Is Causal Perception Similar to How We Perceive Color?

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Abstract

Causality is the abstract notion of cause and effect derived from our perceived environment. We can use causality as a prior foundation to construct notions of time and space to explain observed phenomena and predict subsequent developments in the current scene, etc. At the same time, obtaining and understanding causality is also crucial for building general artificial intelligence. For instance, if an agent cannot reason about the causes of human behavior, it would be unable to understand intent and the effects of actions. However, how humans perceive causal relationships remains controversial, with many compelling theories in this area. This article will first explain the specificity of causal perception. It will then discuss two opposing theories of causal perception - Cause Detector and Cause Schema. Finally, it will consider whether causal perception is similar to color perception and look forward to building a more reasonable human causal perception model.

1 Introduction

As Aristotle said, "We do not have knowledge of a thing until we have grasped its why, that is to say, its cause." Causality is the abstract notion of cause and effect derived from our perceived environment. Causality is important in explanation, prediction, manipulation, misconception, etc. We can use causality as a prior foundation to construct notions of time and space to explain observed phenomena and predict subsequent developments in the current scene [1]. For example, Halley inferred that the sightings of comets in 1531, 1607, and 1682 were not three independent events, but three consequences of a single common cause: a comet that had visited the Earth three times, traveling in an elliptical orbit. He went on to predict that it would return along the same orbit in 1758.

Perceiving causality is an indispensable human ability. However, how humans perceive causality remains a controversial issue [2]. Due to the abstract nature of causal relationships and the complexity of causal phenomena, although there have been many theories and models for modeling and learning causal relationships [3], this problem remains challenging. Since the perception of causality has the characteristics of being fast, automatic, and irresistible, some scholars believe humans can directly perceive causality (that is, there is a causal perception model) [4]. In this view, perceptual causality is entirely accomplished at the perceptual level and does not involve other parts of cognition. However, this theory struggles to explain human reasoning about complex causal relationships and the development of the human ability to perceive causality. Therefore, there is an alternative theory of perceptual causality - Causal Schema [5]. In the subsequent discussion, the rationality and shortcomings of the two theories will be briefly analyzed, and the one I think is more reasonable will be identified.

2 Why is causal perception special?

2.1 The necessity of causality

Causality provides rich prior knowledge for humans to understand the surrounding environment [1]. For instance, humanity's establishment of causality between pathogens and diseases has promoted the development of modern medicine. Clearly, causality is the foundation of functionality, intuitive physics, intent, utility, and more. Let us assume that all things and phenomena in this world are non-causal; then the temporal connection of events would disappear, most variables constituting the world would become independent of each other, and the world would eventually become chaotic with violations of natural law. We can even say the process of civilization's development is the process of mastering correct causality one after another.

2.2 The controversial definition of causality

Since Aristotle proposed causation more than 2,000 years ago, defining causality remains controversial and has been an important topic in philosophy. A widely accepted definition around the world is Hume's Regularity Theory of Causality (RTC) [6]. He claimed our idea of causation is an idea of: (1) Temporal priority - the cause must precede the effect in time, (2) Spatial contiguity - proximity in space between the cause and effect, (3) Constant conjunction - a relationship between two events where one event is invariably followed by the other. However, we can prove regularity is neither sufficient nor necessary for causation, which contradicts the theory. In short, the definition of the concept of causality is incomplete and vague [7]. For the field of AI, precisely defining a concept or problem is very important. Different definitions may lead to completely different problem-solving and modeling methods. Therefore, the vague definition of causality poses an obstacle to addressing how to represent causality in AI.

2.3 The specificity of causal perception and two main theories of causal perception

Many experiments have proven people have innate assumptions about causes, and causal reasoning can be activated almost automatically and irresistibly [8][9]. It seems we can easily derive causal relationships from perceived phenomena, even if we only observe them once or twice. For example, in the famous display presented by Michotte, a square moved horizontally at a constant rate, stopping when it touched a second square. Given the automatic and irresistible nature of perceiving causality, we would naturally associate it with human perception of properties like shape, brightness, color, etc. In other words, we only use the perceptual part to obtain causality. However, we know we cannot directly see causality because it is an abstract concept. As the complexity of phenomena increases, it becomes more difficult or even impossible for us to perceive correct causal relationships, which is partially inconsistent with our perceptual abilities. From each of these perspectives, causal perception is special and complex.

Cause Detector Some psychologists and philosophers take the anti-Humean position that we truly perceive causality. This theory was first proposed by Michotte and can be defined as: A perceptual module (cause detector) exists that produces representations specifying a causal interaction has occurred in the observer's visual environment [10]. Clearly, cause detectors use information solely from perception and the module itself. Under this assumption, causal perception does not involve cognition at all.

Causal Schema The Causal Schema theory can be defined as: all representations specifying a causal interaction has occurred are the result of (non-modular) inferences based on information from long-term memory [10]. The core idea is that we have schemas of causal relationships in long-term memory, and perceiving causal relationships is actually a process of binding a particular schema to observed information. Under this assumption, causal perception results from high-level cognitive reasoning.

We can easily deduce that if the Cause Detector theory is true, developing causal perception would be difficult, just as enhancing human sensitivity to shape, depth, etc. through training is difficult. Therefore, if humans are born with a cause detector, their perception of various causal relationships should be basically the same at different ages. However, after long professional training, some causal relationships too complex for infants can be easily grasped by adults and used for correct reasoning (e.g. Newton's laws and electromagnetic field theory). From this perspective, the Causal Schema

theory based on long-term memory can better explain this phenomenon and is more reasonable. In my opinion, this modeling may be closer to how humans actually use causal perception. In the following section, I will use this hypothesis to analyze the difference between causal perception and color perception.

3 The difference between causal perception and color perception

3.1 Differences in properties of the object itself

Physiologically, color perception stems from stimulation of the eye's cone cells by electromagnetic radiation in the visible spectrum. Therefore, a widely accepted view is that color is a static property of an object. However, causality is not an inherent property of a single object, but is usually defined in relation to two or more objects or concepts. In most cases, colors are independent of objects, unlike causal relationships that can enable reasoning.

3.2 Differences in perception process

If we assume the Causal Schema theory, color perception seems to have many similarities with causal perception. First, we are not born with definitions of various colors. For instance, babies can perceive different colors but do not have concepts like red and blue. How do we know which color it is? One explanation is that we acquire a color spectrum table from experience and long-term memory. When the environment contains color information, we reference the table to "bind" a specific color. This process is similar to using a causal schema to bind information in a scene. However, an important difference is that color perception's binding process does not require high-level cognitive modules, while causal perception's does. More specifically, during causal perception's binding process, we activate multiple schemas to make expectations and confirm a particular schema with subsequent observed information.

Secondly, many studies show different colors can produce different psychological effects [11], indicating high-level cognitive functions may be involved in color perception. We can split this into two processes: First is color perception itself. Second is using the perceived color as input to the cognitive module which, after interacting with experience, produces the desired emotion related to the color. From this perspective, this cannot serve as evidence that causal perception is similar to color perception.

Third, there is a special phenomenon in color perception called Retinex [12]. The signal generated by a scene's light on retinal cells does not directly match the person's experience of the scene. The human brain processes these signals, analyzing and comparing surrounding signals. For example, in a photo of the White House taken with a green filter, the image is actually green. However, due to the brain's inherent impression of the White House and the green tone of the surroundings, it removes the green cast and still perceives the White House as white. If we define color perception here as starting from seeing the picture and ending with saying "white", this color perception would involve cognitive reasoning and seem similar to causal perception. However, such a definition inappropriately expands the boundaries of color perception and conflates perception with cognition.

To sum up, I think color perception and causal perception are two dissimilar processes.

4 Conclusion

Defining causation remains a difficult philosophical and psychological problem. The issue of how humans perceive causality is also highly controversial. I think the Causal Schema hypothesis may come closer to the real way humans perceive causality. Based on this hypothesis, I argue an important difference between causal and color perception is that causal perception requires cognitive modules while color perception does not. It is worth noting this assumption still has flaws. Moreover, issues like how humans can efficiently obtain causal relationships from experience and how AI can learn causality like humans are still not well solved. Research on causal relationships still has a long way to go.

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