The Reality of Experience: Gibson's Way

Abstract

This paper considers some first principles that might provide a basis for an objective science of experience (presence or immersion). Dimensions that are considered include classical Newtonian measures of the distal stimulus, changes in neural mechanisms reflecting the proximal stimulus, information theoretic measures of the statistical properties of events, and functional properties related to intentions and abilities. Gibson's ecological framework is suggested as a promising functional approach for defining the reality of experience in relation to the problem of designing virtual environments. This approach emphasizes the tight coordination between perception and action and fixes the measurement coordinate system relative to the capacity for action.

1 Introduction

> In the early stages of this [relativity] theory, its name led to the erroneous impression that this approach in science is based on the philosophic view of 'relativism'—the idea that all knowledge is relative only to the 'knower'—i.e., that there is no objective knowledge to talk about. Of course, Einstein never had this view in mind—his approach was just the opposite, where one focuses on the invariant (objective) law of nature. To avoid confusion, Einstein tried to rename his theory 'invariententtheorie' (theory of invariants), implying a focus of this theory on absoluteness rather than relativeness. However, he eventually rejected the name change because of further confusion he thought it might entail. (Sachs, 1993, p. 4)

Any science begins with some assumptions about the fundamental nature of "reality"—whether there is an absolute, objective, reality independent of the observer or whether the facts of reality are only relative to an observer. These assumptions guide our choices or guesses about the appropriate "rulers" for describing that reality. This is true for behavioral sciences as well as for physical sciences. The question of the measure for "reality" is also a fundamental starting point for theories and measures of virtual environments. What are the appropriate rulers for measuring the experiences in virtual environments and for comparing those experiences against the experiences of reality? As the title of this article indicates, I have a bias. I believe that the assumptions underlying Gibson's (1979) ecological approach provide a promising basis for framing questions of "presence" and "immersion" with regard to virtual environments. However, the goal of this article is not to convince readers of this position, but simply to heighten awareness to the assumptions and existential commitments that shape our theoretical and experimental perspectives on experience.

2 Newton's Way

Newton chose space and time as the absolutes for his program. Thus, space and time were considered as dimensions of a container whose existence was independent of the objects contained within. This container then became the basis for an "objective" description of an object or event. It became the measure of reality. Fechner (1860/1966) extended Newton's program into the field of psychology, arguing that "it is only the physical that is immediately open to measurement, whereas the measurement of the physical can be obtained only as dependent on the psychical" (p. 8). Thus, Fechner bootstrapped his program on the same existential commit-

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ment as Newton. For the most part, experimental psychology remains committed to Newton's basis in which three-dimensional space and time (e.g., chronometric analysis) are the absolutes against which to measure behavior and experience.

3 Einstein's Way

Einstein, along with many others (e.g., Galileo, Huygens, Leibniz) questioned the decision to use space and time as absolutes. Einstein argued that there was no "objective" test (i.e., experiment) that could distinguish the difference between uniform motion and absolute rest. The implication was that space and time were relative to a reference frame and thus could not be the basis for bootstrapping a science committed to realism. Space and time could not be the measure of reality. These measures were not observer independent. The relative nature of space and time creates a dilemma—either relinquish the commitment to realism, to objectivity, and maintain space and time as the basis for measurement, or, find a new basis. Einstein refused to give up the commitment to realism and chose instead to realign his basis for reality. This commitment led to the choice of the speed of light as the absolute upon which to bootstrap measures of reality.

Einstein's choice, obviously, has had revolutionary implications for our view of the physical world. Because the speed of light has dimensions of space and time, these dimensions which in Newton's program were orthogonal are now viewed as dependent. The speed of light provided a mapping from space to time and vice versa. Such a mapping was inconceivable within the Newtonian program. But what are the implications for a science of cognition and behavior? What are the implications for a science of experience? What are the implications for technologies such as VR whose objective is to shape experiences?

4 Fechner's Way

One response is to persevere with the commitments of Newton and Fechner—to argue that Einstein's insights are not pertinent at the scale of human behavior; to argue that Einstein's insights have implications for atomic and cosmic scales of reality, but not for reality at the ecological scale. For psychology this argument leads naturally to a view of the environment as objects distributed within a container with dimensions of space and time. The container and the objects within are considered to have an absolute existence independent from the animal being studied. For those working in the Fechnerian tradition, Newtonian measures become the touchstone for reality. Classical measures of space and time become the defining properties of a stimulus. They define the "real" object. Human experience is measured against this reality. The implication for virtual reality systems is that fidelity is defined in relation to the correspondence between the simulated world and the "real" world as measured using the ruler and clock of classical physics. Thus, we have constructs of "real time" and "real distance" against which we can compare the "virtual times" and "virtual distances."

5 Helmholtz's Way

Helmholtz (e.g., 1962) chose to bootstrap the psychological program on biology. He noted the difference between the "distal" stimulus, that could be defined in classic Newtonian terms and the "proximal" stimulus, which could be defined in terms of changes in sensory mechanisms. With the emphasis on Müller's "law of specific nerve energies," Helmholtz chose biological mechanisms as the basis for objectively defining the stimuli of experience. Thus, for those who follow the Helmhotzian tradition, the structure of nerves, eyes, ears, muscles, brains, and so on become fundamental touchstones for understanding the experience of reality. With this approach, the "acid" test of a theory is the ability to be "objectified" or instantiated by an underlying biological mechanism. This approach leads naturally to constructs such as "visual space" or "auditory space" where the experience of space and time are specific to the biological mechanisms that mediate the experience. The implication of this approach for virtual reality is that fidelity is defined relative to the ability to simulate the biological mechanisms—the proximal stimulus. Thus, binocular and binaural inputs might be considered essential to a high-fidelity experience of space.

6 Broadbent's Way

Broadbent (1971), Miller (1956), and others chose to emphasize principles of control and communication as the grounds for bootstrapping studies of experience. In this program the properties of communication channels and control systems provided the basis against which to measure reality. This foundation allowed the abstraction of invariant principles using information theory, control theory, and signal detection theory. For those who have followed Broadbent's lead, stimuli are defined in terms of their statistical properties (e.g., bits per second or probability density functions). With this approach, emphasis was shifted from the classical Newtonian dimensions of space and time and the biological dimensions of neural activity to dimensions that reflected the observer's expectations. The probability or likelihood of an event became a defining feature against which to measure the experience of that event. This approach suggests that information processing rate, sensitivity, bias, and stability might provide the best measures of fidelity when evaluating virtual reality systems.

7 Dewey's Way

> The reflex arc idea, as commonly employed, is defective in that it assumes sensory stimulus and motor response as distinct psychical existences, while in reality they are always inside a co-ordination and have their significance purely in the part they play in maintaining and reconstituting the co-ordination. (Dewey, 1896/1972, p. 99)

This quote from Dewey reflects an important concern about the way the concept of feedback has been operationalized within psychology. Figure 1 attempts to illustrate this concern. Part A of the figure illustrates the conventional representation of feedback for an information processing system. This representation retains Newton/Fechner's view of the information processing system as contained within an environment. Stimuli and responses are seen as distinct and are represented as external to the coordination. They are of the environment, not intrinsic to the coordination. The representation in Part B is identical, in terms of control theory. However, the impression created by this representation better captures Dewey's intuitions. In this representation, stimuli and responses are intimately coupled and are at the heart of the coordination. This perspective requires a shift from properties of objects in the environment (in terms of space time or statistical properties) or from static properties of biological processing mechanisms to dynamic properties of the relationship that arises from interaction with an environment. Dewey's perspective represents a functionalist approach where action and the purposes of the action play a significant role in defining the stimuli of experience. The reality of experience is defined relative to the intentions and action capabilities of the "actor." Note that in this functionalist perspective the human is no longer considered a "passive" observer responding to stimuli, but an active and creative force shaping the stimuli of experience. The implication of Dewey's intuitions for virtual reality are that the focus shifts to the coordination between perception and ac-

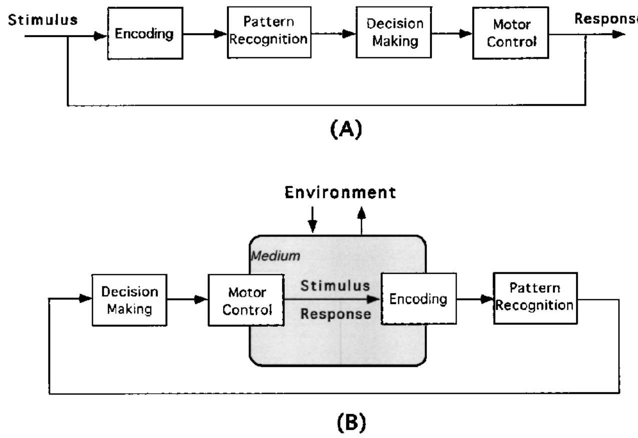

Figure 1. *Alternative views of a closed-loop information processing system. The traditional representation (A) treats stimulus and response as distinct and external to the coordination. The alternative representation (B) illustrates Dewey's intuition that the stimulus and response are coupled within the coordination.*

tion. The measure of fidelity is the degree to which the simulation captures the richness of natural couplings between perception and action.

8 Gibson's Way

Gibson shares Fechner's goal to develop a psychophysics to account for the relation between cognition and a real physical environment. However, unlike Fechner, Gibson does not accept the Newtonian program as an appropriate basis for describing the objects of perception. He argued that "the concept of space has nothing to do with experience. . . . Space is a myth, a ghost, a fiction for geometers" (1979, p. 3). He continues, "The notion of three dimensions with three axes for Cartesian coordinates was a great convenience for mathematics . . . but an abstraction that had very little to do with actual perception" (1979, p. 148). With regard to time, Gibson wrote, "The flow of abstract empty time, however useful this concept may be to the physicist, has no reality for an animal. We perceive not time but processes, changes, sequences" (1979, p. 12).

Gibson shared Helmholtz's appreciation for the constraints that biological mechanisms place on perception. However, whereas Helmholtz focused on the microstructure of sensory and neural processes, Gibson focuses on the macrostructure of action. Gibson was more concerned about the biological constraints on action and how they shape and limit the functional couplings between animals and environments than upon the biological constraints on communication within a nervous system. He argued that "information is not specific to the banks of photoreceptors, mechanoreceptors, and chemoreceptors that lie within the sense organs" (1979, p. 243).

Gibson shares Broadbent's intuition that the invariant properties of human performance might rest with higher-order abstract properties of perception-action systems as might be described by the theory of dynamic systems. However, he had serious misgivings about whether this systems approach could be based on statistical notions of information. On the one hand, he wrote, "What psychology needs is the kind of thinking that is beginning to be attempted in what is loosely called systems theory" (1979, p. 2). On the other hand, Gibson was clearly dissatisfied with traditional operationalizations of systems theory in the study of human performance. For example, he argued that "Shannon's concept of information applies to telephone hookups and radio broadcasting in elegant ways but not, I think, to the firsthand perception of being in-the-world, to what a baby gets when first it opens its eyes. The information for perception, unhappily, cannot be defined and measured as Claude Shannon's information can be" (1979, p. 243). Also, when people responded to Gibson's concept of a perceptual system as "nothing but a case of feedback" he was discouraged and wrote "people did not understand" (1979, p. 244). Gibson chose to focus on the problem of coordination as the fundamental problem rather than on the problem of communication emphasized in the information processing program. This focus is consistent with the functional approach to cognitive systems represented by Dewey's position.

There is a notable similarity between Gibson's way and Einstein's way. The speed of light is a fundamental constraint on action. This is the touchstone upon which Einstein bootstrapped his approach to reality. In a similar way, Gibson has chosen the constraints on action as the fundamental basis for the reality of experience. The speed of light bridges space and time in Einstein's program, constraints on action bridges animal and environment in Gibson's program. The construct of affordance reflects this new fundamental basis for reality in the relationship between actor and environment. It promises an "objective" scientific program for approaching meaning. In this program meaning is not a subjective interpretation, which is the product of information processing. Rather, meaning can be objectively specified and measured in terms of the constraints on action. Constructs such as Pi numbers, in which dimensionless ratios between environmental objects and effectors serve as an objective basis for measurement, reflect this approach to meaning (e.g., Warren, 1995; Shaw, Flascher, and Kadar, 1995). It is not the absolute size of an object or an absolute distance that defines the reality of an event. Rather it is the size relative to hand size or distance relative to a mode of locomotion. Note while this approach measures objects and events ''relative'' to an actor, it is no less objective than other physical approaches to measurements. The ''invariants'' of reality are considered to be objective actor-dependent properties of events, not observer-independent properties.

Einstein and Gibson's program are similar in another respect. Whereas the Newtonian program described the world in terms of interactions between particles, Einstein chose to describe the world in terms of fields. Field descriptions give preeminence to abstract relations as the fundamental basis of causality. In other words, constraints become fundamental. This shift from particle descriptions to field descriptions is clearly reflected in Gibson's constructs such as ''safe field of travel'' and ''optical flow field.'' Kugler and Turvey's (1987) model of termite nest building and Kirlik's (1995) model of skill in a helicopter simulation are important examples that illustrate the power of field descriptions. As Feynman (1965) has noted, equations based on Newton's laws (particles), fields, or minimum principles are mathematically equivalent. However, they are ''completely unequivalent when you are trying to guess new laws'' (p. 53). Physics has discovered that field theories have led to better guesses about laws of ''matter.'' In a similar vein, the ecological approach to psychology is betting that field theories will lead to better guesses about the laws of ''what matters.''

The emphasis on constraints as fundamental is also reflected in the movement of ecological psychology toward nonlinear dynamics as a language for describing the coordination (e.g., Beek, 1989; Haken, 1988; Kelso, 1995; Thelen, 1995). The phase space representations are images of the dynamic constraints on coordination. In this respect, the following quote from Haken (1988) reflects a shift from Shannon's notion of information as constraints on transmission rate, to a theory of information that more directly relates to the constraints on coordination.

> The concept of information is a rather subtle one . . . information is linked not only with channel capacity or with orders given from a central controller to individual parts of a system—it can acquire also the role of ''medium'' to whose existence the individual parts of a system contribute and from which they obtain specific information on how to behave in a coherent, cooperative fashion. At this level, semantics may come in. (p. 23)

The implication of Gibson's approach for virtual reality is a focus on the coupling between perception and action as the focal point of design. From this perspective it is the dynamic interplay between visual, acoustic, and tactile feedback and the actions of looking around and manipulating objects that determines the fidelity of a simulation. Smets (1995) characterizes this perspective and the implications for design for telepresence in terms of a shift from a focus on properties of an image to concern for properties of flow, from focus on motion parallax to focus on *movement parallax*. From this perspective, action takes precedence. The experience depends more on what can be ''done'' than on the quality of visual or acoustic images. In this perspective the experience of space is determined by the degrees of freedom on action, rather than by the resolution or dimensionality of the displays. This does not mean that the display of information is irrelevant, any more than Einstein's choices made Newton's calculus irrelevant. Rather, it is a question of precedence. For Gibson's way, action takes precedence. It fixes the coordinate system against which invariant properties of perception and action can be discovered.

For Gibson's way the reality of experience is grounded in action. Thus, in the design of experiences in virtual environments the constraints on action take precedence over the constraints on perception. This approach predicts that the experience of space will depend more on the mode of locomotion than on the visual and acoustic images. The reality of a surface will be in its implications for action (e.g., does it impede locomotion) rather than in its appearance (e.g., does it look like a wall). In this approach, the reality of experience is defined relative to functionality, rather than to appearances.

9 Summary

As noted in the introduction, a primary goal of this article is to challenge those interested in designing virtual environments to consider possible foundations for understanding and measuring the reality of experience (i.e., presence or immersion). These assumptions represent "first principles" for a science of experience. As such, they are not true or false. They provide a basis for our rules of measurement, a touchstone for objectivity. But these first principles cannot themselves be proven or falsified. These assumptions either provide productive platforms for exploration or not.

A secondary goal of this correspondence is to present Gibson's ecological perspective for consideration. There is no question that the Fechnerian, Helmhotzian, and information processing traditions have stimulated important experimental programs and have produced significant insights with regard to understanding human performance. These are well-accepted perspectives, but creativity often depends on an ability to shift perspectives and to create alternative representations. Alternative representations are not right or wrong, despite the rancor and territoriality of academic debates that imply otherwise. They are simply more or less productive with respect to particular goals of understanding and application. It is unlikely that any single perspective or representation will provide a complete understanding or will be appropriate for every application. We believe that the first principles outlined by Gibson for an ecological approach to human performance provide an important alternative representation that might enrich our understanding of human performance. We further believe that this perspective might make a particularly productive platform from which to launch explorations into applications of virtual reality.

References

Beek, P. (1989). *Juggling dynamics.* Amsterdam: Free University Press.

Broadbent, D. E. (1971). *Decision and stress.* London: Academic Press.

Dewey, J. (1972). The reflex arc concept in psychology. In *John Dewey: The early works, 1882–1898.* Carbondale, IL: Southern Illinois University Press. (Original work published 1896.)

Fechner, G. (1966). *Elements of psychophysics.* (H. E. Adler [Trans.]; D. H. Howes & E. G. Boring [Eds.]. New York: Holt, Rinehart & Winston. (Originally published in 1860 as *Elemente der psychophysik.*)

Feynman, R. (1965). *The character of physical law.* Cambridge, MA: MIT Press.

Gibson, J. J. (1979). The ecological approach to visual perception. Boston: Houghton Mifflin.

Haken, H. (1988). *Information and self-organization.* Berlin: Springer-Verlag.

Helmholtz, H. von (1962). *Treatise on physiological optics.* New York: Dover Press.

Kelso, S. (1995). *Dynamic patterns.* Cambridge, MA: MIT Press.

Kirlik, A. (1995). Requirements for psychological models to support design: Toward ecological task analysis. In J. Flach, P. Hancock, J. Caird, & K. Vicente (Eds.). *Global perspectives on the ecology of human-machine systems* (p. 68–120). Mahwah, NJ: Erlbaum.

Kugler, P. N., & Turvey, M. T. (1987). Information, natural law, and the self-assembly of rhythmic movement. Mahwah, NJ: Erlbaum.

Miller, G. A. (1956). The magic number seven plus or minus two: Some limits on our capacity to process information. *Psychological Review,* 63, 81–97.

Sachs, M. (1993). *Relativity in our time: From physics to human relations.* London: Taylor & Francis.

Shaw, R., Flascher, O., & Kadar, E. (1995). Dimensionless invariants for intentional systems: Measuring the fit of vehicular activities to environmental layout. In J. Flach, P. Hancock, J. Caird, & K. Vicente (Eds.). *Global perspectives on the ecology of human-machine systems* (p. 293–358). Mahwah, NJ: Erlbaum.

Smets, G. (1995). Designing for telepresence: The Delft virtual window system. In P. Hancock, J. Flach, J. Caird, & K. Vicente (Eds.). *Local applications of the ecological approach to human-machine systems* (p. 182–207). Mahwah, NJ: Erlbaum.

Thelen, E. (1995). Motor development. *American Psychologist, 50*(2), 79–95.

Warren, W. (1995). Constructing an echoniche. In J. Flach, P. Hancock, J. Caird, & K. Vicente (Eds.) *Global perspectives on the ecology of human-machine systems* (p. 210–237). Mahwah, NJ: Erlbaum.