The Necessity of Time in the Perception of Three Dimensions: A Preliminary Inquiry

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Abstract

In working with 3-D computer models I came to realize that there would not be much advantage to presenting them as a three dimensional representation rather than on a flat screen. In either case, they would have to be manipulated, over time, in some way to offer much information. This paper is a non-rigorous exploration of why that is true. It begins by presenting some of the mechanisms by which we orient ourselves in space and how we perceive it. The most important of these are visual, but they do not yield much information in a static situation, since they are vulnerable to misinterpretation and illusion. The paper then goes on to examine the importance of a changing point of view in the perception of space, how points of view have been depicted in art, and how time affects point of view. The example of motion pictures provides foundation for the idea that certain perceptions are essentially free of time, while others occur over time. It goes on to discuss time and how it becomes essential to the perception of space. Finally, it offers some insight into the perception of time.

1. Introduction

1.1 How This Paper Came to Be. I was working creating 3-D computer models of four dimensional objects, when I came to realize that, even though these models existed in the computer and in my mind's eye, the only way they could be presented was on a monitor, which was only 2-D. As I started thinking, hypothetically, about how they could be presented in true 3-D, holograms for example, I came to the remarkable conclusion that this would make little difference in the perception of the object. Whether the representation was a hologram, or simply an image on a computer screen, it would still have to be manipulated to get any useful information about its appearance. It is only through movement in space that three dimensions can be perceived, and movement is a function of time as well as space. When I suggested to a colleague that I believed that time was essential to 3-D perception, I was met with mild dispute. Although that discussion went no further, I conceived of this paper as a defense of my position.

1.2 A Note on Methodology. Although I have a degree in mathematics, I am not a mathematician, nor am I a scientist. I have no background in the psychology or physiology of perception. I am an artist and a theorist, whose focus has been on relationships of language, image, and reality. This paper is not intended as a scientific inquiry, nor is it a rigorous logical exercise. But perception is a funny thing, easily influenced by both subjective and objective forces. So what I present here is simply an epistemological essay, offered to stimulate the imaginations of artists, mathematicians, and scientists.

2. Perception and Space

2.1 Spatial Orientation. I will first examine static ways humans perceive space. We exist in a world of three spatial dimensions. We sense the world as spatial with the senses of sight, hearing, touch, and to a lesser extent smell. We learn to orient ourselves visually in relationship to objects in that world using a number of mechanisms. Most obvious is stereo vision, but this is not necessarily the most important. The eyes have a slightly different location in space giving each one a slightly different view. The mind combines these to create a 3-D picture of the world. Holding a pencil in each hand and bringing them together is more difficult with one eye closed, but not impossible because there are other factors involved in depth perception. Because our angle of vision is increased using both eyes, we sense space as surrounding us.

Depth of field is the range of distances that a lens holds effectively in focus. The closer the point of focus is to the lens, the more limited is the depth of field. We can see this in a photograph when the background and/or the foreground is blurred. The lens of the eye changes focus so quickly that we are not likely to see objects as blurred, yet the mind interprets changes of focus as differences in distance.

Optical perspective may be the most powerful indicator of depth. Parallel lines seem to converge in the distance. At the beginning of the Renaissance artists discovered mathematical rules for creating perspective drawings that transformed the nature of art and perception of space. In the middle ages representative art was dominated by the human figure. Multiple figures were situated on a common ground and sized in proportion to their relative importance. Mathematical perspective allowed a new degree of realism and the introduction of architectural and landscape settings. Texture becomes less distinct as distance increases, whereas visual density increases. At a close distance we may not "be able to see the forest for the trees," while at a distance smaller trees in greater density make the forest appear.

2.2 Illusions. All the factors that allow us to judge depth can be manipulated to create illusions of depth as well. Paintings, drawings, and photographs become realistic representations of space by playing on the mechanisms of our spatial perception. A *trompe l'oeil*, representation is a deliberate deception. (Figure 1.) Various 3-D illusions can be created by introducing different images to the left and right eyes. Stereo photography produces images with two lenses spaced similarly to the eyes. As soon as time and motion are introduced into perception most illusions fail.

2.3 Representations of Higher Dimensions. I started thinking about the relationship of time to perception when I was creating computer representations of hyperobjects. A two dimensional representation of a cube is a square within a square. By analogy a three dimensional representation of a 4-D cube is a cube within a cube. This is a simple analogy and a very powerful metaphor. The only trouble is that it represents a straight on point of view in single point perspective. In addition it is dependent on the concept of a wire frame cube. In straight on single point perspective, an opaque cube is simply a square, indistinguishable from a 2-D square. From an analogous point of view an opaque 4-D cube in 3-D is simply a cube, indistinguishable from any other. (Figure 2.)

Figure 1: *Trompe l'oeil mural. Narbonne, France.*

3. Points Of View

3.1 Of Cubes and Cubism. From other points of view the cube becomes various combinations of one, two, or three quadrilaterals. But in no case can more than three sides be seen at any one time. The invention of photography freed painting from pictorial realism and brought on the advent of modernism. The impressionists explored the nature of light, but artists, beginning with Paul Cézanne, began to experiment with nonlinear perspectives. (Figure 3.) "For Cézanne the important point was the discovery that the

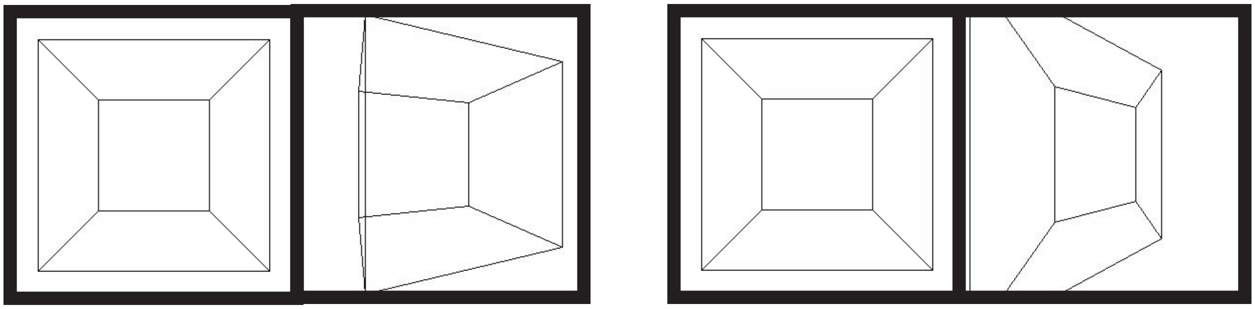

Figure 2: **(***From left to right.) Front view of a computer model of a cube. The same model rotated slightly. A computer drawing of a cube in front view. That drawing rotated slightly. Comment: Until the front views are moved, they cannot be distinguished from each other. It is not until they are rotated that one can be recognized as 3-D and the other as 2-D.*

eye took in a scene both consecutively and simultaneously, with profound implications for the construction of the painting."[1] "Consecutive" and "simultaneous" are both words that describe time. Analytic Cubism continued these experiments by combining various views of an object into one image. (Figures 4 and 5.)

Figure 3: *Paul Cezanne.* ***Gardanne****. 1885-86*

3.2 Time and Points of View. If "point of view" is taken to mean a subject's position relative to an object, then changing the point of view does not necessarily mean movement of the subject, but simply a change in

Figure 4: *Pablo Picasso.* ***Reservoir at Horta****. 1909*

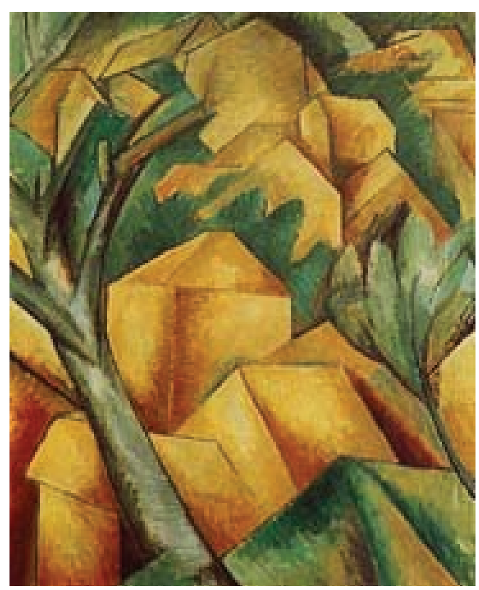

Figure 5: *Georges Braque.* ***Houses at L'Estaque.*** *1908*

relationship that can come about from movement of the object. The obvious implication of differing view points is different locations in space, which of course implies movement, and consequently time. In the 1870s and 1880s, photographer, Eadweard Muybridge did a number of studies of figures and animals in motion. (Figure 6) Although intended to explore the nature of motion itself, these works feature a point of view that changes with time. In his paintings, Marcel Duchamp uses time as a tool of exploration the way the cubists used space. (Duchamp has apparently denied the connection to Muybridge's motion studies.) (Figure 7)

Figure 6: *Eadweard Muybridge.* ***Woman Walking Downstairs*** *from* ***The Human Figure in Motion.*** *(Note that the subject matter could be described as "nude discending a staircase.)*

3.3 Motion Pictures. Muybridge is seen as a seminal figure in film history, and his works are often regarded as proto-movies. Indeed the individual images have been combined into animated versions. A movie consists of a number of discrete movements each represented by a frame. The mind holds each image and merges it into the next 24 time per second giving the illusion of continuous motion. For this reason, it is meaningful to distinguish between instantaneous perception and perception over time. If the time period is so short that there is no subjective awareness of spatial movement, then there is no subjective awareness of the passage of time, and the perception can be regarded as instantaneous.

In the 1950s a few 3-D films were made using optical stereo. But this gimmick never really caught on, because time already gives *movies* a third dimension.

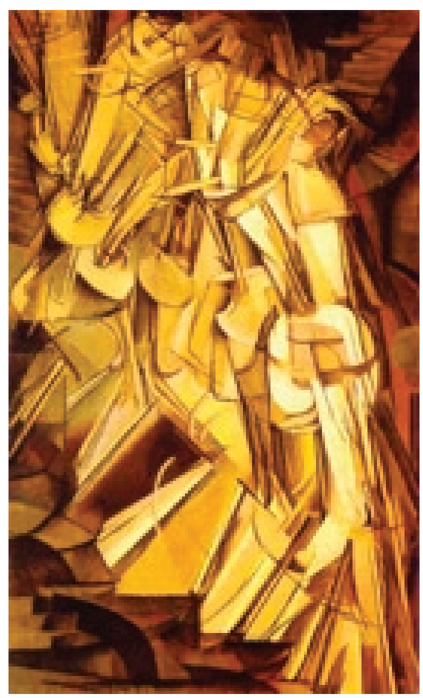

Figure 7: *Marcel Duchamp.*
Nude Descending a Staircase.
1912.

4. Time

4.1 Time and Dimension. Time is often characterized as a fourth dimension, yet it seems different than the other three. We seem to be able to move in any direction in space but only forward in time. Since there are no fixed points in space, the motion of an object can only be seen in relation to another object which is also moving. Our seeming ability to move freely in space only holds in relation to our immediate surroundings. We cannot control our movements on a cosmic level. We can pace back and forth across the room, or we can fly around the world, but the room and the world, with us in it, are all moving around the sun, which in turn is hurling through the expanding universe. We can perceive only movement on the smallest of scales. Our position in time does not change relative to our immediate environment. But according to Einstein's theories, our movement in time is relative to the speed of our movement in space.

Another distinction between time and the other dimensions is that our perception of time seems to lack a spatial component. While we can see or feel an object's position in space we cannot in time. Two objects can seemingly exist at the same point in time but not space. Without motion the idea of time is meaningless. Motion is a change in space over a period of time. Without change time does not exist.

4.2 A Metaphysical Aside. Nonscientific and nonrigorous discussions of time and dimension will invariably, at this point, lead to questions about the metaphysics of space and time. For example, "What if there is only one point in space in which everything exists at different times?" Questions like this may be interesting but their primary focus is objective in nature. One could also call into question the reality of two dimensions. Since concrete reality is dependent on the existence of matter, a very plausible argument could be made that our world consists of no less than three dimensions. A two dimensional object, if it could exist at all, would be invisible, since it could not reflect light. But since, in essence, all that is visible of a 3-D object is its surface, the idea of 2-D perception is conceptually valid. A similar argument could be made against perception outside of time, but again, I would suggest that this argument uses a technicality to trivialize essential concepts.

4.3 Time and Perception. Our perception of two dimensional objects is essentially visual; all the information, including the boundaries of the object, is on the surface of a plane. We can see both the object and its boundaries. Our visual perception of 3-D objects is only of the surface, i.e., the boundary, and we cannot see all of that at once. Stereo vision is the only significant visual mechanism we have to distinguish between two and three dimensional objects, and this does not provide a significant increase in the amount of information about that object. Information is dramatically increased by movement of either the object or the subject in space, and movement is, of course, dependent on time. Immediate tactile examination of an object, while providing a sense of space, does not provide a meaningful amount of information. It is not until perception continues over a period of time that information increases. When this occurs, experience and memory become perceptual mechanisms that condense perceptual time for familiar objects and environments.

The importance of memory in spatial orientation cannot be underestimated. We can easily navigate familiar environments in the dark, which is what the blind must do all the time. It has been shown that mice navigate mostly by memory. If a barrier is placed in a mouse's normal path it will learn to jump over it. When the barrier is removed the mouse will continue to jump at the same location. We often examine unfamiliar objects by turning them with our hands, but we can turn familiar objects with our minds. We become so familiar with the 3-D world that we can easily recognize space in a 2-D representation such as a painting or photograph. Memory is obviously linked to time.

5. The Epistemology of Perception.

5.1 Perception of Space. Although the concept of a two dimensional object is mathematically valid, and easily grasped in the mind, it cannot exist in the physical world. In order to perceive two dimensions, three are necessary. A 2-D entity can move in 2-space, or it can be viewed from the perspective of three dimensions. Similarly, I have shown that time is necessary to the perception of three dimensions. If we consider time to be a fourth dimension, then these propositions become analogous. Extending this analogy could lead to the conclusion that perception of n dimensions requires $n + 1$ dimensions. The +1 being either time or another spatial dimension. This could be seen to suggest an incompleteness conjecture for perception, but I think that, given the methodology used here, this would be stretching my analogy too far. First of all, perception is not an axiomatic system. Secondly, current thinking in theoretical physics does not allow an infinite number of dimensions. Finally, perception is too closely linked to a very subjective view of the physical world. But it would certainly offer a subject for further investigation.

5.2 Perception of Time. While the necessity of time as another dimension in 3-D perception does not lead to any conclusions that can be extrapolated to further spatial dimensions, it does lead to some very interesting answers to questions about perception of time itself. While the other dimensions seem to have no preferred direction, time seems to be asymmetrical. "…what else might lead nature to prefer retarded waves (forward in time) over advanced waves (backward in time), given that both varieties apparently comply with her laws of electromagnetism?"[2] I answer this question with one of my own: If time is necessary for the complete perception of three dimensions, then why shouldn't some further dimension be necessary for complete perception of time?

Notes

[1] H. H. Arnason, *History of Modern Art*, 1986, Harry N Abrams, Inc., New York
[2] Paul Davies, *About Time: Einstein's Unfinished Revolution*, 1995, Simon & Schuster, New York.

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