The Perception of Animacy

Weinan Qian
Yuanpei College
Peking University
ypqwn@stu.pku.edu.cn

Abstract

Humans possess an innate ability to perceive animacy within the most rudimentary shapes or non-living entities. This remarkable capacity allows us to attribute life-like qualities to moving inanimate objects, endowing them with personalities and emotions. The process of perceptual animacy occurs rapidly, involuntarily, and is profoundly influenced by external stimuli. The exploration of factors influencing perceptual animacy and its cognitive underpinnings has been a focal point in fields such as psychology, cognitive science, and Theory of Mind (ToM). In this context, we present three primary factors linked to the perception of animacy, contending that it is both a bottom-up process and a top-down process. Moreover, we delve into the complexities of developing a purely data-driven model aimed at simulating the nuanced nature of perceptual animacy.

1 Introduction

Imagine being presented with a series of static clips from a film depicting three geometric figures moving in the vicinity of a rectangle (refer to Fig. 1 for an example). Your task is to provide a detailed description of the scenario based on these limited visual cues. Despite the static nature of the images, they offer minimal explicit information about the circle and triangles involved. However, remarkably, you effortlessly construct a dynamic, imaginary scene where these geometric shapes move purposefully, exhibiting emotions and intentions. For instance, when interpreting Fig. 1, you might narrate a scenario wherein the red triangle is in pursuit of the other two geometric figures, and upon seeking refuge within the rectangle, a sense of relief washes over them, while the red triangle departs with a tinge of disappointment. This process of imaginative construction appears effortless to us humans, often passing unnoticed despite its remarkable complexity.

Nonetheless, the groundbreaking experiment conducted by Heider and Simmel [7] underscored a fundamental human capacity: the ability to perceive animacy. *i.e.*, they perceptually regard the geometric figures or inanimate objects as alive under specific conditions. Scholl and Tremoulet [9] demonstrated that the combination of two remarkably simple and observable motions can induce the perception of animacy, even when presented against a featureless background. This study highlights the spontaneous nature of this cognitive ability. Furthermore, developmental research has shown that children as young as nine months old can discern impressions of animacy and intentionality by observing object motions [1, 4].

Therefore, a meticulous examination of perceptual animacy holds significant importance. This paper delves deeply into the multifaceted nature of perceptual animacy. In Sec. 2, we introduce three pivotal factors that act as triggers for the perception of animacy: brain structures, motion kinematics, and knowledge of causal principles. Sec. 3 builds upon the factors delineated in Sec. 2, arguing that perceptual animacy emerges from a synergy of both bottom-up and top-down processes. Last but not least, in Sec. 4, we conduct a concise analysis, probing the challenges inherent in devising a purely data-driven computational framework for simulating tehe perception of animacy, highlighting its current technological infeasibility.

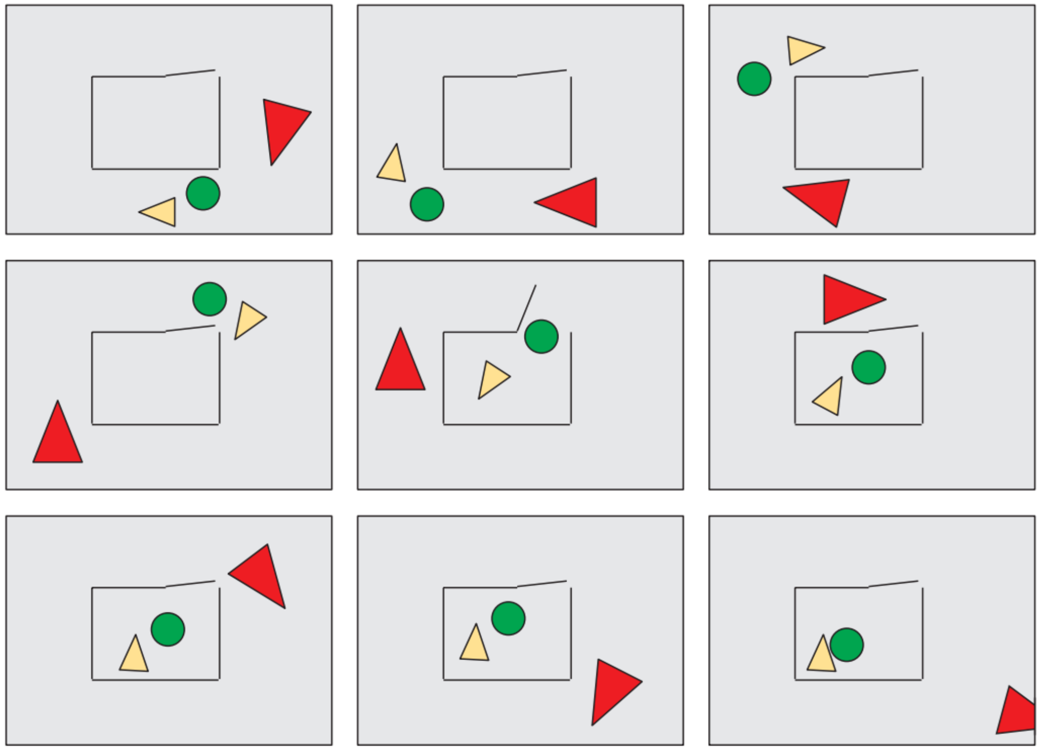

Figure 1: Some sequential snapshots from a dynamic display of the type used by Heider and Simme to demonstrate perceptual animacy [7, 9].

2 Factors Causing Perceptual Animacy

2.1 Brain Structure: The Basis

The foundational investigation into the origins of perceptual animacy involves linking such phenomena to their neural substrates, employing tools from cognitive neuroscience. Heberlein et al. [6] conducted pivotal research demonstrating the role of the amygdala in mediating social perceptions. By exposing individuals with amygdala damage to films akin to those in Heider and Simmel [7], they observed that these patients were unable to describe scenes using social or anthropomorphic terms. Happé and Frith [5] further localized specific brain regions involved in processing perceptual animacy through a Positron Emission Tomography (PET) study. Their findings revealed heightened activity in the temporo-parietal junction, fusiform gyrus, occipital gyrus, and medial frontal cortex when subjects viewed displays featuring goal-directed and intentional movements. These studies furnish invaluable evidence pinpointing certain brain regions implicated in the perception of animacy, underscoring the tangible neural correlates associated with this cognitive process.

2.2 Motion Kinematics: The Cue

It is evident that a singular frame displaying geometric figures or inanimate objects lacks the necessary temporal information to prompt the perception of animacy. Only when presented with multiple static images of objects can we effectively perceive and deduce animacy, highlighting the importance of motion kinematics as a crucial cue for perceptual animacy. Recent research among adults strongly supports the hypothesis that perceptual animacy is primarily driven by motion kinematics rather than the inherent features of objects [9]. Efforts have been made to identify specific motion cues that mediate perceptual animacy. For example, Dittrich and Lea [2] delved into the correlation between the perception of interaction, intention, and animacy. Their experiments concluded that perceptual animacy hinges on both the level of interaction between the target and its goal and the impression of intentionality evoked by the movement of objects. Additionally, Stewart [11] proposed the innovative *energy violation* hypothesis, suggesting that perceptual animacy arises when observed motion implies access to a concealed energy source. Their experiments sought specific motion patterns consistent

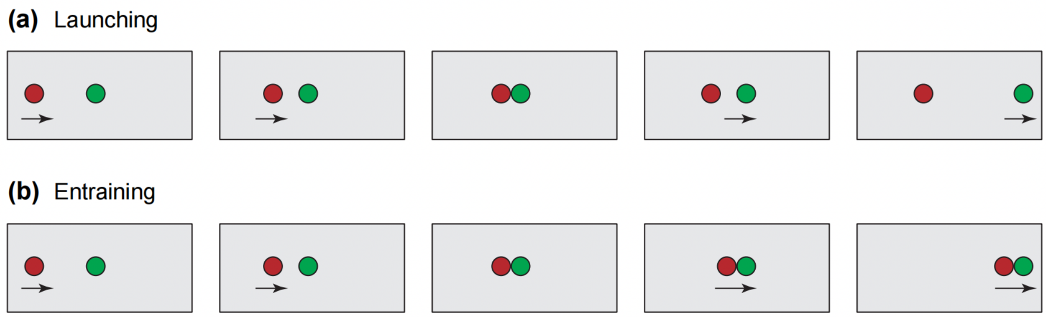

Figure 2: Examples of moving geometric figures that can just trigger perceptual causality rather than perceptual animacy [8, 9].

with this hypothesis, consistently evoking perceptions of animate behavior. The study of motion kinematics in relation to perceptual animacy remains a prominent topic in psychology, with ongoing research gradually revealing its fundamental essence.

2.3 Knowledge of Causal Principles: The Prior

Apparently, sequences of images portraying moving geometric figures in temporal succession alone are inadequate for humans to directly perceive animacy. Consider Fig. 2, where the depiction of two seemingly interacting circles offers a low likelihood of evoking perceptual animacy. Instead, observers are more inclined to attribute causality, viewing the circles merely as inanimate balls adhering to Newtonian laws: potentially interpreting the top process as an elastic collision and the bottom as an inelastic collision. This observation suggests that humans rely on inherent or early-developed knowledge of causal principles to infer animacy. Gelman et al. [3] validated this notion through experiments, noting that observers tended to favor animate interpretations when the movements of the balls aligned with aspects of the environment, such as obstacles or goals. This prior understanding of causal principles serves as a foundational framework for perceptual animacy in humans. It also distinguishes human cognition from that of chimpanzees, who exhibit a higher tendency to attribute goals to events featuring geometric figures purposefully designed to appear more goal-directed [12].

3 Qualities of Perceptual Animacy

In this section, we posit that the perception of animacy stems from a dual process involving both bottom-up and top-down mechanisms, drawing from the factors identified as contributors to perceptual animacy in Sec. 2.

On one hand, The perception of animacy can be considered a bottom-up process, primarily influenced by motion kinematics cues. Initially, our vision system captures presented scenarios through retinal imaging. Subsequently, this visual information undergoes direct processing within the vision regions of our brains, extracting primary visual features and culminating in an intuitive perception of animacy. The interaction between our eyes and brains constitutes a bottom-up process, mirroring the trajectory of perceptual animacy from sensory input to higher cognitive interpretation.

On the other hand, the perception of animacy can be viewed as a top-down process due to the crucial role played by prior knowledge of causal principles. Relying solely on visual information proves insufficient for perceptual animacy; instead, the foundational understanding of causal principles becomes pivotal. This prior knowledge, alongside expectations and beliefs which are integral components of Theory of Mind (ToM), actively guide the decision-making process regarding whether to attribute animacy to observed geometric figures or objects. This interplay between higher-level cognitive factors and the lower-level perception of animacy signifies a top-down process, wherein cognitive elements at a higher level prompt and influence the interpretation of animacy at a lower perceptual level.

4 Difficulties of implementing the Process of Perceptual Animacy

The computational implementation of perceptual animacy demands the capability to process high-level visual information from inputs and effectively utilize prior knowledge of causal principles for inferring animacy. These tasks are challenging and are still evolving. Shu et al. [10] made a notable stride by proposing the Physical-Social Forces (PSF) model, a unified framework that intertwines the perception of physical and social events to simulate perceptual animacy. Despite its contribution, this model encounters limitations such as a confined set of goals and oversimplification of decontextualized scenarios. Effectively representing an infinite range of intentions and causal principles remains a significant challenge for current researchers. Moreover, Computer Vision (CV) techniques are continuously advancing to enable more nuanced extraction of visual information. These challenges underscore the extensive journey ahead for the computational implementations of perceptual animacy.

5 Conclusion

In this paper, we propose three pivotal factors that trigger perceptual animacy: brain structure as the basis, motion kinematics as the cue, and knowledge of causal principles as the prior. These factors collectively enable humans to attribute intentions and emotions to static images of geometric figures or inanimate objects, essential for the perception of animacy. The motion kinematics cue operates as a catalyst, fostering a bottom-up process in perceptual animacy, while the prior knowledge of causal principles highlights the top-down nature of this cognitive phenomenon. Despite the intricate nature of perceptual animacy and its challenging computational implementations, we maintain confidence in our ability to unravel its essence. This pursuit holds promise for advancing robotics by integrating a deeper understanding of perceptual animacy into their development. We remain optimistic that the day we comprehend the core of perceptual animacy and achieve its implementation for enhanced robotics is on the horizon.

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