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ARTICLES

Affordances as Properties of the Animal–Environment System

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In this article, I argue that *affordances* are properties of the animal–environment system, that is, that they are emergent properties that do not inhere in either the environment or the animal. I critique and review the formal definition of *affordance* offered by Turvey (1992). Turvey defined *affordances* as properties of the environment; I discuss some consequences of this and argue that Turvey's strategy of grounding the definition of *affordance* in terms of dispositional properties is problematic. I also suggest that Turvey's definition of affordance may lead to problems for the specification and direct perception of affordances. Motivated by these problems, I propose a new definition of *affordance,* in which affordances are properties of the animal–environment system. This definition does not rely on the concept of dispositional properties and is consistent with direct perception.

Affordances are central to the ecological approach to perception and action. This point has been made by E. J. Gibson (1982), J. J. Gibson (1979/1986), Greeno (1994), Heft (1989, 2001), Reed (1996), Sanders (1997), Stoffregen (2000a), Turvey (1992), Warren (1984), and others. Despite its avowed centrality, there remains considerable uncertainty about exactly what is meant by *affordance.* This uncertainty can complicate attempts to use affordances to understand or study behavior or to design animal–environment systems that optimize behavior (e.g., Okamoto & Hatakeyama, 1998).

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To date, the only formal definition of *affordance* has been offered by Turvey (1992). His aim was, in part, "to encourage the systematic development of the notion of affordance" (p. 173). Turvey was explicit about the underlying assumptions and premises on which his definition rests, and this adds significantly to the value of his analysis. In recent articles (Stoffregen, 2000a, 2000b), I have also sought to develop and clarify the concept of *affordance.* My attempt was built around contrasting *affordance* with another important ecological concept: *event.* Because of my focus on relating these concepts, I did not propose a formal definition of *affordance* or offer a detailed analysis of Turvey's definition.

In this article I propose a formal definition of *affordance.* Because another formal definition has already been offered (Turvey, 1992), some motivation is needed for presenting a new one. To motivate the need for a new definition of *affordance,* I critique the definition offered by Turvey. I note that Turvey did not define affordances as properties of the animal–environment system, and I argue that this is problematic within the larger context of the ecological approach to perception and action. In addition, I argue that Turvey's definition cannot be complete for any real case, that it is incompatible with widely accepted characteristics of affordances, and that it has an uncertain relation to the concept of direct perception. If the existing definition does not work, then a new definition is required. I offer a new definition of *affordance,* in which affordances are emergent properties of the animal–environment system. My definition has implications for the definition of *behavior,* and so I offer a definition of this concept as well. I conclude with a brief discussion of some of the implications of my definition of *affordance.* As will be seen, my definition differs qualitatively from Turvey's. For clarity, when there is ambiguity I will use *opportunity for action* rather than *affordance.*

DEFINITIONS IN PROSE

James Gibson (1979/1986, p. 127) coined the term *affordance* as the noun form of the verb *to afford.* The environment of a given animal affords things for that animal. What kinds of things are afforded? The answer is that behaviors are afforded. If a gap in a wall has a certain size relative to the size of a person, the gap affords passage (E. J. Gibson, Carroll, & Ferwerda, as cited in E. J. Gibson, 1991; Warren & Whang, 1987); if an object has a certain rigidity relative to an infant's jaws and gums, it affords mouthing (E. J. Gibson & Walker, 1984); if a stair is a certain proportion of a person's leg length, it affords climbing (Warren, 1984); if a surface is rigid relative to the weight of an animal, it affords stance and perhaps traversal (E. J. Gibson et al., 1987); if a ball falls with a certain velocity relative to a person's running speed, then it affords catching (Oudejans, Michaels, Bakker, & Dolne, 1996); if the time gap between the passage of successive cars on a road is greater than the time needed for a pedestrian to cross the road, then safe crossing is afforded (Lee, Young, & McLaughlin, 1984), and so on.

These and similar examples have led to numerous attempts at prose definitions of *affordance*. Although there is variety in vocabulary and phrasing, I believe that the diverse prose definitions correspond to one or the other of the following: First, affordances are *relations between an animal and its environment that have consequences for behavior* (Chemero, 2003; Stoffregen, 2000a; Warren, 1984; cf. Sanders, 1997); second, affordances are *properties of the environment of an animal that have consequences for the animal's behavior* (Greeno, 1994; Heft, 2001; Lombardo, 1987; Reed, 1996; Turvey, 1992). I once asserted that these definitions are equivalent (Stoffregen, 2000a); however, that assertion was made in the context of a comparison of the concepts of *affordance* and *event*. I did not assert that the definitions are completely or formally equivalent. When compared with one another (rather than to another concept, such as *event*), I believe that the two prose definitions of *affordance* differ significantly.

THE ANIMAL–ENVIRONMENT SYSTEM

There is agreement that the ecological approach to perception and action is a systems approach to behavior and that affordances are a central part of this systems-based approach. There is also agreement within the ecological approach in general, and in the context of affordances in particular, that the unit of analysis is the animal–environment system (e.g., J. J. Gibson, 1979/1986, p. 2; Lombardo, 1987; Stoffregen, 2000a, 2000b; Turvey, 1992). Thus, candidate definitions of *affordance* should explicitly position the concept in the context of the animal–environment system.

THE FIRST FORMAL DEFINITION OF *AFFORDANCE*

Turvey (1992, p. 180) grounded his definition of *affordance* in an explicit discussion of several basic aspects of the ecological approach to perception and action. Among these were the ubiquity of the prospective control of action; a materialist, dynamicist, and realist metaphysics; and dispositions as causal propensities within this metaphysics. Working from these premises, Turvey developed a formal definition of *affordance:*

> Let W_{pq} (e.g., a person-climbing-stairs system) $= j(X_p, Z_q)$ be composed of different things Z (e.g., person) and X (e.g., stairs).
>
> Let p be a property of X and q be a property of Z.
>
> Then p is said to be an affordance of X and q the effectivity of Z (i.e., the complement of p), if and only if there is a third property r such that
>
> (i) $W_{pq} = j(X_p, Z_q)$ possesses r
>
> (ii) $W_{pq} = j(X_p, Z_q)$ possesses neither p nor q

(iii) Neither Z nor X possesses *r* (Turvey, 1992, p. 180), where *j* is a joining or juxtaposition function.

The heart of Turvey's (1992) treatment is his definition of *affordance* as a property of the environment. There is considerable support for this in the affordance literature, in the writings of J. J. Gibson (1979/1986), E. J. Gibson (1982), Lombardo (1987), Reed (1996), and others. Nevertheless, in a later section I argue that this approach is problematic. Before addressing this issue, I discuss other problems with Turvey's definition.

Turvey (1992) rooted his definition in the concept of dispositions, particularly in the fact that dispositions occur in pairs: "Complementarity occurs in the very definition of dispositional property" (p. 178). If an affordance is a disposition, then there must be a corresponding disposition that is something else (i.e., not an affordance). By choosing to frame his analysis in terms of dispositions, and by choosing to define an affordance as a property of the environment, Turvey was obligated to identify another entity, not a property of the environment, which can serve as the "other" disposition, complementary to the affordance. Turvey asserted that the complement of *affordance* is *effectivity,* a property of the animal.

In the following sections, I identify what I take to be serious problems with Turvey's (1992) definition of *affordance.* I argue that some of these problems are so serious as to be fatal; that is, I argue that Turvey's definition cannot be correct. In later sections, I propose a new definition of *affordance* and argue that it is not subject to these problems.

PROBLEMS WITH DISPOSITIONS

A major part of Turvey's (1992) attempt to define *affordance* was his proposal to treat opportunities for action as dispositional properties. Turvey argued that this approach could account for the prospective nature of affordance perception: To perceive an affordance is to perceive a possibility, something that *could be,* rather than something that currently *is.* Dispositions naturally imply prospectivity, because they are tendencies or potentialities rather than actualities: When a disposition becomes real, it is said to be *actualized.* The prospective nature of dispositions is compatible with Turvey's attempt to develop a definition of *affordance* that explicitly includes the prospectivity of opportunities for action. Another advantage of defining opportunities for action in terms of dispositions is that this approach captures the complementary nature of opportunities for action; *opportunities for action* refers to a complementary fit between the animal and the environment, just as a single disposition implies a complementary disposition. However, dispositions have additional properties that, I believe, render them inappropriate for use in defining *affordance.* In addition, I argue that opportunities for action have properties that cannot be captured within the framework of dispositions.

Disposition, Actualization, and the Multiplicity of Opportunities for Action

A problem arises with the third characteristic of dispositional properties:

> 6.3. Dispositionals never fail to be actualized when conjoined with suitable circumstances. Disposition and suitable circumstance equals actuality. (Turvey, 1992, p. 178)

Turvey (1992) asserted that affordances are dispositional properties of the environment, that effectivities are dispositional properties of the animal, that these two types of properties are the complements of one another, and that action is the actualization of these paired dispositions. In light of the characteristic (item 6.3) just presented, this clearly implies that the conjunction of complementary animal and environment properties must produce the action afforded. However, in any given situation many actions are possible, but the great majority of them do not come to pass; that is, they are not actualized. This is a problem, because it appears to contradict the premise of item 6.3.

The number of actions that are available to a given animal in a given situation is unlimited (this does not mean that all actions are possible, only that the number of possible actions is uncountably large). It is not possible for an animal to engage in all of them at once, in part because many of them are mutually exclusive (e.g., talking and drinking, eating and sleeping, or sitting and running). More to the point, animals will ignore many if not most of the available actions because these actions would not aid in the realization of the animal's current goals. Humans and other animals actually do only a tiny percentage of the things that they can do. My arm can be used to pound on tables, and tables can be pounded upon by arms, but the conjunction of my arm and tables does not oblige me to pound on tables and, in fact, I rarely do. Similarly, the packed bookcases in my office combine with my status as a literate person to make it possible for me to spend the day reading, but I rarely indulge in this pleasant occupation. Finally, the fact that I am larger and stronger than infants makes it possible for me to steal candy from a baby, but I have never done so. Animate events (e.g., pounding on tables, reading, stealing candy) differ from inanimate events (e.g., the refraction of light by crystals) in that they are not obligatory. For living things, the conjunction of particular properties of the animal with particular properties of the environment does not lead to the involuntary actualization of the action afforded. Affordances are what one *can* do, not what one *must* do.

Turvey (1992, p. 179, section 7.3) recognized this problem and attempted to deal with it. He acknowledged that the animal and the environment each have many dispositions. He then asserted that the actualization of any particular affordance depends on the animal and environment being joined in such a way as to "filter" one particular disposition of the animal and one particular disposition of

the environment from the total set of their dispositions. Turvey suggested that the filtering is carried out by *j,* the juxtaposition function. He did not elaborate on the nature of this filtering, or on how it is carried out; that is, his definition of *affordance* in terms of pairs of dispositions contains no means for the actualization of particular affordances rather than the (impossible) actualization of all affordances.

The need for a filter renders Turvey's (1992) formal definition fatally incomplete. The filter is not defined in the definition of *affordance,* and for this reason the definition cannot account for the actualization of any given affordance when multiple affordances exist. Because multiple affordances always exist, Turvey's definition is incomplete for any real case.

Dispositions and Unrealized Opportunities

In the previous section I argued that the existence of unexploited opportunities for action constitutes a problem for Turvey's (1992) definition of *affordance.* In this section I argue that the existence of unexploited opportunities for action also creates a problem for Turvey's attempt to define affordances in terms of dispositions. As noted earlier, in any real situation an unlimited number of opportunities for action exists, but only a subset of these actually are actualized. This means that, if "dispositionals never fail to be actualized when conjoined with suitable circumstances" (Turvey, 1992, p. 179), then affordances, as defined by Turvey, cannot be dispositional properties. A filter that prevented some affordances from being actualized would be consistent with the nature of dispositions only if the unactualized affordances were not dispositions. This, in turn, would mean that affordances, in general, cannot be defined as dispositional properties.

SPECIFICATION OF AFFORDANCES

Turvey (1992, p. 181) briefly discussed the specification of affordances. He characterized affordances as unobservable properties that bear a lawful relation to visible properties of surfaces that, in turn, structure light in such a way as to specify the affordances.[1] His discussion of relations between affordances and the surface properties of things refers to the complementary properties of the animal (e.g., the lawful connection between environmental properties and visible surface properties is "within the scope of" the complementary properties of the animal, p. 181). However, in his assertion relating visible surface properties to the

[1]Turvey's (1992) discussion of specification is limited to visible properties that structure the optic array. The ecological approach does not assert that information is limited to the optic array; that is, the ecological approach does not assert that light is the only form of ambient energy that carries informative structure, and so, presumably, this phrasing is an oversight. For a discussion of specification that is superordinate to individual forms of ambient energy, see Stoffregen and Bardy (2001).

structuring of light, there is no reference to animal properties or to scaling of the visible environment in terms of the animal. Similarly, his discussion of information pickup (section 10.3 of his 1992 article) refers only to the pickup of information specifying environmental properties, not to the pickup of information specifying animal properties and not to information specifying the complementarity of animal and environmental properties.

What information specifies that a given property of the environment, *p,* is the complement to a property of the animal, *q?* Specification of a property of the environment (e.g., specification of an affordance, in Turvey's, 1992, definition) does not imply specification of the complementarity of animal and environment properties. Light reflecting from a surface may specify that the surface will support forces over a certain range but that does not imply specification of the range of forces that any particular animal (e.g., the observer) can impose upon the surface. The same is true in reverse: Specification of the range of forces that an animal can develop does not tell one about the range of forces that any given surface can resist.

It is true that the point of observation and the environment are cospecified (e.g., Lombardo, 1987). For example, the optic array is structured not only by the shapes of things but also by the position of things, relative to a point of observation. This cospecification provides information not only about the environment but also about the space–time kinematics (i.e., position and motion) of the point of observation within (and relative to) the environment. However, animals need more information than this. The fact that we can see where we are and how we are moving does not imply that we must also be able to see who we are, or what we are, or what we can do (Stoffregen, 2000a).[2] Thus, a demonstration that a parameter of some ambient array specifies a particular property of the environment does not guarantee that that array property will also specify the corresponding, complementary property of the animal (and vice versa). It is critical that an array parameter that specifies a property of the environment might *not* specify the complementarity of that environmental property with some property of the animal (and vice versa). If properties of the environment and properties of the animal are specified separately or independently, then there might not be any specification of the complementarity of the animal and environment properties. In such a situation, direct perception of properties of the environment (affordances, in Turvey's, 1992, view) and direct perception of properties of the animal (effectivities, in Turvey's, 1992, view) would not imply or guarantee direct perception of the complementarity of animal and environment properties. If affordances are properties of the environment, and effectivities are properties of the animal, then it would appear that knowledge about the complementarity of affordances and effectivities must be

[2]Position and motion are kinematic facts, whereas dynamics are influenced by kinetics as well as by kinematics (Stoffregen, 2000a). Specification of a point of observation is not the same thing as specification of an animal or of an animal–environment system.

obtained indirectly and must be something derived from directly but separately perceived information about affordances and effectivities.

Turvey's (1992) presentation focuses on ontology, that is, on the nature of affordances. It might be possible to develop a satisfactory definition of affordances without an explicit treatment of how affordances are specified; however, if one wishes to develop a theory of behavior in which perception is direct, in general, then any definition of affordances must be compatible with specification in such a way as to permit opportunities for action to be perceived directly.[3] Thus, any definition of affordance must be considered tentative until and unless it can be shown that the definition is compatible with a general theory of direct perception.

PROPERTIES OF THE ANIMAL–ENVIRONMENT SYSTEM

As noted earlier, Turvey (1992) prefaced his definition of *affordance* with an explicit statement of his underlying metaphysics as being materialist, dynamicist, and realist (cf. Chemero, 2003; Sanders, 1997). I accept these metaphysics. I assert, however, that Turvey's definition of *affordance* is not the only definition that can be derived from these metaphysics.

Affordances as Relational Properties

Turvey (1992) took a disposition of the environment (the affordance, *p*) and a disposition of the animal (the effectivity, *q*) and conjoined them to yield an actualization, *r,* which is the act that was afforded. The properties *p* and *q* are what can happen, and *r* is what actually happens. Thus, *r* is not an affordance; one might call it the exploitation of an affordance. Because it is a conjunction of a property of the environment (*p*) and a property of the animal (*q*), the actualization of the affordance, *r,* is a property of the animal–environment system. It is in this sense that Turvey's definition places affordances within the context of the animal–environment system. However, the affordance, per se, is not a property at the level of the animal–environment system; Turvey was explicit in defining affordances as properties of the environment only.

In the context of affordances, Turvey (1992) did not discuss the existence of properties at the level of the animal–environment system (he considered properties at this level only in the context of the actualization of affordances). The component parts of systems have properties, but the system itself also has properties. Both the properties of the parts and the properties of the system are real (Turvey, 1992, p. 176, referred to the latter as *mutual* or *relational properties*). However, the

[3]The concept of affordances does not require either specification or direct perception; that is, it is logically possible for affordances to exist yet not be specified (cf. Norman, 1988).

properties of the parts and the properties of the system may differ, and they may differ qualitatively (e.g., Vicente & Rasmussen, 1990). To illustrate this point, consider a triangle and the lines that it comprises.[4] The lines exist, as such, and have properties, such as length, width, and color. The triangle also exists, as such, and has properties, such as being equilateral, right, or isosceles. The properties of the triangle differ qualitatively from the properties of the lines. System properties (e.g., triangularity) that are not properties of the components of the system (e.g., individual lines) are referred to as *emergent properties.* In the same sense, the animal–environment system has properties that differ qualitatively from properties of the animal and of the environment; that is, the animal–environment system has emergent properties that do not inhere in properties of the animal or of the environment, considered separately. This raises the possibility that affordances might be properties of the animal–environment system rather than being properties of the environment. Chemero (2003) took an equivalent position, arguing that affordances are relations between the animal and the environment rather than properties of the environment.

Turvey (1992) considered only emergent properties that come into existence with the actualization of opportunities for action. However, the animal–environment system has emergent properties that are persistent, that exist prior to and independent of actual behavior. Turvey took properties of the animal and environment as ontological primitives (Sanders, 1997), whereas in my view it is properties of the animal–environment system that are ontological primitives. In the next section I attempt to formalize this idea.

Definitions of *Affordance* and *Behavior*

I have argued that affordances are relational (i.e., emergent) properties of the animal–environment system (Stoffregen, 2000a, 2000b). Here is a definition of affordance that is consistent with this view.

New definition of affordance.

Let W_{pq} (e.g., a person-climbing-stairs system) = (X_p, Z_q) be composed of different things Z (e.g., person) and X (e.g., stairs).

Let p be a property of X and q be a property of Z.

The relation between p and q, p/q, defines a higher order property (i.e., a property of the animal–environment system), h.

Then h is said to be an affordance of W_{pq} if and only if

(i) $W_{pq} = (X_p, Z_q)$ possesses h

(ii) Neither Z nor X possesses h.

[4]In this example, I consider physical triangles made up of physical lines, not the idealized, nonphysical entities of formal geometry.

In this definition, affordances are properties of the animal–environment system, and they exist only at the level of the animal–environment system.[5] An important feature of this new definition is that it does not refer to or include behavior; that is, it does not include the actualization of affordances. Affordances are opportunities for action; they are properties of the animal–environment system that determine what can be done. To return to the example of stair climbing, one can identify properties that inhere separately in the animal and in the environment, as when Turvey (1992, p. 180) invoked dynamics of animal locomotion and resistive forces generated by stairs. However, one can also (simultaneously) identify properties that inhere in the animal–environment system. The dynamics of animal locomotion are influenced by the dynamics of the surface of support, and vice versa. The result is that there are dynamics that are unique to "this animal if it climbed these stairs" or "this animal when climbing these stairs," but that do not inhere in either the animal or the stair. The dynamics of the animal–environment system are an emergent property and, as such, cannot be identified in the dynamics of the animal or in the dynamics of the environment.

Because they arise from relations between animal and environment, affordances are emergent properties of the animal–environment system. This is one way in which my definition of affordance differs qualitatively from Turvey's (1992) definition. For Turvey, affordances (as properties of the environment) are not emergent properties of the animal–environment system.

Defining affordances as properties of the animal–environment system preserves their prospective nature while at the same time reflecting the fact that opportunities for action arise out of extant reality. The higher order relation between leg length and stair height (*h,* in my definition) constitutes an actualized fact (*h* is a fact, rather than a potential), but this fact constrains what might happen in the future; that is, present reality gives rise to prospective possibilities. If *h*

[5]The possibility that affordances are properties at the level of the animal–environment system is relevant to the two-minds problem, as discussed by James (1912/1976). It was historically believed that things exist (e.g., animals, objects in the environment) but that relations between things do not exist: They are mental constructs only. James argued that relations between things also have real existence and are not restricted to mental constructs (cf. Runeson, 1994). When construed as properties of the animal–environment system, affordances can offer a solution of the two-minds problem (Chemero, 2003). A given object or event (e.g., a chair) may be part of the environment of different animals, A and B. In classical terms, the chair as something that may be perceived and acted on is the same for A and for B. This leads to the two-minds problem: If two animals can both perceive the same environmental entity, then how is it appropriate to say that the animals' perceptions are really separate? However, if relations between the animal and its environment are real—that is, if properties of the animal–environment system are real—then, in addition to the chair, per se, there are two other entities: the chair-in-relation-to-A and the chair-in-relation-to-B. These relational entities are not identical but distinct. If animals perceive these relational entities and do not perceive the chair, per se, then there is not overlap of minds. Recent research has demonstrated that individuals can accurately perceive the possible actions that are available to other people in a shared environment (Stoffregen, Gorday, Sheng, & Flynn, 1999). This research may constitute an empirical demonstration of this solution of the two-minds problem.

is within a certain range of values, then stair climbing is possible; that is, it may happen in the future.

I have used stair climbing as an example to illustrate my definition of *affordance.* In stair climbing (for healthy adults), the relevant property of the animal is biomechanical (leg length; Warren, 1984). By using this example I do not mean to imply that only biomechanical properties of animals figure in affordances. Any property of an animal can bear a relation to some property of the environment that gives rise to an affordance, including biomechanical properties, such as leg length, and other types of properties, such as strength and flexibility (Konczak, Meeuwsen, & Cress, 1992), skills, beliefs, and emotional states. An example is the idea that the affordance for safely crossing a road consists of a relation between the time available (i.e., the time gap between successive cars passing by a pedestrian) and the time required (i.e., the time needed for the pedestrian to cross the road), where time required is a function of the width of the road and the locomotor velocity of the pedestrian (Lee et al., 1984). As another example, consider the scaling of hand and arm movements in prehension as a function of the size and mass of objects. Cesari and Newell (2002) determined that reach, grasp, and displacement components of prehension are influenced by properties of the to-be-moved object and that object properties are scaled in terms of the grip configuration used and in terms of temporal properties of the subcomponents of prehension (e.g., grasp time, displacement time). Relations between the size and mass of objects and the reach, grasp, and displacement capabilities of the person combine to determine not only whether prehension is possible but also how it should proceed (see also L. S. Mark et al., 1997).

Definition of behavior. Behavior is what happens at the conjunction of complementary affordances and intentions or goals:

> Let W_{pq} (e.g., an animal–environment system) $= m(h, i)$ be composed of different affordances, h (e.g., c, the opportunity to climb stairs, e, the opportunity to eat lunch, f, the opportunity to solve a mathematical equation), and intentions, i (e.g., s, the intention to get to the top of the stairs, l, the intention to eat lunch, b, the intention to solve the equation), where both affordances and intentions are properties of the animal–environment system.
>
> A given behavior b (e.g., climbing stairs) will occur if and only if (and when) an affordance (e.g., c) and its complementary intention (e.g., s) co-occur at the same point in the space–time continuum, where m is a psychological choice function.

Many affordances exist (and persist) that are not exploited at any given place or time. At any given place and time, one does not do everything that one can possibly do at that place and time. From among the unlimited set of possible behaviors, intentions select those that will be attempted (e.g., Van Orden &

Holden, 2002). The persistence of affordances prior to their exploitation permits them to be specified and detected prospectively, which in turn permits affordances to function as the cornerstone of prospective control. Similarly, many intentions exist that cannot be satisfied at a given place or time. From the unlimited set of intentions, the existing set of affordances determines those that can be satisfied at any given place and time. Casting behavior in terms of paired affordances and intentions (both of which are properties of the animal–environment system) preserves the circular causality that is inherent in dynamicist, systems-based approaches to perception and action (e.g., Lombardo, 1987; Swenson & Turvey, 1991).

A separate issue arises from the fact that one does not attempt to do all of the things that one might want to do. In any given situation, an unlimited number of affordances exist. Similarly, in any given situation, some large number of intentions exists. Despite this multiplicity of intentions and affordances, only a small subset of affordances is exploited; only a small subset of intentions is acted on. Of the complementary fits between affordances and intentions, only some are actualized.[6] Thus, in defining behavior there is a need to determine which intentions will be acted on. This is the role of the psychological choice function, *m*.[7] I do not know where intentions come from, and I do not know how the choice among intentions operates (i.e., I cannot at present define *m*). These are issues for future resolution (for initial treatments, see Shaw, 2001; Shaw, Kadar, & Kinsella-Shaw, 1995; Shaw, Kugler, & Kinsella-Shaw, 1990). These are important issues that must be understood; however, I believe that although they are central to the definition of *behavior,* they are not central to the definition of *affordance.*

Affordances (as I have defined them) persist when they are not being exploited, and intentions persist when they are not being acted on. It is these two facts, I believe, that motivate the great majority of perceptual–motor learning and exploration. Perceiving that a given intention cannot be satisfied here, now, can motivate an animal to seek out conditions under which the intention can be satisfied. This can motivate exploration of the existing animal–environment system (e.g., a search for properties of the environment that will mesh with existing properties of the animal to enable the achieving of an intention), it can motivate the acquisition of new perception–action skills (e.g., development or acquisition of properties of

[6]In strict terms, I should refer to *attempts* to actualize affordance–intention pairs. The fact that an action is affordance and is sought out by the animal does not guarantee that the intention will be satisfied. This fact is perhaps most obvious in development (e.g., Adolph, 1995), but it applies throughout the lifespan.

[7]In my usage, *psychological* does not imply consciousness, conscious intention, or conscious choice. I use *psychological* to indicate that the choice is made by the animal and is not compelled by facts or events in the environment. The choice may be influenced by environmental factors, for example, by the known preferences of another person, or by a deadline, but the actual choice is internal to the animal. Animals sometimes make choices that arguably are incorrect, and they sometimes make choices that are deliberately self-sacrificing or even self-destructive.

the animal that will mesh with existing properties of the environment to enable the meeting of an intention), and it can motivate the prospective modification of the environment (the alteration or manufacture of objects or circumstances that will mesh with properties of the animal to enable the meeting of an intention).

IMPLICATIONS

My proposed definition of *affordance* has a variety of implications for the concept of affordances in particular and for the ecological approach to perception and action in general. I discuss several of these next.

Ontology and Epistemology

Affordances sometimes are described as entities that constrain behavior. The idea of constraints on behavior can be used to understand the ontology of affordances. What constrains behavior? Properties of the environment do not constrain behavior. It is not meaningful to suggest that the height of a stair constrains stair climbing. Turvey (1992) defined *affordances* as properties of the environment. Accordingly, affordances, as defined by Turvey, do not constrain behavior. Behavior is constrained by relations between properties of the environment and properties of the animal, for example, by the ratio of riser height to leg length (Warren, 1984). Relations between the animal and the environment constitute emergent properties of the animal–environment system, and so it is meaningful to suggest that behavior is constrained by these properties of the animal–environment system.

The preceding discussion has implications for epistemology, that is, for what one knows (or what one should know) about reality. If behavior is constrained by properties of the animal–environment system, then information about properties of the animal–environment system can be used directly for the control of adaptive action. In contrast, information about properties of the environment (i.e., information about affordances, as defined by Turvey, 1992) cannot be used to guide behavior. If emergent properties of the animal–environment system can be perceived as such, then there may be no motivation to perceive (separately) properties of the environment, or properties of the animal (Turvey's *p* and *q,* respectively). My definition of *affordance* suggests that affordances might be perceived without prior or concurrent perception of underlying or constituent properties of the animal and environment as such (Stoffregen, 2000a, 2000b).

I have proposed that affordances (defined as emergent properties of the animal–environment system) are the sole constraints operating on behavior and that affordances can be perceived without prior or independent perception of properties of the animal or properties of the environment as such. If these contentions are true, they raise the question of whether adaptive perceivers would be motivated to

perceive anything other than affordances. I have argued that the ecological approach to perception and action motivates perception of affordances but that it may not motivate the perception of events as such (Stoffregen, 2000a, 2000b). I here expand this argument to the following: My reading of the ecological approach to perception and action suggests that one should perceive affordances and nothing else (Stoffregen, 2002). My definition of *affordance* includes all opportunities for action. This means that anything that is not an affordance cannot have consequences for action. I know of no basis within the ecological approach to perception and action for motivating perception of anything that had no consequences for action.[8] As Sanders (1997) put it, "Perception is always an activity that goes on in a world of significances-to-the-organism, and these latter are to be understood in terms of opportunities for action. That is, they are to be understood as affordances" (p. 107).

Effectivities

Turvey (1992) described his analysis as yielding a definition of *affordance,* but it also produced a definition of *effectivity.* What is the role of effectivities in the ecological approach to perception and action? Are effectivities central entities that differ meaningfully from affordances? Or are effectivities minor entities that are secondary to or redundant with affordances? Some scholars have asserted that effectivities are critical to the ecological approach (e.g., Greeno, 1994; Shaw, Turvey, & Mace, 1982; Turvey, 1992). This must be true, if Turvey's definition of affordance is correct, that is, if affordances are properties of the environment, and effectivities are properties of the animal. In Turvey's definition, affordances and effectivities differ qualitatively and have equal importance. Others have suggested, or implied, that effectivities are minor, that they are derivative of affordances and have secondary status. For example, Warren (1984) described effectivities as reciprocals of affordances. For Warren, affordances were ratios of the form *E/A,* in which the numerator was a property of the environment, *E,* and the denominator a property of the animal, *A.* "Conversely, for effectivities, environmental properties are taken as standards against which or-

[8]Following E. J. Gibson (1988), I have argued that behavior includes not only inertial displacement or movement but also (in some species) mentation, that is, thought (Stoffregen, 1997, 2003). In addition to inertial or movement-based manipulations of the animal–environment system, one can also think about it. Thought is something that is afforded to human–environment systems but does not appear to be afforded to, for example, cockroach–environment systems. Humans spend a lot of time thinking about things, and I contend that thought (e.g., contemplation, reasoning, problem solving) is one of the things that are afforded in human–environment systems. Similar arguments have been made by Heft (1989, 2001) and Sanders (1997). Note that by *thought* I do not mean *cognition* as classically understood (i.e., where cognition consists of inferential processing of mental constructs derived from indirect perception). For a discussion of mentation that does not rely on classical concepts of cognition, see Costall and Still (1987).

ganism properties are measured, and the resulting ratios are the inverse: *A*/*E*" (Warren, 1984, p. 686). In Warren's presentation, the difference between affordances and effectivities is trivial (cf. Sanders, 1997).

My definition of *affordance* places effectivities in a status similar to, although not identical to, that implied by Warren (1984). For Warren, effectivities are the trivial reciprocals of affordances. For me, effectivities are lower level constituents of the higher order animal–environment relations that constitute affordances. Contra Turvey (1992), my definition implies that effectivities are not qualitatively distinct complements of affordances; rather, effectivities are subordinate to affordances. Effectivities are properties of the animal, whereas affordances are higher order, emergent properties of the animal–environment system.

Implications for Specification

If, as I claim, affordances are higher order, emergent properties of the animal–environment system, then specification of affordances poses no special problems. This is because the specification of emergent properties is not problematic in general. As one example, triangularity is specified as a result of structure imparted to the optic array by triangles. For an example in a behavioral context, consider *translation,* that is, movement from place to place, such as occurs in locomotion. Translation is an emergent property of the animal–environment system. This is because translation can be defined only relative to some environmental referent. In a relativistic universe, there is no absolute translation, just as there is no absolute motion. Yet translation as an emergent property of an animal–environment system is widely believed to be specified in the optic array. This example suggests that emergent properties of the animal–environment system can be specified as such, in which case affordances (as I have defined them) may be specified as such, and so the perception of affordances may be direct.

Identifying information that specifies affordances is a critical challenge for ecological theory. J. J. Gibson (1979/1986) stated this plainly: "The central question for the theory of affordances is not whether they exist and are real but whether information is available in ambient [arrays] for perceiving them" (p. 140). Studies of affordance perception often include detailed analyses of the physical relations (i.e., the ecological physics) between animal and environment that constitute the affordances under study (e.g., Burton, 1992; Konczak et al., 1992; Warren, 1984). However, identifying the physical relations is not sufficient for an ecological account of perception and action. Describing the physical relations and showing that participants detect them does not explain how they are detected (Stoffregen, 2000a; Stoffregen et al., 1999). We must identify patterns in ambient arrays that are specific (i.e., uniquely related) to the perceived animal–environment relations. A small number of studies have addressed the issue of the specification of affordances (e.g., Carello, Grosofsky, Reichel, Solomon, & Turvey, 1989; Jiang &

Mark, 1994; L. M. Mark, 1987; L. S. Mark, Balliet, Craver, Douglas, & Fox, 1990; Stoffregen et al., 1999), but this work is in its infancy.

J. J. Gibson (1979/1986) described some affordances of water: "Its surface does not afford support for large animals with dense tissues" (p. 131). This is consistent with the argument that *affordances* are defined as relations between properties of the animal and of the environment. However, Gibson's next sentence seems to deviate from this: "The optical information for water is well specified by the characteristics of its surface, especially the unique fluctuations caused by rippling" (p. 131). Information for water may not be the same as information for the affordances of water. In this case, "information for water" could be the same for an elephant as for a water strider (imagine that, blown by the wind, a water strider found itself perched on the elephant's head, near its eyes), yet the affordances of water differ for these two animals. Information for affordances may exist only as higher order relations between array structures relating to water and array structures that relate to relevant properties of an animal.

The issue is highlighted by considering the case of affordances for interceptive action (Stoffregen, 2000a). If time to contact, T_c, and its time derivatives are not affordances, then parameters of ambient arrays that are related to T_c (τ and its time derivatives) do not provide information about affordances. If T_c does not refer to behavior, then τ does not refer to behavior (for an argument to this effect, see Stoffregen, 2000a). The τ variables are scaled to a point of observation but are not scaled to the observer's behavioral capabilities. Thus, information about T_c may be insufficient even for the timing of interceptive action (cf. Lee et al., 1984; Lintern, Waite, & Talleur, 1999; Smith, Flach, Dittman, & Stanard, 2001; Stoffregen & Riccio, 1990, pp. 270–272). An example might be the case of collision versus passage studied by E. J. Gibson, Carroll, and Ferwerda (as cited in E. J. Gibson, 1991).

Analyses of information have concentrated on patterns within individual energy arrays. One example is the fact that the structure of the optic array is influenced by eye height (L. M. Mark, 1987; Warren & Whang, 1987). Another example is the "visual" guidance of stair climbing (Warren, 1984). The structure of the optic array is influenced by the height of a stair, but it is not clear that information for the chair–leg-length relation can be found in the optic array (Stoffregen, 1990). Finally, consider specification of the affordance for safe road crossing (Lee et al., 1984). The time gap between the passage of successive cars may structure the optic and acoustic arrays, but the locomotor capabilities of the pedestrian (relating to the time needed to cross the road) likely will structure (at least) patterns of somatosensory stimulation. Specification of the crossability of the road, then, might depend on the existence of an emergent relation between structure in multiple forms of ambient energy. Specification of such emergent properties may be simple and coherent in the context of the global array (Stoffregen & Bardy, 2001; cf. Bingham & Stassen, 1994). This is, in part, because the global array provides information about the reciprocal position and motion of the animal and its environment, relative to multiple, simultaneous refer-

ents, whereas information of this kind does not, in general, exist in single-energy arrays.[9]

Just as higher order properties of ambient arrays are real (e.g., optic flow or any structure in the global array), so too are higher order properties of the animal–environment system real and thus may be specified as such. If, as I claim, properties of the animal–environment system constitute affordances, then the specification of affordances is not a logical problem.

CONCLUSION

I have proposed a definition of *affordance* that differs qualitatively from the definition offered by Turvey (1992). Turvey defined affordances as properties of the environment (complemented by *effectivities,* which Turvey defined as properties of the animal), whereas I define affordances as emergent properties of the animal–environment system. I have argued that the attempt to define affordances as properties of the environment cannot work, that it is incompatible with widely accepted characteristics of opportunities for action and with basic tenets of the ecological approach to perception and action. An important issue for the ecological approach is to identify and understand properties of the animal–environment system that constitute opportunities for action. If this can be done, it will also be necessary to address the possible specification and detection of such properties and their exploitation in adaptive action.

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[9]Oudejans, Michaels, van Dort, and Frissen (1996) demonstrated that perception of the affordance for road crossing is more accurate when the pedestrian is walking toward the road relative to when a pedestrian is standing still beside the road. Similarly, Oudejans, Michaels, Bakker, and Dolne (1996) showed that observer movement facilitates perception of the catchability of fly balls. One can presume that observer motion would be of little value by itself, that is, when there were no cars on the road or before the ball was in the air. Such a result (this is a testable hypothesis) would be consistent with the idea that information about the crossability of roads and the catchability of fly balls exists as an emergent property of stimulation extending across different forms of ambient energy, that is, as a parameter of the global array (Stoffregen & Bardy, 2001).

University in the early 1980s (e.g., Gary Riccio, Jack Carroll, myself). In writing this article, I have formalized this idea, but I cannot claim to have originated it. I did not discuss this idea with James Gibson (whom I never met), and I do not recall discussing it with Eleanor Gibson (in whose lab I worked), so I do not know how they may have felt about the ideas that percolated in the subculture of their graduate students.

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