 28° off perpendicular to the ground. This allowed participants to complete the experiments in a more conventional position, as if simply looking down at the ground while seated normally. This also allowed participants to better retain their sense of vertical and horizontal, as they were seated vertically looking down at dots travelling across a horizontal field. Lastly, this negated the need to create a story about a "super-sized microscope"; instead participants were simply instructed to judge whether each "microscopic particle" appeared alive.

Combining the replicated stimuli and response methods with the new viewing method, we were able to replicate Tremoulet and Feldman's general findings, with some notable differences. A notable – and subtle – difference between the findings of the original study and our replication concerned the influence of velocity on the perception of animacy. While Tremoulet and Feldman reported a gradual increase in ratings of animacy corresponding to an increased velocity (from 0.5x the initial velocity to 4x), our replication found that the *magnitude* of velocity change was indicative of a greater perception of animacy: no change in velocity was the weakest indicator of animacy; weaker even than a decrease in velocity (0.5x), contrary to the original study. Additionally, the magnitude of direction change was not a reliable indicator of whether an object was perceived as animate or not, although no change in direction (0°) was rated as appearing animate less often than any of the direction changes.

Together these similarities and differences offered a meaningful direction of study. Having obtained confirmation of both the general findings of Tremoulet and Feldman (2000) and of the robustness of our stimuli to create a perception of animacy, we next sought to improve the methodology while addressing novel questions with greater external and evolutionary validity. To this end, we increased the size of the stimuli from 0.123° to 0.24° subtended. This allowed the removal of the "microscopic particle" cover story to something that participants would be more visually familiar with and thus more ecologically valid, such as a small bug (animate) or piece of dirt (inanimate).

In addition to the change in stimuli and the introduction of a new viewing station, we also replaced the use of a Likert ratings scale to avoid certain inherent limitations. Primary among these limitations is that Likerts only allow participants to judge a stimulus relative to other stimuli, and not judge it according to qualities independent of the trials occurring before and after it. For instance, a moderate change in velocity and direction would appear relatively greater when following no change in velocity and direction, likely resulting in a high rating of animacy *relative to* what was viewed immediately before. However, the same motion qualities would likely appear to be of a lesser magnitude (and would receive a correspondingly weaken rating of animacy) when viewed immediately after a trial containing great changes in velocity and direction. The same trial, therefore, can result in two very different relative ratings. One aim in introducing improvements in the new methodology was an attempt to record absolute differences; accomplishing this can be complicated. One possible solution is to weight each trial by some value dependent on the trial that preceded it; another solution is to show all possible pairs numerous times, in order to obtain an average for each. Both of these possible solutions have drawbacks: the former introduces statistical complexity simply to undo what the Likert method does by its very definition (that is, a relative rating); the latter requires either an inordinate amount of time to run the hundreds of ordered pairs repeatedly, or a drastic reduction in the number of stimuli tested.

A more robust and efficient method of recording participants' judgments is to show all possible pairings at the rate of one pair per trial, and ask participants to judge which of the two objects in a given pair appeared more animate. This method is known as a two-interval forced-choice task (2IFC) and is common to the field of signal detection. The main advantages of presenting the stimuli using a 2IFC is that it reduces the number of trials necessary to display all possible pairs while still testing a large number of individual stimuli. Testing all possible pairs repeatedly has the additional advantage of negating the influence of relative judgements on the analysis, without needing to remove the possibility of a relative judgement occurring; a common difficulty in perceptual experiments. Another benefit of using the 2IFC method is the removal of a mid-point response option, where a participant can report a neutral response (e.g., "It did not appear animate nor inanimate"). Unlike a Likert scale, a 2IFC forces the participant to choose one of the two stimuli in a pair as appearing more animate than the other. Therefore the question of which stimulus appears overall the most or least animate will be revealed by the analyses, leaving the participant free to concentrate on the individual trial at hand, instead of keeping a relative running total throughout the experiment. In the case of a participant choosing (seemingly) randomly across many trials, it will appear to the researcher as though the participant did not make a reliable judgment regarding the appearance of animacy, instead judging all motions as identical to all others. If this were to happen, the analyses would reveal an accurate lack of perceptual distinction.

The 2IFC methodology is common to signal detection experiments in the psychophysical literature. In a typical 2IFC signal detection task, the researcher wants to determine how accurately a participant (and by extension, the population) can detect the presence or absence of some perceptual quality (the "signal"). Typically, participants are shown a pair of stimuli. On some trials both stimuli contain only "noise"; on some trials one of the two stimuli contains a "signal". These variables can take any form, but there is always something to be detected – the signal – and something that is impairing the ability to detect it – the noise. The task is made easier or harder depending on how similar or different the signal is from the noise (see Wicken, 2002).

There are important differences between a typical 2IFC as used in psychophysics and the present task, including the analyses. On a typical 2IFC trial, participants respond by stating either that there is or that there is not a signal present. Over many trials, a researcher can analyse a number of defining qualities about a participants' ability to detect the presence of a signal. Typically of interest are the participants' accuracy (how often they reported the presence of a signal when it was present), and their bias (i.e., their propensity to report, "yes, there was a signal present" independent of their accuracy). However, both of these analyses require there to be a predetermined signal to be coded as accurate. As the purpose of the present research programme is to determine *post-hoc* the motions that participants judge as appearing animate, it would be erroneous to predetermine any specific stimuli as "accurate" or indicative of the presence of an animate object. Regardless, the 2IFC remains a valid method for recording participants' bias when judging a display as appearing animate (or not), and to compare all possible absolute differences in the motion qualities presented. There are, however, more appropriate statistical tests to determine a participants' perceptual performance in this form of the 2IFC, while will be discussed in the relevant chapters.

This method of testing peoples' perception of animacy provides the basis for most of the research contained with the current research programme. Four major studies describe how the perception of animacy is influenced by simple motion cues, and how these perceptions may have been shaped by our experiences over an individual's life span and over our species' evolution. The first chapter presents three experiments demonstrating that people will judge an object moving at a relatively faster constant velocity as animate more often than a relatively slower object. This is shown to be the case regardless of whether the objects actually travel at different velocities or if they only appear to do so as the result of a perceptual illusion. In Chapter two, the hypothesis that, since reliable features of terrestrial life such as gravity, shape our perceptions, we should be sensitive to this as a cue to the cause of an objects' motion is tesed. We revealed that people are more likely to judge a falling object as appearing faster than one that appears to rise into the air. However, they are also more likely to judge the same slower, rising object as appearing alive more often than the faster, falling object. This directly contradicts the previous trend of relatively faster objects appearing to be animate more than relatively slower objects; however it is also predicted by an evolutionary-informed hypothesis, and illustrates how these perceptions make use of the regularities in the world. In the third chapter, a series of experiments examines whether there are clear boundaries between velocities that do and do not elicit perceptions of animacy. Additionally, in the third chapter we examined whether peoples' ability to discriminate velocities differs when they think they are viewing animate or inanimate objects. Complementing the evolutionary findings of chapter two, we reveal – in the final experimental chapter – that the language we read influences our perceptions of speed and animacy. We revealed that monolingual English readers are biased to judge objects travelling from left-to-right as appearing faster and more animate than objects travelling in the opposite direction. Bilingual readers of English and a language read from right-to-left did not show any bias for speed or animacy, suggesting that their reading experiences have influenced their perceptions differentially.

Collectively, these studies demonstrate that we are able to judge if an object appears to be alive based solely on the simple motions of anthropomorphically featureless objects. These perceptions appear to be reliable and robust across typically developing adults, they are shaped by regularities in the environment, and they are influenced by our experiences. As a research programme devised to look at visual socio-perceptual processing, the current research programme provides the foundation of other, equally valuable, studies and adds meaningful insights into our understanding of the quality and basis of our social perceptions.

Chapter 2

Actual and Illusory Differences in Constant Speed Influence the Perception of Animacy Similarly

Szego, P., & Rutherford, M.D. (2007).
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Authors' Contributions

Paul Szego: Concept, formation of experimental design, data collection, literature review, data analysis and manuscript writing.
Dr. Mel Rutherford: Assistance with concept development and experimental design, data analysis and manuscript editing.

Abstract: 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.

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 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 2.1). 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.

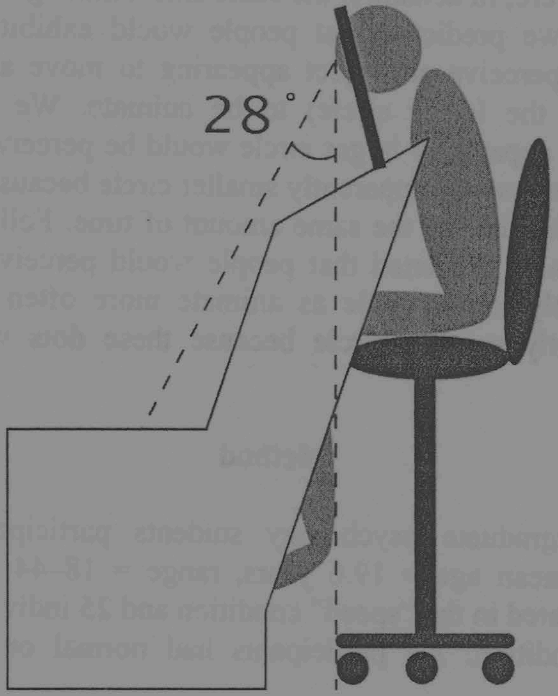

Figure 2.1. Presentation apparatus containing a monitor oriented horizontally. All participants sat on a stool, looking down at the screen at an angle of 28° off perpendicular, using a chin rest.

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 G .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 2.2). 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 2.1), 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 2.2 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).

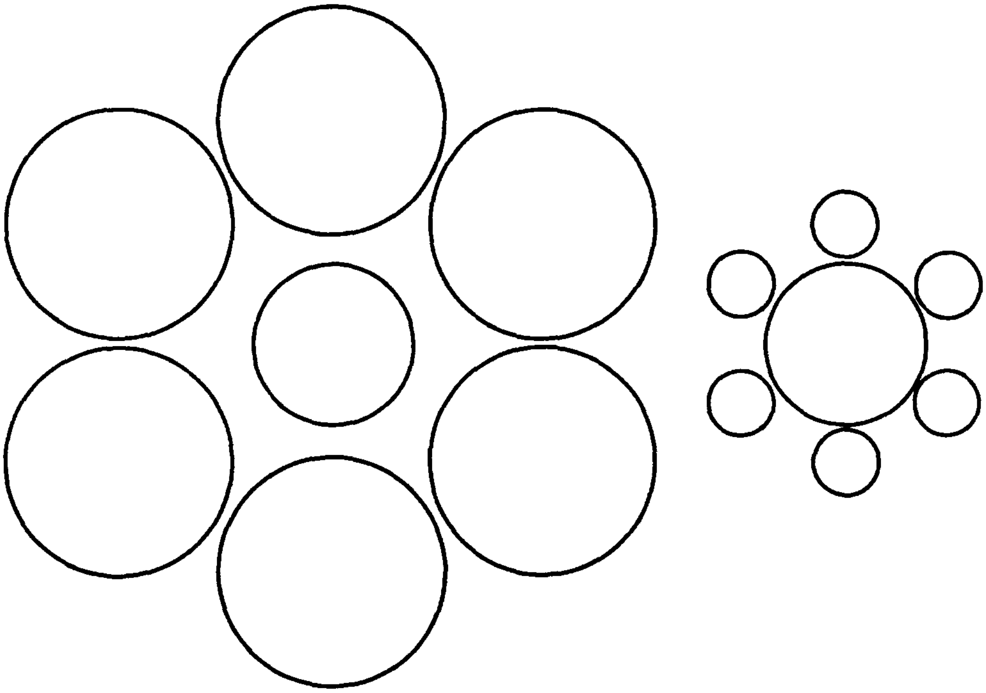

Figure 2.2. The Ebbinghaus illusion. Participants viewed dots traveling across the apparently larger central circle on the right and the apparently smaller central circle on the left. The central circles were the same size as in Experiment 1.

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 G .01;

Figure 2.3, 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 2.3, 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.

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.

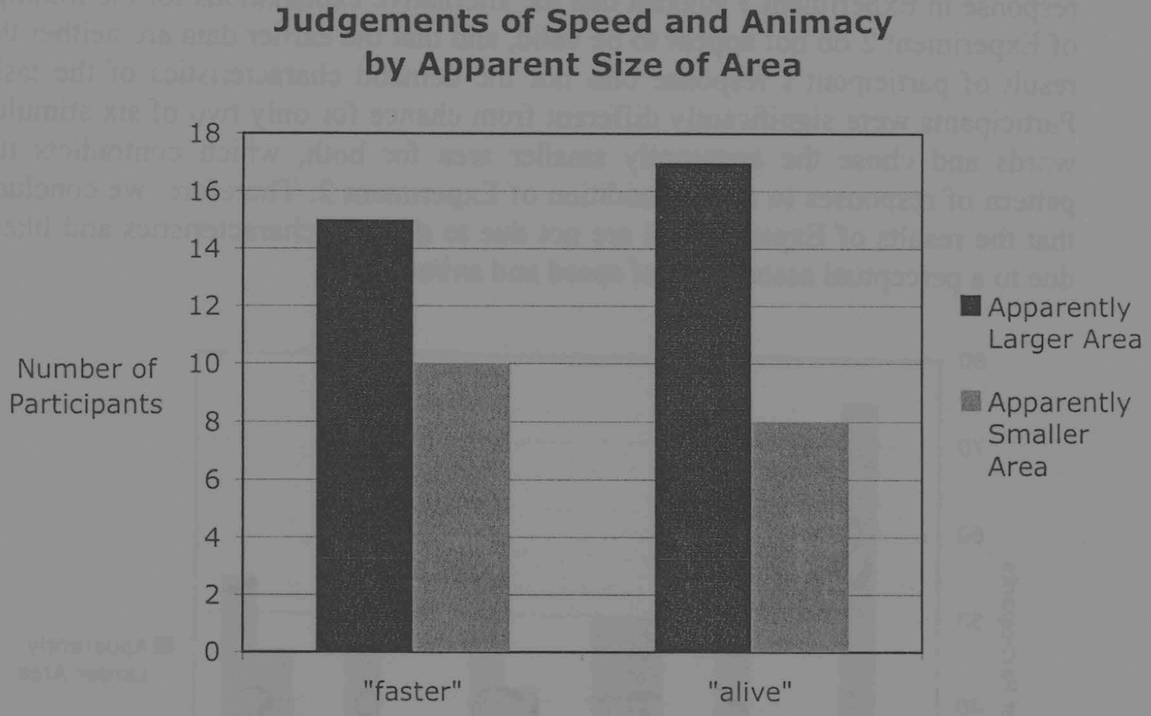

Figure 2.3. Percentage of people who judged a dot as faster (left, speed condition) or alive (right, animacy condition). More people said a dot was faster or alive when it traveled across an apparently larger area versus an apparently smaller area.

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 2.1).

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 G .01). On all other trials, people did not significantly favor one circle over another (see Figure 2.4). 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.

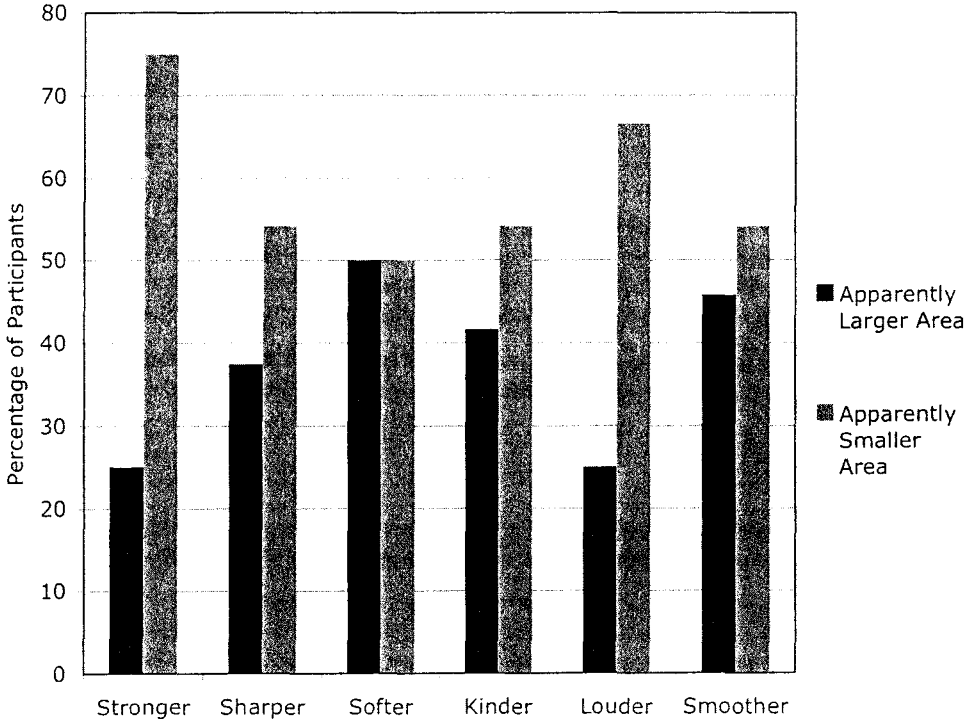

Figure 2.4. Percentages of people choosing the dot moving across the apparently smaller area or apparently larger area for six qualities predicted to be unrelated to animacy.

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 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 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

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Chapter 3

Dissociating the Perception of Speed and the Perception of Animacy: A functional approach

Szego, P. & Rutherford, M.D. (2008).
Evolution and Human Behavior, 29, 335-342.

Authors' Contributions

Paul Szego: Concept, formation of experimental design, data collection, literature review, data analysis and manuscript writing.
Dr. Mel Rutherford: Assistance with concept development and experimental design, data analysis and manuscript editing.

Abstract: Differences in acceleration, differences in constant speed and illusory speed differences are all associated with predictable differences in animacy perception. The current study describes a dissociation between perceived speed and perceived animacy, apparently resulting from the human visual system taking gravity into account. In Experiment 1, participants compared dots moving at the same speed up and down a vertically oriented computer screen. Dots moving up were judged as animate more often than dots moving down, while dots moving down were judged as faster most often. To test whether this pattern of results was sensitive to changes in the orientation of the stimuli relative to gravity, Experiment 2 presented the same stimuli on a screen oriented horizontally. The dissociation between the perception of speed and the perception of animacy was maintained: The difference between the perception of animacy of dots moving away vs. toward was much reduced, while the effect on speed perception was more pronounced, compared to the vertical orientation. These results are consistent with the idea that the human visual system is designed to perceive animacy in a functionally reasonable way given the terrestrial environment in which it evolved.

Introduction

Solutions to human adaptive problems require perceptual and cognitive systems that incorporate the statistical regularities found in the environment of evolutionary adaptedness (EEA). Because of this, we should expect adapted psychological processes to be organized functionally. There is evidence of this functional organization in, for example, the perception of colour (Shepard, 1992) and size, shape and brightness (see Palmer, 1999 for review).

Many of the adaptive challenges in our EEA were social in nature, and we appear to have evolved numerous perceptual and cognitive solutions to social adaptive problems (Dunbar, 1998; Humphrey, 1983). These include greater accuracy for solving problems presented in a social exchange context compared to a nonsocial context (Cosmides, 1989; Cosmides & Tooby, 1992), a preference for looking at faces that is present from birth (Mondloch, Lewis, Budreau, & Maurer, 1999) and that direction of eye gaze captures attention even when it is not predictive of a target's location (Friesen & Kingstone, 1998), for example. These perceptual and cognitive adaptations relating to social stimuli are primarily concerned with animate objects, including predators, prey and conspecifics, since there was likely great selection pressure for detecting these objects in the EEA. For example, New, Cosmides, and Tooby (2007) found that people are better at identifying a change in the visual scene when an animate object disappears (e.g., an elephant) than when an inanimate object disappears (e.g., a car) in a change-blindness paradigm.

Our social perceptions allow us to identify, anticipate and manipulate peoples' intentions, desires and goals (Baron-Cohen, 1995), beginning in the first year of life and for unfamiliar actions (e.g., Biro & Leslie, 2007; Johnson, 2000; Hamlin, Wynn, & Bloom, 2007). These mental states (which cannot be accessed directly) often manifest themselves as actions, which even children can perceive (Baldwin, Baird, Saylor, & Clark, 2001). The attributes and qualities of these motions are highly informative and humans are very sensitive to variations in them. For example, Guajardo and Woodward (2004) observed that 7- and 12-month-olds interpret a bare hand as goal directed when moving towards an object, but do not interpret a gloved hand moving in an identical manner as goal directed unless they see the gloved hand at the end of an arm. Prior to attributing mental states to agents, one must first discriminate those objects that are alive from those that are not. A crucial question is: how do we identify objects that are alive?

This perception of animacy is a basic and fundamental social ability underlying other social cognitions and provides the starting point for more complex social abilities. There are a number of possible cues to animacy, including the presence of morphological features such as heads, eyes, limbs and asymmetry (Gelman, 1990). An alternative and ubiquitous cue available in our EEA would have been an objects' motion. Heider and Simmel (1944) were the first to demonstrate that animations of simple geometric shapes interacting with one another can elicit the perception of animacy, as well as more complex social behaviour such as chasing, cowering and protecting. Numerous studies since have shown that similar animations of geometric shapes can elicit a variety of social perceptions as complex as intentionality (Gergely, Nadasdy, Csibra, & Biro, 1995), chasing (Rochat, Morgan, & Carpenter, 1997) and helping or hindering (Kuhlmeier, Wynn, & Bloom, 2003). These perceptions have been shown to emerge early in life (Luo & Baillargeon, 2005; Hamlin et al., 2007) and to be stable cross culturally (Barrett, Todd, Miller, & Blythe, 2005). Manipulating motion cues allows researchers to selectively examine the underlying movements, both individual and relational, that influence our social perceptions and allows researchers to study our perceptual strategies. Most studies have examined our perceptions of animacy as defined by goal-oriented and interactive actions (e.g., chasing, fighting, avoiding); only a few studies to date have attempted to identify the most basic and rudimentary motion cues such as speed and direction that reliably trigger our perceptions of animacy.

Tremoulet and Feldman (2000) and Szego and Rutherford (2007) explored the association between simple motion cues, such as speed and acceleration, and the perception of animacy. In these studies, participants saw a simple geometric figure (a dot or line) travelling against an otherwise empty background. Features of the objects' motion (viz., speed, acceleration or deceleration, or a change in direction) were systematically manipulated to determine the features most predictive of a perception of animacy. The results of these experiments consistently found a strong and reliable association of speed and animacy, such that relatively greater speeds are associated with more frequent perceptions of animacy. This has been shown for differences in accelerations, constant speeds and even illusory differences in speeds. Regardless of whether the speed differences were actual or illusory, perceptions of animacy were similar: Participants in both experiments judged the (apparently) relatively faster object as appearing alive more often than the relatively slower object. Notably these studies presented stimuli on a monitor oriented horizontally — such that the objects were travelling across a horizontal plane while being viewed from above — to avoid any suggestion of a gravitational context.

There are sound evolutionary reasons why there should be a perceptual association between speed and animacy. In our EEA, a living organism might well have appeared that was small, fast-moving, far away, or partially obscured, and these organisms could have been predator or prey. Surfaces in the EEA were generally rough, rocky or bumpy rather than smooth. Under these circumstances, an inanimate object travelling across such a surface would be slowed by friction, so any object that could maintain speed across these natural surfaces was likely to be self-propelled. Self-propelled motion has been argued to be a cue to animacy (Biro & Leslie, 2007; Gelman, Durgin, & Kaufman, 1995; Leslie, 1994; Premack, 1990; Stewart, 1982).

Additionally, a bias to consider fast moving objects as animate may be advantageous. There would likely be a relatively small fitness cost associated with frequently mistaking an inanimate object for a possible predator or prey, while the cost of erroneously categorizing an animate object as inanimate could be great. This reliable and asymmetrical distribution of costs and benefits regarding speed as an indicator of animacy would be an adaptive form of error management (see Haselton & Buss, 2000).

The purpose of the current study was to investigate the relationship between the perception of speed and the perception of animacy with and without the context of an apparent gravitational field, using the methods similar to that of Tremoulet and Feldman (2000) and Szego and Rutherford (2007). We reasoned that since our visual strategies for perceiving animacy evolved in a terrestrial environment — specifically in the context of a constant gravitational field — introducing the context of gravity and the perception of a gravitation field (Experiment 1) should be sufficient to dissociate the previously reported perceptual association of speed and animacy. We predicted that objects that are able to move against gravity without an apparent external power source will be seen as having an internal power source and thus be seen as animate, regardless of perceived speed. If people judge a dot that appears to travel against gravity (by "rising" up a monitor) as animate more often than a dot that appears to move with gravity (by "falling" down a monitor), this dissociation would be evidence that peoples' perception of animacy is influenced by at least one ubiquitous and systematic influence on motion in our EEA (viz., gravity). Additionally, we reasoned that people would not have a bias to judge either the "rising" or "falling" dot as faster or slower, given equivalent speeds for both dots in a given trial. If different patterns of results for judgments of speed and judgments of animacy were observed, it would be evidence that the perceptions of animacy and speed are not rigidly linked and can be dissociated. Conversely, if participants' perceptions of speed and animacy are not dissociated, we should expect participants to be consistent in their judgments of speed and animacy for both directions, judging the same dots as both faster and animate regardless of the presence or absence of a gravitational context.

In both experiments, participants viewed objects travelling up and down a monitor that was oriented vertically (i.e., conventionally) or horizontally. Both experiments utilized a two-interval forced choice task, presenting a pair of dots whose motions were matched for all factors except direction; this allowed us to test whether the pattern of perceptions seen in Experiment 1 was sensitive to changes in the orientation of the stimuli when the context (and apparent influence) of gravity is absent in Experiment 2.

Experiment 1

Experiment 1 was designed to test for a dissociation between the perceptions of speed and animacy, by introducing the apparent context of gravity. We predicted that attributions of gravity's influence would dictate the presence or absence of a perception of animacy (via an internal power source), independent of the perception of speed. Participants viewed simple motions on a vertically oriented computer monitor that appear consistent or inconsistent with gravity, either by "falling" or "rising". We predicted that people would be more likely to perceive the falling dots as inanimate, since they were merely succumbing to external forces while obeying the laws of physics. Conversely, the rising dots are more likely to be perceived as animate since such a motion would denote a violation of gravity, likely due to attributions of an internal power source. Perceptions of speed were thus expected to be dissociated from perceptions of animacy.

Methods

Participants

Twenty-eight undergraduate psychology students (23 females, 5 males; mean age=19 years, range 18–24 years) participated for course credit. All had normal or corrected-to-normal vision.

Stimuli

White, high-luminance dots (subtending 0.24°) entered into a grey, medium-luminance circular area (subtending 12.7°). Dots entered from one of six points distributed at the top and bottom of the circle's perimeter. All dots travelled at a constant speed through the centre of the circle, without changing direction. Three linear paths were presented, randomly: from the 11:00 position to the 5:00 position, from 12:00 to 6:00 and from 1:00 to 7:00. The beginning and end positions were randomized across trials. Three speeds were tested: 2.8°/s (travelling 2.1°), 3.9°/s (travelling 2.9°) and 5.2°/s (travelling 3.9°). Thus both dots in a given trial travelled the same distance at the same speed. Speeds and starting positions (and, therefore, direction first presented) were randomized across trials.

Each trial consisted of a dot moving along a particular linear path, a pause of 400 ms, followed by a dot moving at the same speed in the opposite direction along the same linear path. Displays began with the dot already in motion, thereby suggesting no impetus of motion, neither self-propulsion nor collision. Similarly, displays ended with dots still in motion; dots never came into contact with the perimeter of the circular viewing area and were never stationary.

Stimuli was presented on a Macintosh G4 using Matlab and the Psychophysics Toolbox (Brainard, 1997; Pelli, 1997) and displayed on a 21-in. monitor. The entire display subtended 17.8° by 23.5° and was viewed at a distance of 95 cm using a chin rest.

Procedure

Participants viewed 192 two-interval forced choice trials. For half the trials (speed condition), participants were instructed to judge which dot was "faster". For the other half (animacy condition), participants were told to judge which dot appeared "alive". The order of condition was counterbalanced across parti cipants. Participants were instructed to make all judgments "as quickly as possible, by pressing buttons on a joystick". The experiment took place in a darkened room. The entire experiment lasted approximately 35 min. (An additional 192 trials from a similar experiment were viewed during participants' experimental visit; thus only half of the 35 min was spent on the experiment described here).

Results and Conclusions

Participants' responses did not differ significantly between the three speeds tested across trials, so speed was collapsed for all analyses. The interaction between condition (animacy×speed) and direction (rising×falling) was significant

[Blalock's difference of difference of proportion test (Blalock, 1972); z = 3.59, p < .01; Fig. 3.1, left]. Rising dots were judged as alive by more participants more often than they were judged as faster. This is contrary to previous research that has consistently found relatively faster objects appearing animate more than relatively slower objects.

There were significant main effects of direction in both the animacy and speed conditions. A significant majority of the participants (68%) in the animacy condition judged dots moving up the screen as alive more often than dots moving down the screen (19 vs. 8; one participant responded exactly at chance and was not included in this statistic: Wilcoxon sign test, z = 2.41, p = .016; Fig. 3.1, left). Post hoc paired-sample t-tests revealed that participants' judgments were influenced by the order in which they viewed the pairs of dots: participants judged a rising dot as alive more often if they first viewed a falling dot than if they first viewed a rising dot (t(27) = 4.07, p = .01). Participants' judgments of animacy did not differ when they viewed a rising dot first (see Fig. 3.2, left).

In the speed condition, velocity cues were interpreted differently if moving up vs. down. Sixty-one percent of the participants judged a falling dot as faster than a rising dot (17 vs. 10; a different participant responded exactly at chance and was not included in this statistic: Wilcoxon sign test, z = 2.559, p = .011; Fig. 3.1, left). Post hoc paired-samples t-tests on the order of presentation revealed that participants judged a falling dot as faster more often if they first viewed a rising dot, than if they first viewed a falling dot (t(27) = 3.92, p = .01); participants' judgments of speed did not differ when viewing a falling dot first (see Fig. 3.2, left).

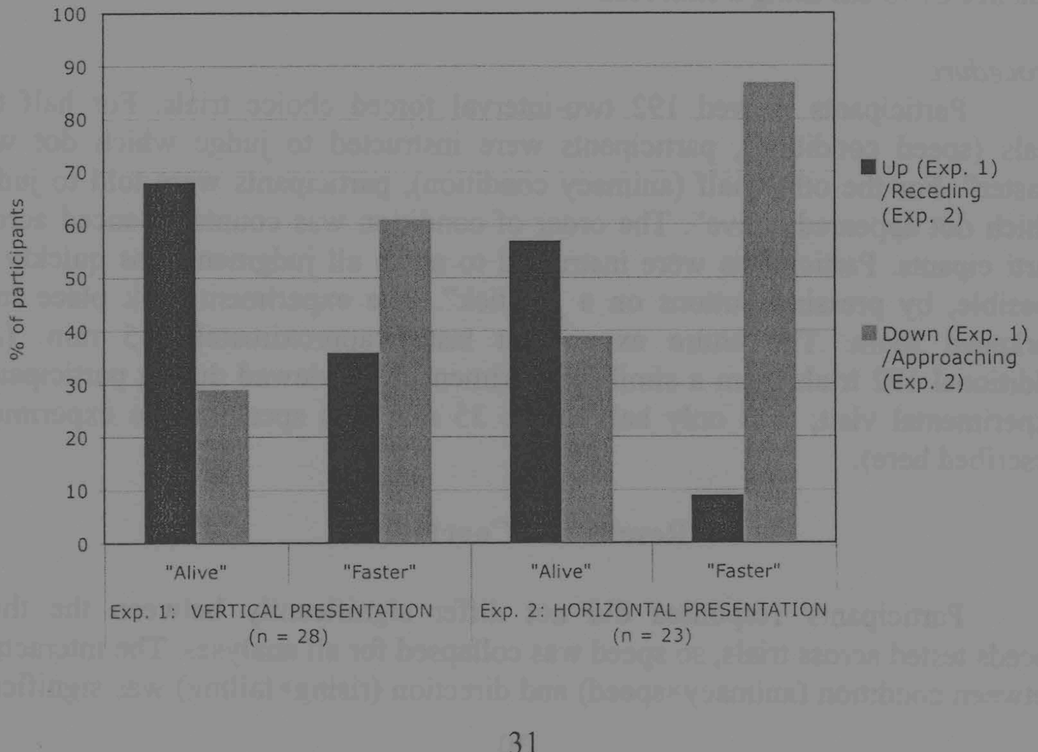

Figure 3.1. More participants judged "rising" objects as appearing alive, but judged "falling" objects as faster (Experiment 1, left). When identical displays were presented horizontally to remove the context of gravity (Experiment 2, right) participants exhibited no bias for animacy, but overwhelmingly judged approaching objects as appearing faster.

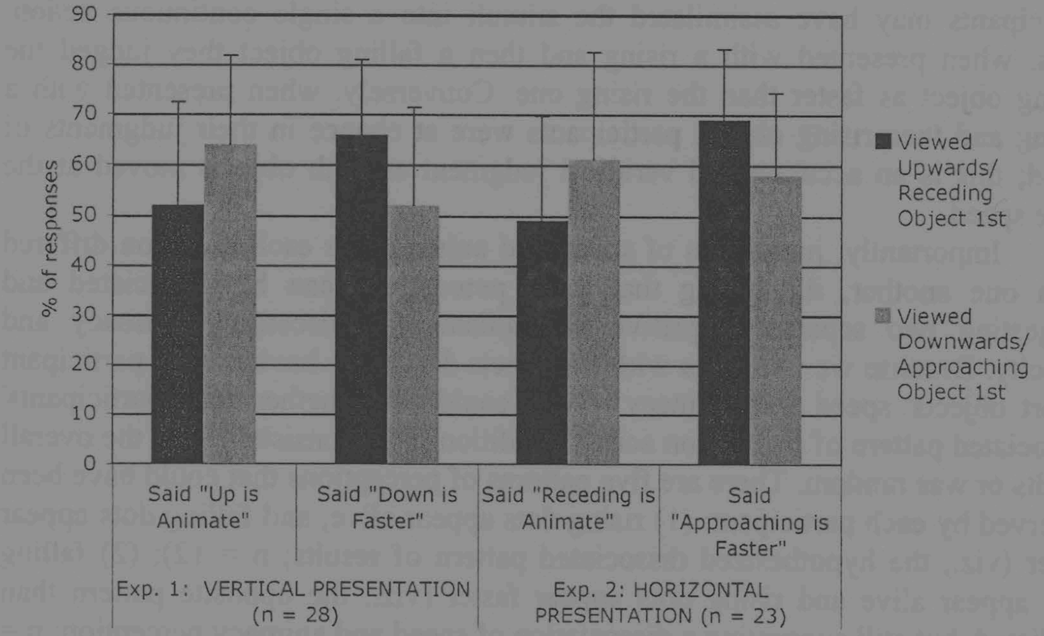

Figure 3.2. Order effects from Experiments 1 (left) and 2 (right). Participants were influenced by the order of presentation; see text for discussion. Error bars indicate standard deviations.

Participants' judgments of animacy are consistent with the idea that in the terrestrial environment in which the human visual system evolved, objects moving upwards were likely to have an internal power source and thus were likely to be animate. This suggests that our perception of animacy is sensitive to an apparent gravitational field and that the cognitive mechanisms involved in this judgment interpret motion cues accordingly. That participants were more likely to judge a rising object as alive after viewing a falling dot suggests that their judgments were influenced by immediately prior experience. On each trial, people were asked to judge which of two dots appeared alive or appeared faster. While we intended the two dots in each pair to be compared to each other as two independent objects, it is possible that participants' judgments were made by integrating both dots into one complete action. If this were the case, then for half the trials participants perceived a rising then falling object and were at chance in their judgments of which was alive. Objects rise into the air and fall back to earth constantly, making judgments of whether such an object is alive or not difficult.

Conversely, perceptual judgments of an object falling and rising object continuously would be perhaps simpler, as very few inanimate objects fall to earth only to rise back up, while many animate ones do.

Participants' judgments of speed were also influenced by direction in a way that is functional given a terrestrial visual system: rising objects will typically decrease in speed, while falling objects will often increase in speed (until — and if — they reach terminal velocity). As was perhaps the case in Experiment 1, participants may have assimilated the stimuli into a single continuous action. Thus, when presented with a rising and then a falling object they judged the falling object as faster than the rising one. Conversely, when presented with a falling and then rising object, participants were at chance in their judgments of speed; this is an accurate and veridical judgment as both objects moved at the same speed.

Importantly, judgments of speed and animacy for each direction differed from one another, illustrating that these perceptions can be dissociated and suggesting two separate cognitive mechanisms for discerning animacy and velocity. Because we utilized a within-subjects design — having each participant report objects' speed and animacy — we could ask whether each participants' dissociated pattern of perception across conditions was consistent with the overall results or was random. There are five patterns of perceptions that could have been observed by each participant: (1) rising dots appear alive, and falling dots appear faster (viz., the hypothesized dissociated pattern of results; n = 12); (2) falling dots appear alive and rising dots appear faster (viz., the opposite pattern than predicted, but still suggesting a dissociation of speed and animacy perception; n = 2); (3) rising dots appear both alive and faster (n = 7); (4) falling dots appear both alive and faster (n = 5); (5) absolute ties, showing no influence of direction on speed and animacy (n = 2). Overall, participants' pattern of responses across conditions was significantly different from chance (20%) ($\chi 2(4) = 12.357$, p = .015), suggesting that participants were not random in their perceptions across conditions. The first two patterns represent a dissociation of perceptions; only the first is functional. That more participants chose this pattern most often (12 vs. 2) supports the notion that the dissociation is functional.

Given this, we wanted to know whether more participants reported the hypothesized pattern of perceptions (viz., that rising dots would appear alive, but would not appear faster) than did the other possible patterns of perceptions. To do this, we compared the number of people who said rising dots were alive and slower (n = 12) to any other pattern of perception (n = 16). Five separate a priori binomial tests, each with chance set at 0.2 (given five patterns, described above), were conducted. The only significant result was that more people chose a rising dot as alive and a falling dot as faster than would be predicted by chance (p = .003); all other patterns of judgments were reported at chance.

Experiment 2

The human visual system evolved in the context of a gravitational field; data from Experiment 1 suggests that our perceptions of speed and animacy take into account the influence of gravity differently, as a functional approach would predict. Experiment 2 was designed to test whether our perceptions are influenced by the orientation of the stimuli, such that the context of gravity is no longer present. Participants viewed displays identical to Experiment 1, now presented in a horizontal orientation. Objects that appeared to be rising and falling in Experiment 1 appeared to be moving toward or away from participants (approaching or receding) in Experiment 2 and thus were unlikely to be perceived as affected by gravity.

Participants

Twenty-three undergraduate introductory psychology students participated for credit (17 females, 6 males; mean age: 19 years, range: 18–32 years).

Stimuli and procedure

Participants were seated at a viewing station that allowed a horizontally oriented monitor to be viewed from above at an angle of 28° off perpendicular to the ground, when seated normally (see Fig. 3.3). The viewing distance (95 cm) was the same as in Experiment 1. The viewing angle was not exactly perpendicular to the screen, as in Experiment 1, causing the distances travelled to be very slightly foreshortened. However, the distances were identical for both objects in a given trial and thus were equated across the experiment. All stimuli and procedures were the same as in Experiment 1, including number of trials.

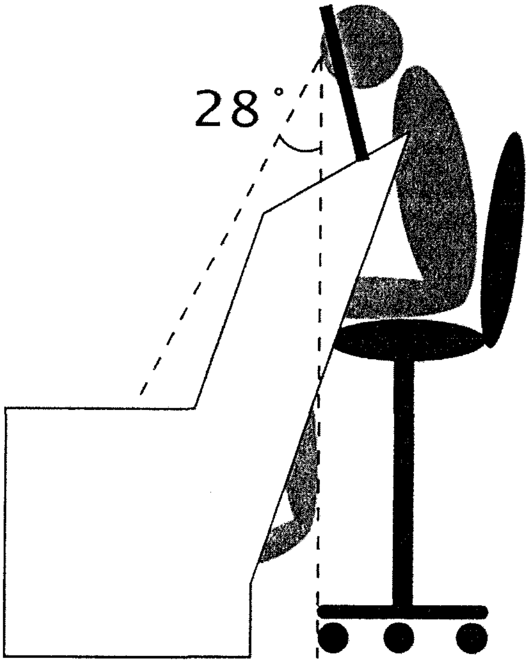

Figure 3.3. Viewing station used in Experiment 2.

Results and Conclusions

Responses were not significantly different for the three speeds tested, so speed was collapsed for all analyses. As in Experiment 1, Blalock's difference of difference of proportion test revealed a significant interaction between condition (animacy × speed) and direction (looming × receding) (z = 5.59, p = .01; Fig. 3.1, right): looming dots were judged as faster by more participants more often than they were judged as alive. This again provides evidence of a dissociation between the perception of animacy and the perception of speed.

In the animacy condition, direction had no significant influence on judgments (13 vs. 9; a single participant responded at chance and was not included in this analysis: Wilcoxon sign test z = 1.28, p = .20; Fig. 3.1, right). However, post hoc paired-samples t-tests revealed that participants judged a receding object as alive most often if they first viewed an approaching object (t(22) = 3.314, p = .01) and did not differ when viewing a receding object first (see Fig. 3.2, right).

In the speed condition there was a pronounced main effect of direction: Approaching dots were judged as appearing faster than receding dots by 87% of the participants (20 vs. 2; again, a single — but different — participant responded at chance for this condition and was not included in the analysis: Wilcoxon sign test, z = 3.7, p = .01; Fig. 3.1, right). Post hoc paired-samples t-tests revealed that people judged an approaching object as faster more often when first viewing a receding object (t(22) = 3.513, p = .01; Fig. 3.2, right).

Discussion

There was clearly strong evolutionary pressure for the ability to discriminate objects that were alive from those that were not. Past research has shown that some qualities of an object's motion can be a cue to animacy. Specifically, research to date has shown a consistent association between an object's speed and the perception that it is alive, such that relatively faster objects appear alive more often than slower objects (Tremoulet & Feldman, 2000; Szego & Rutherford, 2007). The current study illustrates a dissociation of these perceptions and reveals that motion cues are interpreted functionally in the context of gravity.

In Experiment 1, participants reported that rising objects appeared animate more often than falling objects. An object that is able to rise directly into the air is likely to have an internal power source, which has been argued to be a cue of animacy (Biro & Leslie, 2007; Gelman et al., 1995; Leslie & Keeble, 1987; Premack, 1990; Stewart, 1982). When the same stimuli were presented without the gravitational context (Experiment 2) participants did not favour one direction over another in their judgments of animacy. In both experiments, participants' responses cohered with motion attributes that reflect actual features affecting motion in the real world. Like other visual perceptions (e.g., colour and size constancies), our perceptions of animacy are structured around functional processes. Having perceptual biases that allow quick encoding of objects as animate or not would allow great advantages in gaining resources and avoiding threats when coping with an environment full of conspecifics, predator and prey objects.

Perceptions of speed did differ from the perceptions of gravity in both experiments, revealing that these perceptions can be dissociated and suggesting the presence of two different cognitive mechanisms: one that is concerned with animacy and is sensitive to cues of gravity in ways that appear functional given the terrestrial environment in which it evolved; another that is concerned with judgments of speed. Perceptions of animacy and speed differed from one another with regard to the influence of gravity. How the mechanisms concerning animacy and gravity interact during development is unknown. It may be that the animacy and gravity systems develop along separate trajectories. Research on gravity perception has shown that understanding the influence of gravity begins early in life (Kim & Spelke, 1999) and continues to develop through adolescence (Krist, 2000); however, errors are common even in adulthood. Hood (1998) has shown that 2-year-olds make more errors predicting the location of an object if it is falling than if it is rising along the same trajectory, and adults will often make errors in predicting the influence of gravity on an object's motion (Rohrer, 2002). More studies investigating the influence of gravity on infants' judgments of animacy are needed.

Participants' responses were influenced by the order of direction presented. This may be due to their having integrated both motions into one complete action and perceiving a solitary object rising and falling or approaching and receding. If this were the case, then judgments of animacy and speed cohere with the behaviour of animate and inanimate objects in the natural world. Both animate (e.g., frogs, grasshoppers, birds, leaping ungulates) and inanimate (e.g., leaves, small pieces of organic material) objects will, at times, rise into the air, and most will immediately fall back to earth. Judgments of animacy when viewing objects rising and then falling were, correspondingly, at chance. On the other hand, very few objects are light enough to fall to the earth only to rise up into the air again, and one can imagine that the majority are inanimate objects (e.g., leaves and small pieces of organic material carried by wind). But a great many animate objects can and do perform exactly this action as part or all of their locomotion (e.g., frogs, grasshoppers, birds travelling from spot to spot, leaping ungulates). Judgments of animacy and speed when viewing falling-and-rising or rising-and-falling objects appear to support the influence of real-world experience in our perceptions. These interpretations presume that participants were combining the trajectories of both dots in a trial into one cohesive motion; this may not have been the case. Further studies with pairs of dots that are explicitly differentiated from one another may eradicate this effect.

Across both experiments, the stimuli on the retina were identical. Therefore in addition to being able to examine across conditions within each experiment (as the main analyses do) we can also compare similar conditions between experiments (viz., falling vs. approaching, and rising vs. receding). Despite the visual similarities, there were significant perceptual differences in judgments of speed. Comparing data between experiments revealed that people judged approaching objects as faster more often than falling objects ($z = 3.34$, $p = .01$). The observed bias to judge an approaching object as appearing faster than a receding object (that actually travels at the same speed) conforms to the evolutionary principle behind Haselton and Buss' error management theory (Haselton & Buss, 2000). In the EEA, approaching humans and animals may have represented threats or opportunities, either of which would have had implications for ones' fitness. Perceptual biases to approaching motion are well documented: people have a perceptual bias to judge directionally ambiguous motion as approaching rather than receding (Lewis & McBeath, 2004) and to judge directionally ambiguous point-light walkers as walking towards the viewer rather than walking away (Vanrie, Dekeyser, & Verfaillie, 2004). Infants as young as 2 weeks of age will respond defensively and show signs of distress to impending collisions (Ball & Tronick, 1971). Franconeri and Simons (2003) report that approaching motion captures attention while receding motion does not. While this may address the directional bias for speed observed in the horizontal presentation (Experiment 2), no directional bias was reported in the animacy condition showing the same stimuli, suggesting that something other than attentional capture was driving the results. More work is needed to determine the nature of the bias in the speed condition and its relation to animacy in general and as representing threat objects.

It appears that the perception of animacy is organized functionally around real-world motion cues that are based on statistical regularities in our EEA. There is one important theoretical similarity between the current study and previous research that should be addressed. Both this study (looking at violations of gravity) and previous ones (looking at speed and acceleration) address a similar fundamental quality concerning the nature of the objects as animate or not: in all experiments across these studies, objects that appeared most likely to possess an internal power source (by travelling faster, accelerating more greatly or violating — rather than succumbing to — gravity) were judged as animate. Given this similarity and the results of the current study, it appears that some motion attributes are more informative — at least in some circumstances — than speed, but that speed can be a cue of animacy perhaps because it suggests an internal power source. Whether this functional organization applies to the perception of an internal power source remains to be determined.

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Chapter 4
An Investigation into Categorical Perception and Animacy

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Authors' Contributions

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Introduction

The research described so far has illustrated that relatively faster objects are perceived as animate more often than relatively slower objects (see Chapter 2) but also that this relationship is dissociable under certain circumstances. As Chapter 3 illustrates, the visual system is sensitive to at least some features of motion in ways that are functionally adaptive and correlated with predictable features in our environment of evolutionary adaptedness (EEA). One example of this specialized adaptation is that greater importance is placed on the apparent influence of gravity, making rising objects appear slower than falling objects but also appear more animate (Szego & Rutherford, 2008a).

Generally, the current research programme has focused on how particular motion cues influence people's perceptions of animacy. There are, however, other ways of investigating the nature of our animacy perception; one could also examine the nature of people's decision-making process while judging whether an object is animate or not as based on velocity cues. Rather than documenting specific elicitors of a particular perception, we can focus on the nature of the perceptual judgment itself.

This approach allows us to ask a number of interesting and informative questions: Are judgments of velocity affected by thinking about an animate object versus an inanimate object? Do people categorize ambiguous moving objects as being *either* animate or inanimate? Are the motion cues that appear animate and inanimate mutually exclusive? Are these motion cues stable across individuals, or does each person have their own barometer of what velocities appear animate?

The extant literature implies – following commonsense knowledge – that animacy is categorical, and therefore our perceptions of animacy should be as well (Gelman, Durgin, & Kaufman, 1995). For objects in the real world (that is, outside the laboratory) this is veridical: at a single point in time, an object is either alive or it is not. This is the position taken when discussing both the nature of objects and the development of our understanding of animacy (Opfer, 2001; Opfer & Gelman, 2001; Gelman & Opfer, 2002). When determining if an ambiguous moving object is alive (either in the laboratory or the real world) it becomes reasonable to determine if people have a mental metric, and if the particular qualities of the metric is unique to an individual or if it is universal. When viewing colours, for instance, it has been shown that individuals have a well-defined perceptual metric of what constitutes a particular colour, that many colours are psychologically distinct from each other, and that many people share this metric. In the realm of colours, there exists a psychological metric that places certain boundaries within the visible range of the electromagnetic spectrum; these boundaries illustrate the presence of specific and reliable boundaries between some values and others. Boundaries in the electromagnetic spectrum create the perception of green when viewing the section of the electromagnetic spectrum corresponding to both light green and dark green, but not when viewing the section corresponding to blue.

Although there are not physiological reasons to expect animacy to be perceived this way (unlike colours), a comparable examination of velocity may illustrate analogous boundaries about our perceptions of animate and inanimate motions. If present, this would reveal important facets about our perceptions of animacy, such as whether boundaries exist between velocities eliciting a perception of animacy and velocities that do not, and how stable these boundaries are across individuals. This type of examination introduces a large field of psychological research called categorical perception (CP), which examines how people discriminate and identify objects as belonging to one of many subsets within a continuous range.

In a typical CP experiment, objects tested fall along a shared physical continuum that can be manipulated and recorded, such as electromagnetic wavelengths (for testing the perception of colour) and frequencies (for testing pitch). Even minute differences in facial musculature can create a categorical perception corresponding to the perception of various facial expressions such as happy, sad, and fear (Etcoff & Mcgee, 1992). In each case, categorical perception compares varying levels along a continuum to detect if our sensory and perceptual systems create a boundary such that (1) objects lying on either side of a boundary appear more similar to each other than objects on the other side of a boundary, and (2) differences can more accurately be discriminated between pairs that straddle the boundary than between pairs on either side of the boundary (Harnad, 1997). In a colour task, all stimuli in the green region of the electromagnetic spectrum (e.g., light green, dark green) appears more similar to each other than they do to stimuli in the blue region, and individuals would be more accurate discriminating between a green and a blue than they would a light and dark green or light and dark blue.

To detect if categorical perception is present, a discrimination task and an identification task are employed. In a discrimination task, participants are shown a pair of exemplar objects (e.g., colour patches of green and blue) followed by a single target object that matches one of the preceding pairs (e.g., blue); the participant's task is to identify which object the target matches. One of the two required components of categorical perception occurs when people can discriminate smaller differences within a category than differences that straddle the category boundary (e.g., if light green and green are harder to discriminate than light green and blue). The second component is experimental confirmation that people will reliably *label* the stimuli as one or another category. Researchers test this by showing a single exemplar and asking participants to identify which category it belongs to (e.g., "Is this green or blue?"). While this task adds evidence of categorical perception, the hallmark of categorical perception requires demonstrating that the categories identified in the second task predict a participants' accuracy on the first task. If this prediction is observed – and the two tasks correspond to a common boundary between what is perceived as "something" and what is perceived as "something else" – then categorical perception is said to occur (Calder, 1996; p. 82).

To test people's perception of animacy as elicited by motion cues using a CP paradigm a continuum of velocities will be created, ranging from relatively slower to relatively faster values. This continuum will be employed to test whether there is a boundary between the velocities that elicit perceptions of animacy and those that do not. However, as participants will be asked to discriminate between objects that may or may not be perceived as animate, it must first be determined whether simply viewing animate and inanimate objects influences people's abilities to discern velocity differences.

Although this specific type of investigation is not part of the extant literature, there is research suggesting the presence of differential performance when performing a related task. Using a change-detection task, New, Cosmides & Tooby (2007) reported that people were better at detecting a single change between two otherwise identical scenes when the displaced object was an animal than compared to inanimate objects. This was found even when the inanimate object was presented much larger (on the retina) than the animate object (e.g., a silo vs. a pigeon) and when the inanimate object was movable (e.g., a car). Plants, however, were not detected as accurately as inanimate objects, suggesting that the visual system preferentially attends to *moving animate* objects. Given the possibility of a biased mechanism, it may be that discriminating differences in velocity also use separate cognitive mechanisms for perceiving animate versus inanimate objects; Experiment 1 tests this possibility. In doing so, it also tests whether the continuum of velocity differences employed is reliable regardless of whether people judge an object as animate or not. If so, this continuum will be used in Experiment 2, which asks participants (in a typical CP paradigm) to discriminate between objects moving at velocities along the continuum, and then to identify the objects as animate or not.

Experiment 1

Discriminating Differences of Animate and Inanimate Objects Moving at Constant Velocities

Before testing whether people's perceptions of animacy are categorical or not, it was necessary to determine if people can reliably discriminate between different velocities. In addition to testing the stimuli for Experiment 2, this also tested people's discrimination of velocities when primed to think of an animate object or an inanimate object.

Methods

Participants

Forty-four undergraduate students (34 females, 10 males; mean age: 18) participated for credit. All participants had normal or corrected-to-normal vision.

Stimuli

White, high-luminance dots subtending 0.24°/sec were shown moving against an otherwise empty grey screen. Each trial displayed a pair of dots, shown sequentially on either side of a monitor. A continuum of ten speeds ranging from 2.2°/sec to 8.2°/sec in equal increments was created (see Table 1). From this continuum a series of twenty-one pairs was extracted; pairs were either two-steps (n = 8), three-steps (n = 7) or four steps (n = 6) apart on the continuum (see Table 2). On each trial, one dot travelled at a constant velocity for 600 ms and the other for 700 ms; this helped ensure that participants could not compare speeds by comparing the distance travelled across the screen.

Stimuli were displayed on 21" CRT monitor connected to a Macintosh G5, using Matlab and the Psychophysics Toolbox (Brainard, 1997; Pelli, 1997). Viewing distance was 95 cm.

Procedure

Participants viewed 164 two-alternative forced-choice trials. Half of the trials showed a pair of dots travelling at identical constant velocities, half showed a pair of dots travelling at different constant velocities. All velocities corresponded to one of the 21 2-steps, 3-steps, or 4-steps pairs. Each trial began with an orienting fixation cross presented on one side of the monitor for 500 ms, to indicate the location of the first dot. This ensured that participants did not miss the onset of the motion of the first dot, possibly affecting their perception of its speed and distance travel, and thus their comparisons. The presentation of dots in a pair was separated by 500 ms.

Fifteen participants in the non-animate condition were informed that they would see a pair of "dots" moving across the screen; fifteen additional participants in the animate condition were informed that they would see a pair of "bugs" moving across the screen. All participants were instructed to report whether the pair of dots/bugs moved at the same speed or at different speeds using a joystick, and were instructed to be as accurate as possible. Participants completed the task while seated at a viewing station that allowed stumuli to be presented on monitor oriented horizontally (with the screen facing the ceiling); participants remained seated in a conventional, vertical, orientation (refer to Figure 4.1). All parameters of the stimuli and procedure were identical between conditions, with the sole exception of the terms "dots" or "bugs" in the instructions.

Results

To determine if participants' accuracy in the dot and bug condition differed from one another for trials showing the same velocity or velocities that were 2-, 3-, or 4-steps apart, a mixed-model ANOVA was conducted with condition (dot and bug) as a between-subjects variable and steps (0, 2, 3, 4 steps apart on the continuum) as a within-subjects variable. No significant differences were found for steps (F(1) = 0.031, p = 0.8), condition (F(1) = 0.357, p = 0.5), or their interaction (F(1) = 0.006, p = 0.9). The average accuracy was identical in both the dot (mean = 63.6%) and bug (mean = 62.3%) conditions (refer to Figure 4.2). Participants were able to discriminate constant velocities equally well whether thinking about animate or inanimate objects, providing no evidence for the existence of separate visual mechanisms. This confirmed that the continuum of velocities is suitable for using in a categorical perception study.

Experiment 2

Categorical Perceptions and Animacy

Having established that people reliably discriminate constant velocities along the continuum equally well when primed to think about animate or inanimate objects, Experiment 2 sought to examine whether people perceive animacy using these motion cues categorically or not. The CP methodology can be applied to the question of whether people will reliably create a boundary between velocities identified as appearing animate or inanimate, while also discriminating between pairs of velocities that straddle the boundary more accurately than pairs on either side of the boundary. As there have been no published accounts of this methodology in the animacy literature, and there is no common agreement regarding what constitutes an animate velocity, the results of this experiment may or may not confirm that animacy is perceived categorically.

Methods

Participants

Sixty-six undergraduate students (54 females, 15 males; mean age: 19) participated for credit. All participants had normal or corrected-to-normal vision.

Stimuli

All parameters of the dots (e.g., size and colour), motions (e.g., velocities), display (e.g., background colours, monitor size and resolution) were identical to Experiment 1, unless otherwise mentioned.

Procedure

For both the discrimination and the identification tasks, participants sat in front of a monitor oriented horizontally (with the screen facing the ceiling) while seated in a conventional (vertical) orientation, to prevent any biasing effects of gravity (refer to Figure 4.1).

Discrimination Task

Participants first viewed a solitary target dot travelled for 800 ms across the middle of an otherwise empty grey screen. After a short (250 ms) pause, a pair of moving dots was presented sequentially, one on either side of the screen. The velocities of all dots were taken from the continuum of Experiment 1; velocity differences within each pair on a given trial were 2-, 3-, or 4-steps apart, chosen randomly. On every trial one of the dots in a pair matched the velocity of the target dot. One dot in each pair travelled for 600 ms, the other travelled for 1000 ms; these differences helped ensure that participants could not use the distance travelled or time presented on screen to match velocities. As in Experiment 1, a fixation cross was presented for 500 ms preceding first dot in the pair (after viewing the solitary target dot), to ensure that participants could view each motion in its entirety. The side of presentation for the first dot in a pair and the matching dot in a pair was randomized; dots in each pair were separated by 500 ms.

After viewing each target and subsequent pair of dots, participants were instructed to indicate "which of the dots on the sides of the screen matched the one in the middle: the one on the left, or the one on the right" using the corresponding left and right buttons on a joystick. Participants completed 168 trials before going on to the Identification task.

Identification Task

On each trial participants viewed a single dot travelling for 800 ms across the centre of the screen. Dots travelled at one of the ten velocities from the continuum used in Experiment 1 and the Discrimination task of Experiment 2. Each velocity was displayed eight times, resulting in 80 trials. After each dot completed its motion and disappeared from the screen, participants were asked to indicate whether they thought the dot appeared alive or not, using a joystick.

Results

Categorical Perception: Identification and Discrimination

Evidence of categorical perception comes from corroborating patterns of data in both the identification and discrimination tasks (e.g., Calder, 1996). This was almost exclusively not observed in the current study. Of sixty-six participants, only two demonstrated the requisite combination of identification and discrimination results (refer to Figure 4.3). Participant 8 judged the relatively slower objects as appearing alive, illustrating a boundary at 4.9°/sec, which is approximately halfway through the continuum (the fifth of ten speeds). This participant also displayed a peak in accuracy when judging pairs that straddled this particular velocity (i.e., the 4.2°/5.5° and 4.9°/6.2° pairs). The only other case of a typical pattern of categorical perception was participant 52, who judged the relatively faster speeds as appearing accurate, with a boundary directly halfway through the continuum between the fifth and sixth velocities (5.5° & 6.2°). This participant also illustrated greater accuracy at approximately these values, peaking one step away at 4.2/5.5 pair.

Individual Differences in Identification

Given that so few participants demonstrated a typical CP pattern of results, further investigation into individual patterns was conducted. This revealed that nearly two-thirds of all participants (40/66) fell into one of two typical identification patterns illustrating a sigmoid distribution with an inflection point at 50%. One pattern, illustrated by fifteen participants (refer to Figure 4.4), revealed that relatively slower objects were judged as appearing alive more than chance and that relatively faster objects were judged as appearing animate less than chance (see Figure 4.4, triangles). Six additional participants showed this pattern with the inclusion of a solitary addition speed that crossed their established boundary (i.e., a solitary dip or peak; see Figure 4.4, circles). The inclusion of participants having a solitary stray data point does not change the sigmoidal nature of the distribution, as shown in Figure 4.4 (circles).

The other pattern, illustrated by eleven participants, revealed faster objects as appearing animate on more than half the trials and slower objects as appearing animate on less than half the trials (see Figure 4.5, triangles). Eight additional participants showed this general trend with the inclusion of a single velocity that crossed the participants' established boundary; again these solitary data points do not change the sigmoidal nature of the distribution, as shown in Figure 4.5 (circles).

The modal boundary location for all participants combined was between the fifth and sixth velocities (4.9°/sec and 5.5°/sec). This was also found for participants judging the faster velocities as appearing animate. Participants who judged the slower velocities as appearing animate had the slightly lower modal boundary location, between the third and fourth velocities (3.5°/sec and 4.2°/sec).

Collectively, these typical and atypical participants account for 61% of all participants. This majority implies that people are generally able to reliably identify some speeds as animate and others as inanimate in a mutually exclusive manner.

Of the remaining twenty-four participants, some judged all velocities as appearing animate ($n = 4$) or inanimate ($n = 5$). The remaining participants showed two distinct boundaries ($n = 5$), three boundaries ($n = 5$), or more ($n = 5$), although these often consisted of a single velocity comprising a particular category and are likely not reliable indicators of perceptions of animacy.

Individual Differences in Discrimination

Fifteen participants (23%) completed the discrimination task in typical manner, having a single peak in accuracy. Of these participants, two also completed the identification task in a typical manner (see above; refer to Figure 4.3). The remaining fifty-one participants revealed a variety of distributions consisting of a single valley (n = 20; 30%), a series of alternating peaks and valleys (n = 14; 21%), a sigmoidal distribution of accuracy (n = 14; 21%) or a relatively flat distribution (n = 3; 5%).

Discussion

Three experiments demonstrated that people are able to use constant velocities to discriminate differences and identify objects as appearing animate or inanimate. Although the results did not conform to typical categorical perceptions, numerous reliable findings were revealed.

Participants' overall accuracy in Experiment 1 did not differ when encouraged to think of the objects as dots or as bugs, demonstrating that people discriminate differences in constant velocity equally whether thinking about animate or inanimate objects, and whether judging similar or closely-matched velocities. This suggests that the visual system is employed similarly for animate and inanimate stimuli, which is contrary to what New, Cosmides, and Tooby (2007) revealed. The present findings suggest that discriminating differences in velocities may rely on different mechanisms than detecting changes in the position of moving objects, regardless of animacy, at least when such stimuli is ambiguous regarding morphological features. Given this and other differences between the two studies, more research is necessary to determine whether the different findings represent a difference in perception or experimental methods.

In the present study, ambiguous dots were shown travelling against an empty screen, whereas New et al. (2007) used pictures of animals and scenes. If tested with actual bugs and pieces of debris, differences in accuracy may have been revealed in the current study. However this would introduce many new variables (e.g., the estimated velocity of each object), which is beyond the realm of the current research programme.

Given that people were able to discriminate between differences in constant velocities whether thinking about animate and inanimate objects (Experiment 1), it was possible to examine whether people's decisions-making processes about animate velocities illustrates a pattern of categorical perception (Experiment 2). Evidence of categorical perceptions is said to occur when 1) participants consistently judge some range of a continuum as being different from stimuli in another range in the same continuum (thus creating a boundary between these two ranges); 2) participants make more mistakes when discriminating differences between pairs on either side of the boundary than when discriminating between pairs that straddle the boundary; 3) there is a correspondence between the location of the boundary on the continuum (identification task) and the accuracy when discerning differences across the continuum (discrimination task) (Calder, 1996). Only two out of sixty-six participants demonstrated this typical categorical perception results, suggesting that the perception of animacy as elicited by constant velocities is not perceived categorically. Due to the vast majority of participants failing to demonstrate a CP pattern, it appears that this may represent the true state of our perceptions; further replication will be necessary to make this conclusion reliably.

Looking at results individually revealed that the majority of participants (61%) were evenly split between identifying the slower (32%) or the faster (29%) objects as appearing animate. Despite the split between these participants, the relatively large number in both groups confirms that people can reliably use constant velocity as an indicator of the presence of animacy, as earlier studies have shown (e.g., Szego & Rutherford, 2007).

The location of people's boundaries appears to be somewhat reliable. Across all participants, the modal velocity for the boundary between animate and inanimate identifications was between the fifth and sixth values on the ten-velocity continuum. This was also the case when looking only at participants who judged faster objects as appearing alive. For participants who judged slower objects as appearing alive, the average boundary was slightly lower, falling between the third and fourth velocities. Participants favouring slower speeds as alive therefore identified fewer velocities overall as appearing animate (approximately one-third of all velocities, compared to more than one-half of the velocities for participants identifying faster velocities as animate).

The almost even split between the number of participants rating slower or faster velocities as appearing animate, combined with the slight but common derivations from typical results, suggests a lack of shared bias or category boundaries for perceiving particular velocities as relatively animate. If these same participants had demonstrated typical discrimination results, this would likely speak to two distinct, but reliable, instances of animacy being perceived categorically; however this was not the case.

Less than one-quarter of the sixty-six participants (n = 15) demonstrated a typical pattern of discrimination, with values straddling a boundary being discriminated from each other with greater accuracy than values lying within either boundary. Of these fifteen participants, only two also showed a typical pattern of identification. The remaining participants showed a range of perceptions, consisting mainly of a single dip in accuracy (which is opposite to the typical categorical pattern), a series of valleys and dips, or a sigmoidal distribution of accuracy.

A limitation of the current study, which if changed may demonstrate different results, concerns how the stimuli were presented in the discrimination task. Participants viewed the standard display, followed by the test displays, one of which matched the first motion. It is possible to present the stimuli in the opposite order, showing a pair of motions followed by a single motion, asking participants to judge which motion the solitary motion matched. This change would perhaps encourage participants to compare the two initial motions using some perceptual ruler, thereby categorizing them (e.g., as "faster" or "slower", and "dot" or "bug"). If participants were encouraged to categorize the objects before attempting to match them, we might have seen different results. However, this may introduce a confirmation bias into the experiment, which is likely why categorical perceptions studies present the tasks in the order that they do, as was done in the present study.

A second limitation of this study is the restricted range of the velocities tested. The values were based on the findings of previous experiments (Szego & Rutherford, 2007; 2008a; 2008b) and have been shown to reliably elicit a perception of animacy. However, it is possible that including faster or slower velocities will result in different perceptions of animacy, perhaps even resulting in more instances of a categorical pattern of perceptions.

It is possible that the brief presentation of stimuli was not sufficient to make a judgment of animacy, however this has not been the case in previous experiments (Szego & Rutherford, 2007, 2008a, 2008b). Given that participants in Experiment 1 were able to reliably discern differences in velocity across the entire continuum, it seems unlikely that increasing the duration of presentation would change the results. In the natural world, one would expect that a speedy reaction would be the norm; this is supported by visual mechanisms such as the orienting reflex, whereby our visual attention is attracted to any motion occurring in the periphery.

The current results are mixed, making any definite claims regarding the categorical nature of animacy perception difficult without further research. Previous research has demonstrated that our animacy perceptions have some continuous properties such that *relatively* faster objects appear alive more often than relatively slower objects (Szego & Rutherford, 2007), but that these perceptions are contingent on other factors, such as the apparent influence of gravity (Szego & Rutherford, 2008a). Given these, and present, findings, more research that explicitly tests whether our animacy perceptions are continuous would likely prove valuable. It may be that animacy, having been shaped by possibly many different elements in the environment (e.g., self-propulsion, gravity, morphological features) is a multifaceted percept, relying differentially on the presence or absence of many different elements in a variety of combinations.

If the perception of animacy were reliably and robustly categorical, these changes would need to be replicated in a more typical manner to be accepted as evidence of categorical perception. Even the current results need to be replicated and expanded upon to conclude that people do not perceive animacy categorically. However, based on the current results, it appears that some features of how people use constant velocity to make decisions about animacy are reliably common, while some features appear to be reliably unique.

Table 1. Speeds (in degrees per second) used in Experiments 1 and 2.

Speed 1	Speed 2	Speed 3	Speed 4	Speed 5	Speed 6	Speed 7	Speed 8	Speed 9	Speed 10
2.2°/sec	2.9°/sec	3.5°/sec	4.2°/sec	4.9°/sec	5.5°/sec	6.2°/sec	6.9°/sec	7.5°/sec	8.2°/sec

Table 2. Speeds (in degrees per second) of 2-step, 3-step, and 4-step pairs used in Experiments 1 and 2.

2-Step Pairs	Pair 1	Pair 2	Pair 3	Pair 4	Pair 5	Pair 6	Pair 7	Pair 8
Speeds	2.2°/sec & 3.5°/sec	2.9°/sec & 4.2°/sec	3.5°/sec & 4.9°/sec	4.2°/sec & 5.5°/sec	4.9°/sec & 6.2°/sec	5.5°/sec & 6.9°/sec	6.2°/sec & 7.5°/sec	6.9°/sec & 8.2°/sec
3-Step Pairs	Pair 1	Pair 2	Pair 3	Pair 4	Pair 5	Pair 6	Pair 7	
Speeds	2.2°/sec & 4.2°/sec	2.9°/sec & 4.9°/sec	3.5°/sec & 5.5°/sec	4.2°/sec & 6.2°/sec	4.9°/sec & 6.9°/sec	5.5°/sec & 7.5°/sec	6.2°/sec & 8.2°/sec	
4-Step Pairs	Pair 1	Pair 2	Pair 3	Pair 4	Pair 5	Pair 6		
Speeds	2.2°/sec & 4.9°/sec	2.9°/sec & 5.5°/sec	3.5°/sec & 6.2°/sec	4.2°/sec & 6.9°/sec	4.9°/sec & 7.5°/sec	5.5°/sec & 8.2°/sec		

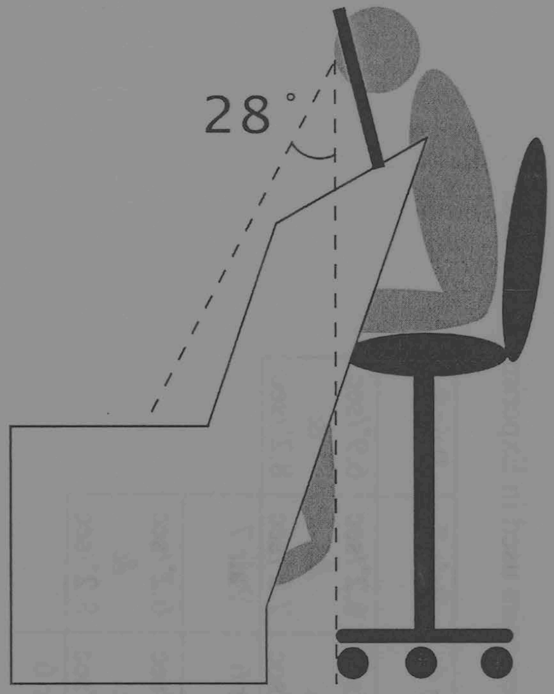


Figure 4.1. Viewing station used in Experiments 1 and 2.

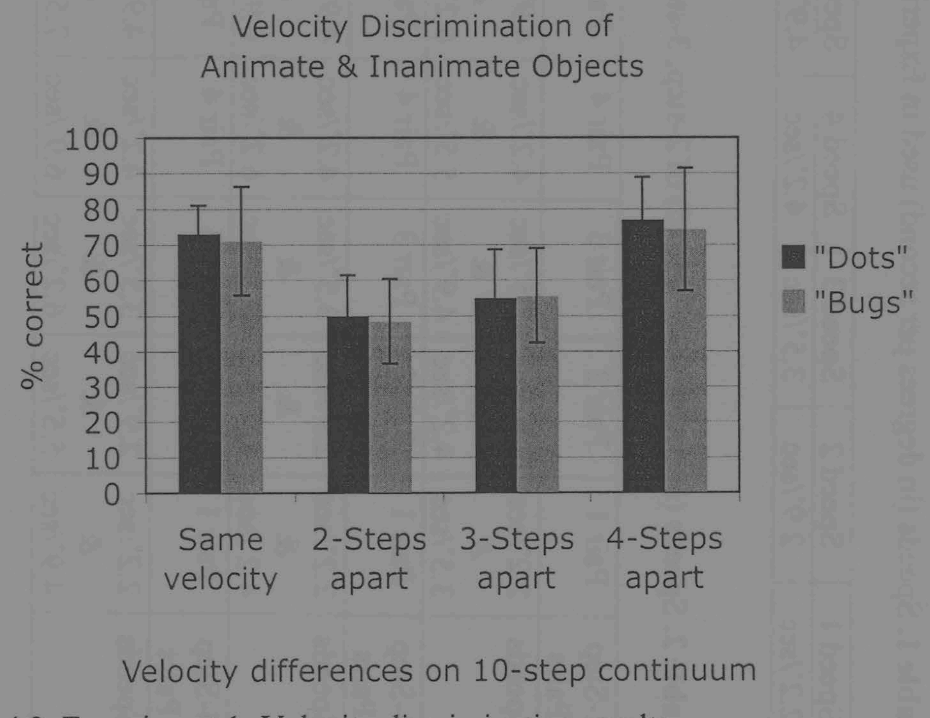
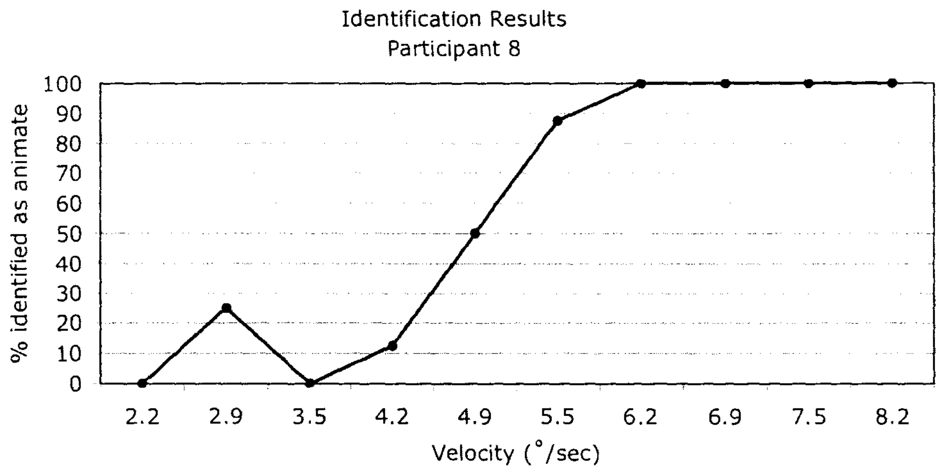
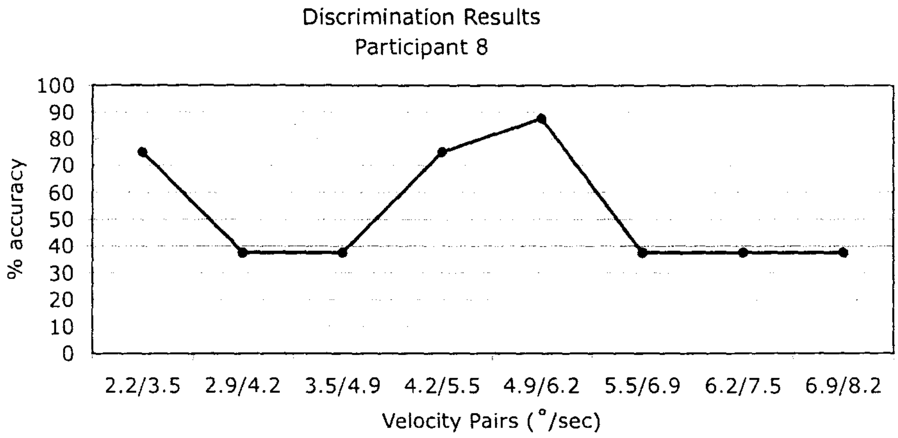
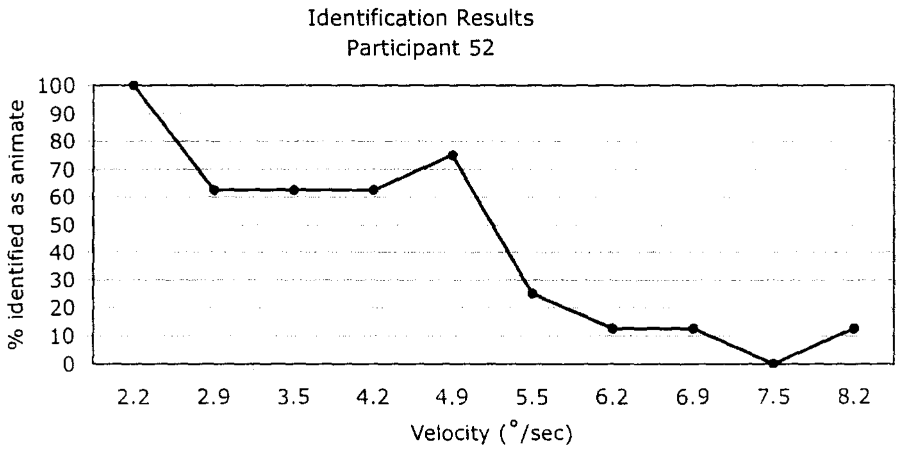


Figure 4.2. Experiment 1: Velocity discrimination results.


Identification Results
Participant 8


Discrimination Results
Participant 8


Identification Results
Participant 52

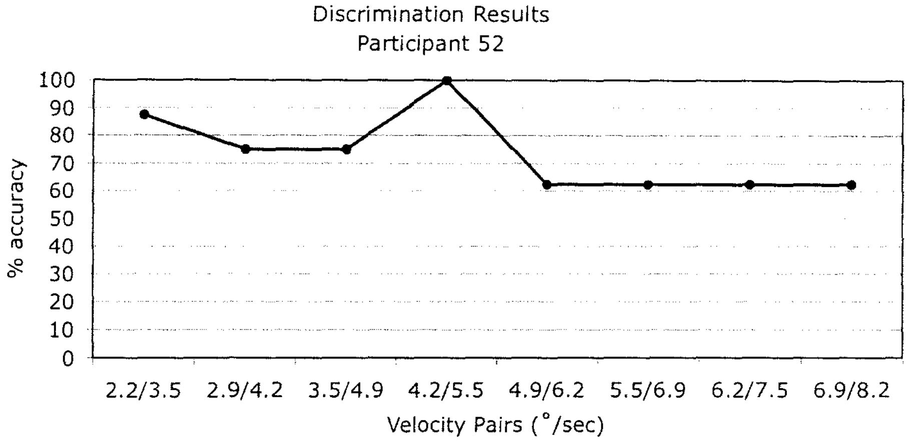


Figure 4.3. Experiment 2: Typical categorical perception (Identification and Discrimination tasks) results for two participants.

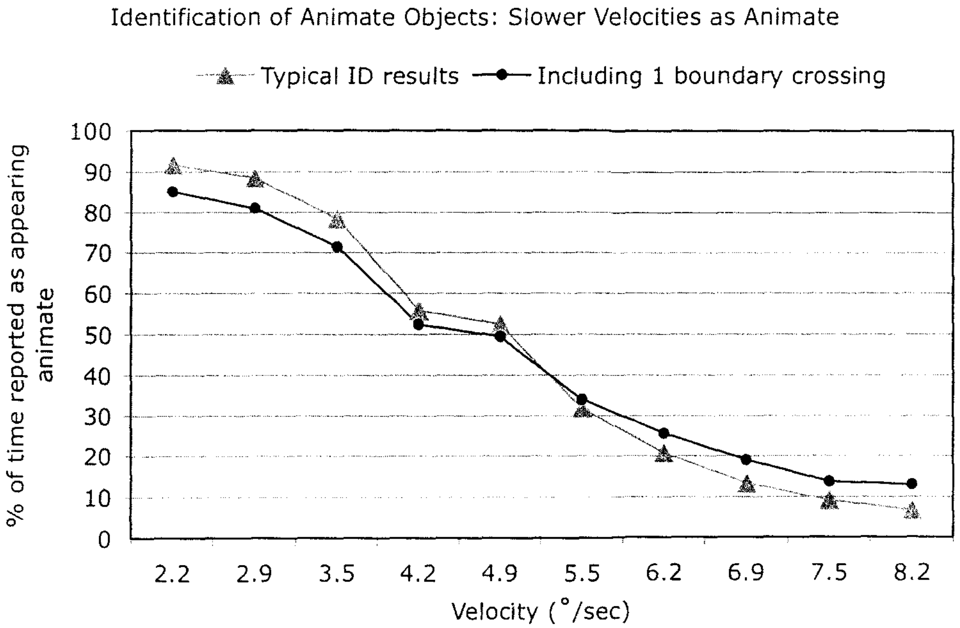


Figure 4.4. Experiment 2: Identification task. Data from participants reporting slower objects as appearing alive. Triangles represent fifteen participants showing typical patterns of results; circles illustrate all participants, including six whose judgments stray from the sigmoid pattern for a single point.

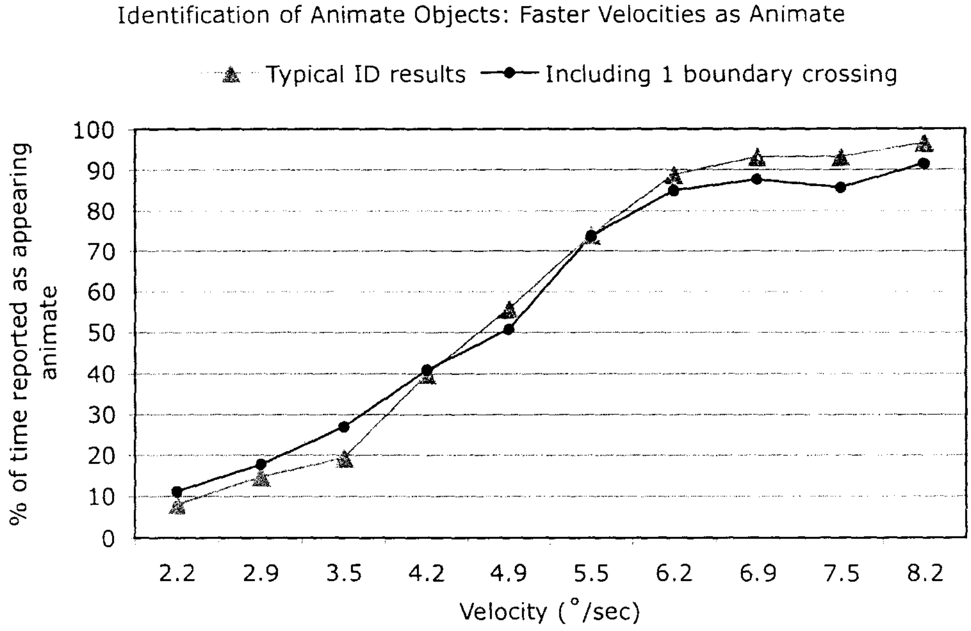


Figure 4.5. Experiment 2: Identification task. Data from participants reporting faster objects as appearing alive. Triangles represent eleven participants showing typical patterns of results; circles illustrate all participants including eight whose judgments stray from the sigmoid pattern for a single point.

Chapter 5

Reading-Related Habitual Eye Movements Produce a Directional Anisotropy in the Perception of Speed and Animacy

Szego, P., & Rutherford, M.D. (2008).
Perception, 37, 1609-1611.

Authors' Contributions

Paul Szego: Concept, formation of experimental design, data collection, literature review, data analysis and manuscript writing.
Dr. Mel Rutherford: Assistance with concept development and experimental design, data analysis and manuscript editing.

Abstract: Judgments of speed and animacy from monolingual English readers were compared with those of bilingual readers of both English and a language read from right to left. Participants viewed a pair of dots moving horizontally across a screen at the same speed. Using a two-alternative forced-choice task, participants judged which dot in a pair moved faster (a direct measure of speed perception) or appeared to be alive (an indirect and correlated judgment of speed perception). In two experiments monolingual participants judged dots moving left to right to be faster and alive more often than dots moving right to left. In contrast, bilingual participants exhibited no directional bias for speed or animacy. These results suggest that the highly practiced eye movements involved in reading are associated with the presence or absence of a directional anisotropy for speed and animacy.

Evolution has formed the basis of our visual processing, and experience accumulated throughout the lifespan influences how these processes work. For example, Morikawa and McBeath (1992) reported a directional bias in monolingual English participants when viewing moving shapes, but not in bilingual participants who read a text from right to left as well as an English text. Their participants viewed a row of diamonds that would shift exactly half a cycle, creating the equally likely perception of leftward or rightward motion. American university students overwhelmingly judged the diamonds as moving from left to right. When testing participants from Japan – where people drive on the left – they found the same pattern of results. Only when testing people who read a language from right to left (eg Arabic, Farsi, or Urdu) did they find no significant bias for direction. They attributed the directional bias to a "habitual asymmetry in the direction of eye movements during reading" (page 1139).

We wondered if a similar bias existed for the perception of speed when direction was unambiguous. Furthermore, we hypothesised that an identical bias for judgments of animacy would also exist. The perception of speed and animacy has been shown to be associated such that greatly accelerating objects appeared more animate than objects that accelerate less (Tremoulet and Feldman 2000), and faster objects appear more alive than slower objects, even if the speed differences between the objects are illusory and not actual (Szego and Rutherford 2007). Recording participants' judgments of animacy, known to be associated with the perception of speed, allowed us to test if a related social perception was susceptible to the same effects of visuomotor experience.

To discern whether such a bias existed in Western individuals, we recruited monolingual undergraduates from an English-speaking university in Ontario, Canada. Participants viewed a dot travelling horizontally across a screen in one direction, followed by a dot travelling in the opposite direction. Each pair of dots travelled at the same speed and distance for 750 ms. Three speeds (2.8°, 3.9°, and 5.2°/sec 1) were used in 384 trials. In the first 192 trials, participants judged which dot appeared faster (speed condition); in the last 192 trials, participants were instructed to indicate which dot appeared alive. Twenty-eight participants (mean age 19.0 years; seven males, twenty-one females) viewed the displays presented in a conventional orientation (vertically), and twenty-three participants (mean age 19.4 years; six males, seventeen females) viewed the displays while looking down on a monitor oriented horizontally (facing upwards).

While viewing the vertical presentation, 68% of the participants (nineteen versus eight; one participant responded at chance) reported the left-to-right motions as appearing faster than the right-to-left motions [Blalock's (1972) two-tailed difference of proportion test; $z = 2:92$, $p = 0.01$]. A non-significant majority (sixteen versus eleven; a different participant responded at chance; $p = 0.09$) reported the left-to-right motion as appearing animate more often than that of dots travelling in the opposite direction (figure 5.1, left). Of the participants viewing the displays presented horizontally, a non-significant majority of 61% (fourteen versus nine; no participants responded at chance) reported the left-to-right motions as faster than the right-to-left motions ($p = 0.07$). However, a significant majority of 61% (fourteen versus seven; two participants responded equally to each trial type; $z = 2.11$, $p = 0.02$) judged the dots travelling from left to right as animate most often (figure 5.1, centre).

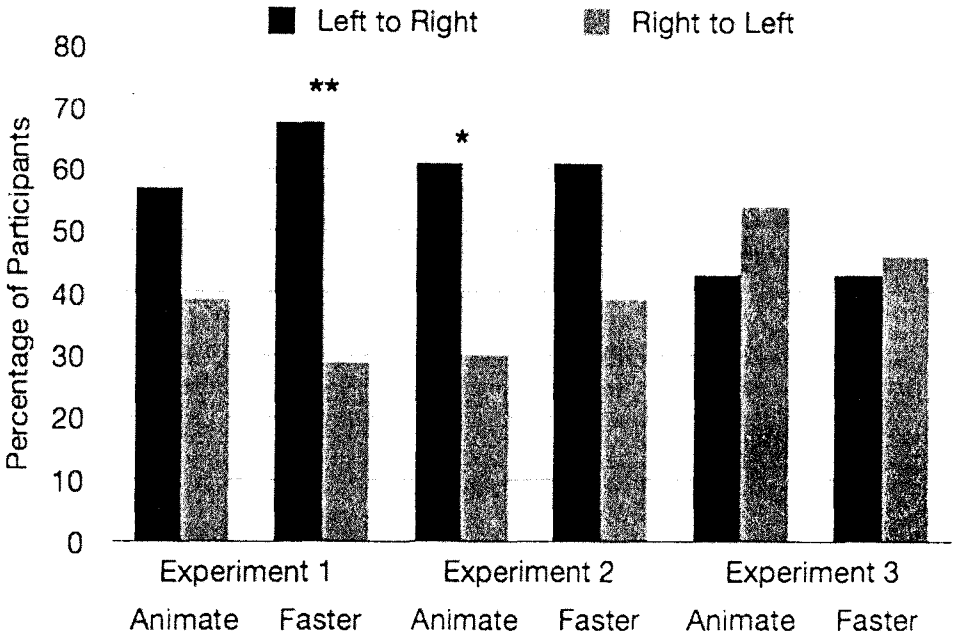


Figure 5.1. Results of speed and animacy conditions for stimuli presented to monolinguals vertically or horizontally, and to bilinguals.

In both orientations, the speed judgments extend the general finding of Morikawa and McBeath (1992) and demonstrate the presence of a speed anisotropy in onolingual English readers. Participants exhibited a similar perceptual trend for animacy, confirming previous findings that (seemingly) faster objects appear to be alive more often than (seemingly) slower objects. The similar perceptual bias for animacy – associated with judgments of speed – illustrated in both orientations addresses the strength of the speed anisotropy.

To investigate whether highly practiced eye movements such as those reinforced by direction of reading mediate this bias, we recruited twenty-eight bilingual participants (mean age 19.4 years; nine males, nineteen females) from the same university. These bilingual participants came from households where the native language was read from right to left, and they were exposed to this language from birth. They read either Arabic (n = 10), Farsi (n = 6), Korean (n = 5), Urdu (n = 5), Hindi (n = 1), or Assyrian (n = 1) on average every other day, along with daily reading of English (being enrolled in an English-speaking university, in an English-speaking town). Stimuli were presented exactly as in the vertical orientation described above. Bilingual participants, unlike the monolingual groups, showed no bias for either speed (twelve versus thirteen; three people responded at chance; p = 0.2) or animacy (twelve versus fifteen; one person responded at chance; p = 0.4) (figure 5.1, right). The absence of a speed or animacy bias in bilingual participants suggests that highly practiced eye movements influence our visual perceptions differentially, depending on the quality of the experience (in this case, the direction of eye movements).

The findings of all three experiments resemble the perceptual bias reported by Morikawa and McBeath (1992). Our monolingual and bilingual participants differed in their perceptual judgments of speed and animacy, suggesting that visuomotor experience reinforced during reading can mediate our perception of speed and animacy. We recruited our monolingual and bilingual participants from the same university to ensure that as many factors of their background are as similar as possible: the language they were exposed to and had to use each day (English), their age, and their experience with the languages. Although we did not expect to find any obvious gender effects, because we had small and unequal groups of males and females in each experiment, we are unable to discount the presence of a gender effect; more research is needed to clarify if such an effect exists. The one apparently defining difference appears to be exposure to a language read from right to left and the related visuomotor experience. It is possible that young children with little directed exposure in reading might not exhibit this anisotropy for speed or animacy until more experience has been acquired. How much experience with bi-directional reading is needed, and at what age this visuomotor influence becomes perceptually apparent, remains to be seen.

This study provides additional evidence for the association between the perception of speed and the perception of animacy, as in Szego and Rutherford's (2007) illusory speed study: the speed difference does not have to actually be there in order to create the perception of animacy. As one group of participants (bilinguals) did not exhibit any bias for speed or animacy, this study is a first step in identifying the sources of this perceptual association.

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Chapter 6
General Discussion

When this research programme began, extant research documented how the human visual system determines whether an object appears alive or not based on the motion of an object with respect to other objects and its environment (e.g., Gelman, Durgin & Kaufman, 1995; Kuhlmeier, Wynn & Bloom 2003). Conversely, much less was known about how the actual motion – apart from interactions with other objects – influenced our perceptions of animacy (see Tremoulet & Feldman, 2000 for exception). After conducting four studies comprised of numerous experiments, we now have a much better understanding of how the visual system is influenced by simple motion cues.

We now know that people are more likely to perceive a simple geometric object as alive if it moves at a faster constant velocity compared to an identical object that moves at a slower constant velocity, and this perception is maintained even if the differences in velocity are only illusory (Chapter 2; Szego & Rutherford, 2007). Incorporating regular and predictable features of our environment of evolutionary adaptedness (EEA) such as the apparent influence of gravity shapes people's perception of animacy. This was demonstrated by people's bias to judge an ambiguous object that appears to fall through the air as appearing faster, but not alive, more often than an identical object that appears to rise into the air at the same velocity (Chapter 3; Szego & Rutherford, 2008a).

In Chapter 5, we demonstrated that our perceptions of animacy are shaped not only by experiences in our evolutionary history, but also in our lifetime. People who only read languages from left-to-right will judge an object travelling in that direction as appearing faster than an identical object travelling at the same velocity in the opposite direction. Conversely, people who have significant experience with a second language that is read from right-to-left will not show this bias (Szego & Rutherford, 2008b).

Lastly, it has been demonstrated that people's perception of animacy, while maintaining some regularity with regards to the above constraints of velocity and direction, do not appear to have consistent boundaries regarding the velocities that appear alive and those that do not. The perception of animacy does not appear to resemble other categorical perceptions such as the perception of colour or emotional expressions (Szego & Rutherford, unpublished; see Chapter 4).

Collectively, these data support the notion that people are more likely to judge an object as appearing alive if the object appears to exert a relatively greater amount of effort. This effort can be represented as an object traveling relatively faster, as in Chapter 2, or appearing to work against an external force such as gravity even when appearing to move relatively slower, as in Chapter 3. The appearance of an internal power source as being a perceptual cue to animacy has been proposed before (e.g., Biro & Leslie, 2007; Gelman, Durgin, & Kaufman, 1995; Leslie, 1994; Premack, 1990). These reserachers have predicted similar theorectical findings to what has been reported here experimentally. What remains to be determined is whether people adhere to this – or any – metric of animacy regarding motions; Chapter 4 suggested this might not be the case, but that more research is clearly needed.

In addition to these novel findings, a number of valuable methodological innovations were also introduced into the study of animacy. The first modification from existing studies was the exclusion of line segments, focusing on only dots. Line segments had been used in many earlier studies, most notably by Tremoulet and Feldman (2000). Tremoulet and Feldman reasoned that, when deciding if an object appeared alive or not, viewers would "base their decision upon inferences about the causes of its motion" (p. 944). They found the highest ratings of animacy were elicited by lines, which not only changed speed and direction greatly, but also changed their orientation to be aligned with the new direction. These ratings were overall significantly higher than ratings for the circle and the misaligned line, suggesting "impressions of volitional control over its motion path, a capacity normally exhibited only by living things" (p. 947). As we intended to examine the features of motion – such as orientation, speed, direction – and not qualities or perceived features of the object itself (such as its ability to change orientation, or to appear to have a "head" or "tail" end), we chose to only present dots moving in straight lines for the duration of the displays.

The next methodological modification was to change from a Likert rating to a two-interval forced-choice task. Tremoulet and Feldman (2000) had used a seven-point Likert rating to gauge participants' perception of animacy. By instead having participants compare pairs of stimuli on each trial, a greater number of stimuli were tested repeatedly, while using a measure that does not compare a stimulus relative to the previous trial.

The final modification to the methodology was to show two objects travelling at identical velocities while creating the illusion of differences in velocity. By holding velocity constant on each trial, it was possible to measure the perception of speed as a cue of animacy rather than measuring people's ability to detect actual differences in speed, which was not the focus of the research.

Limitations of the current research programme

Miniscule stimuli

All of the stimuli used in the present studies were relatively small dots, typically 0.24°/sec. Therefore, they were likely perceived as either small organisms such as bugs or larger but far-away organisms such as animals. Typically, participants were instructed to think about the stimuli as the former, such as in Experiment 2 of Chapter 2, when they were told to judge which dot appeared similar to a "bug moving across a flower" rather than a "piece of dirt being blown across a flower." Because of the size of the stimuli, our findings may or may not generalize to perceptions of animacy involving even small organisms such as mice. There is, however, no reason to expect that our perceptions of animacy as based on motion cues would be contingent on the size of animal unless one was making hypotheses about the nature of the animal itself, such as the locomotion of a snake versus a mouse. Regardless of size, being able to quickly detect small and/or far away creatures would be beneficial to the survival of an organism

Low ecological validity

Perhaps the most striking issue concerning the present research is the level of ecological validity, especially considering the focus of animacy and living objects. Great efforts were made to make the displays as realistic as possible, while maintaining a high level of ambiguity, by removing featural cues such as faces and limbs. The result was to display solid white moving dots. This was necessary, as Gelman and Opfer (2002) have pointed out, because people are all too capable of identifying an object based on these featural cues. Adding something that might be perceived as a face or limbs would likely produce a perception of animacy, but would have little to do with the objects' motion. This is likely what occurred in Tremoulet and Feldman's (2000) aligned and misaligned conditions; even the appearance of a "head" and "tail" end appears to be sufficient to influence our perceptions of animacy as compared to a dot which has no such asymmetry. To avoid these cues ecological validity by means of visual resemblances to actual living organisms was reduced. However, others have attempted to address this issue by displaying featureless objects against a photographed background displaying a stream and foliage. Williams (Williams, 2000) briefly displayed a photo of a natural scene (e.g., mountain, stream) with the sounds of wind blowing and/or water flowing down a stream. The photo quickly faded to black (although the sounds remained) and a white dot travelled across the screen in a curvilinear trajectory. The same trajectory would be shown at different locations corresponding to a particular feature in the photo, such as the substrate, the top of a mountain, or the stream. Williams was interested in determining how people judge the intrinsic (i.e., animate or psychological) and extrinsic (i.e., inanimate or physical) causes of motion, and found no clear consensus across adults or 3- to 4-year-olds for judgments of animacy. Although not a direct test of current question (understanding causal inferences of a moving objects' context, trajectory, and animacy), these findings suggest that simply adding an amount of ecological validity may not shed more light on the subject.

Separating animacy from intentionality

The other major limitation of this research programme concerns intentionality, a concept that is intimately tied to animacy. Intentionality is the perception that some motion (of an entire animal or just an arm, and usually described as "action") is being performed for the purpose of achieving some specific goal or end state. Intentionality explanations are both irresistible, (Michotte, 1963), and helpful, (Dennett, 1987) and (Malle, 2006). An underlying question regarding the current research is whether or not perceptions of animacy can be created without an accompanying perception of intentionality.

The perception of intentionality has been argued to be a fundamental way of interpreting the world, going back to Heider and Simmel's original studies (Heider & Simmel, 1944; see also Dennett, 1987, Malle, 2006). One difficulty in examining the motion cues of animacy is that, as these researchers have theorized, the human brain can not help but interpret motions as being either intentional or not. The present research may have induced or elicited attributions of intentionality in the viewer. These perceptions were neither examined nor recorded, so there is no way of knowing what role – if any – they play in determining whether a moving object appears alive or not.

Minor limitations

As in any research programme, minor limitations exist. Many are specific to a particular experiment and are therefore discussed in the appropriate chapter. The issue of restricted range persists across the various experiments, as only a limited selection of velocities was tested in any given experiment. This was both intentional, as the present experiments were intended as a first foray into the perception of animacy and were based on the stimuli (including the velocities) of Tremoulet and Feldman (2000), and inevitable, as it was only possible to present a finite set of stimuli,.

Future directions: Developmental studies

While the results of the current studies are valuable, there is still much to discover about our perceptions of animacy. Because the perception of animacy is argued here to be a fundamental component and developmental precursor of theory of mind and of a fully developed social cognition, likely the most fruitful and rewarding line of study will likely be in development research. Any studies in this area will likely address two overarching questions: 1) At what age does a perception of animacy emerge? 2) What motions (or qualities of motion) elicit a perception of animacy in infants? A fundamental difficulty of mapping this question on to the existing stimuli is that there is no veridical answer using the present stimuli. In the experiments described herein, participants were asked to judge which objects appeared alive. This can not be done easily with non-verbal infants, however there are methods commonly employed in developmental psychology research that allow researchers to infer that infants have made a discrimination between two classes of stimuli.

A variety of studies looking at related perceptions and cognitions have been conducted. Rochat, Morgan and Carpenter (1997) showed adults and 3- to 6-month-olds two pairs of moving dots on side-by-side monitors. The motion of one pair suggested (to adults tested) one chasing the other; the motion of the second pair was similar in variables (speed, distance, etc.) but did not suggest a chase to adult viewers. Younger infants looked longer at the chasing pair, suggesting that they were more interested in it than the non-chasing pair. Older infants and adults looked longer at the non-chasing pair, suggesting that they understood the relation between the chasing pair and were attempting to discern the relation between the non-chasing pair.

Gergely and Csibra (2003) have shown that infants as young as one year of age will make inferences about an objects' actions in ways that suggest an understanding of intentions. They used a habituation paradigm that displayed two paths to an end state, and then changed the path after infants habituated to the displays. Across a series of studies, one-year-olds consistently looked longer when a small white ball that previously travelled around an obstacle to get to an end state (typically a large red ball), performed some the same motion that did not result in the same outcome. Conversely, infants did not look longer when the object performed a new motion that did result in the same outcome.

Future studies in this area would most likely benefit by following the methodological leads of Gergely and Csibra (2003) using a habituation paradigm. While similar to the preferential looking paradigm used by Rochat, Morgan and Carpenter (1997), habituation is preferred because it can inform researchers about expectations that an infant may have made concerning the qualities of an object, such as the qualities of its motion and its possible end location. Preferential looking can merely tell whether an infant prefers one display to another, which seems secondary to the underlying research questions being asked.

To accommodate these research questions, infants would view one of two objects whose motions corresponds to some predetermined qualities such as trajectory or velocity. The qualities of motion should be such that an infant is expected to have made some expectations about the object, presumably that it is able to move in ways that explicitly suggest animacy or inanimacy. (These qualities would likely need to be tested on adult populations for verification of the ensuing perceptions and expectations.)

After habituating an infant to an object and its particular motions, a researcher could change some aspect of the motion such that it no longer suggests the same properties (viz., the object no longer appears animate or inanimate, as tested on adult populations). Depending on whether an infant reorients their attention to the modified display, a researcher could determine whether the infant had made expectations about the object based on the qualities modified (viz., motion).

The specific motion qualities tested would be the most important (and difficult) component. One presumably fruitful starting point would be the motions described in this dissertation. Relative differences in velocity, changes in trajectory, and orientation may produce expectations about an object that a researcher can exploit. One concern that should be examined is that these motion cues of animacy may be learned over the lifespan, and therefore not yet present in infants.

A second source of fruitful motion cues would be organisms that likely presented a source of danger to infants. To adults, the sporadic bursts of motion that frequently change direction may resemble the motion of a spider, while the long curvilinear paths may resemble a snake. These same motions may elicit predictable responses in infants' attentional states, which a researcher can document. If one were to test these motion cues, a preferential looking paradigm would be helpful in determining whether infants will attend more to an ecologically-valid motion cue than to other motions. It is possible that an aversion to some predators can be observed in young infants. Given that infants were very likely placed on the ground in the EEA, as they are today, there would be a number of insects that would possibly present a health threat if they were to bite or sting an infant. Infants who attend to such creatures and produce an alarm call of sorts – alerting any nearby adult who can pick the child up, thereby removing them from the threat – would have a benefit over infants who did not. To test this, an experimenter could place an infant on the ground in a lab, and project simple geometric shapes moving around him or her. By recording whether the infant attends to the object, along with any signs of distress such as vocalizations or galvanic skin responses, an experimenter could determine if infants of some age (but not younger) are attentive to such organisms. This would allow for the testing of specific motions (e.g., linear, constant velocity, abrupt start/stops), patterns of locomotion (i.e., like a snake) or shapes (e.g., eight-legged versus hundred-legged) to determine exactly which features are most likely to elicit reactions that may relate to animacy. It would also allow for repeated simultaneous measurements, beneficial when dealing with very young (and often disagreeable, colic, or simply gassy) infants who do not offer more than a single trial of useable data.

In addition to expanding our understanding of when a sensitivity to animacy first emerges, and how animacy influences other social cognitions relating to theory of mind in typically developing infants, all of the above studies can be conducted on infants who are at a higher risk of developing atypically. Being able to determine whether there are differences between typical and atypical populations in the emergence of a perception of animacy may prove to be a valuable means of early detection of risk, and a very rewarding outcome of the present research programme.

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