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Affordances and Prospective Control: An Outline of the Ontology

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Actions must be controlled prospectively. This requires that the behavioral possibilities of surface layouts and events be perceived. In this article, the ontological basis for an understanding of prospective control in realist terms is outlined. The foundational idea is that of affordances and the promoted ontology is materialist and dynamicist. It is argued that research in the ecological approach to prospective control is ultimately the search for objective laws. Because lawfulness is equated with real possibility, this amounts to the study of the affordances (the real possibilities) underlying prospective control and the circumstances that actualize them. The ontological assumptions and hypotheses bearing on this latter proposal are articulated. It is suggested that critical evaluation of the identified ontological themes may benefit the experimental and theoretical study of perception in the service of activity.

My specific goals in this article are twofold: to formulate the ontological hypotheses that I believe should guide the scientific research into Gibson's (1979/1986) concept of affordance and to express these hypotheses in the context of a fundamental feature of animal activity, namely, its prospective control (PC). At a more general level, my goal in this article is to encourage the systematic development of the notion of affordance. Perhaps an airing of one person's interpretation of the underlying dimensions of this central ecological concept will spur a second round of theorizing that will add to and refine the important insights engendered by the first round of theorizing (Gibson, 1979/1986; Reed & Jones, 1982). In what follows, I define *ontology* as the study

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of generic (nonspecific) features of reality. The proposed analysis, therefore, is intended to be so general as to apply with equal validity to all of the affordances and all of the instances of PC at the scale defined by living things and their niches.

1. SUCCESSFUL ACTION REQUIRES PROSPECTIVE CONTROL

PC is control concerned with future events, usually interpretable as goals to be realized. In order to perform an act as simple as walking across a room cluttered with furniture to close a door, or as complex as positioning oneself to receive a pass in a game of football, it is essential to see what movements are possible, what encounters are possible, and to control behavior accordingly. To be specific, conducting an act requires that one perceive whether the act as a whole is possible, what subacts are possible with respect to the surface layout, and the possible consequences of current subacts if current (kinetic, kinematic) conditions persist. Gibson (1966, 1979/1986; Reed & Jones, 1982) coined the term *affordance* to provide a description of the environment that was directly relevant to behavior. An affordance is an invariant combination of properties of substance and surface taken with reference to an animal. One invariant combination of properties affords grasping, another affords support for upright posture, another affords catching, and so on. (Other invariant combinations might be said to afford interactions or relations more so than a given behavior; e.g., a predator at a critical proximity might be said to afford danger. My analysis is of the affordances for actions. I take these as fundamental and their explication as propaedeutic to any extension of affordances to other domains.)

From an ecological standpoint, PC requires that the affordances of the environment be perceived. As Gibson (1979/1986) expressed it: "The theory of affordances implies that to see things is to see how to get about among them and what to do or not to do with them" (p. 223). In the development of the ontological basis of PC along the lines anticipated by Gibson (1979/1986; Reed & Jones, 1982), I lean heavily on Bunge's (1977) effort to establish a system of ontology in tune with contemporary science. This article elaborates and extends earlier efforts along similar lines (Shaw, Turvey, & Mace, 1982; Turvey, Shaw, Reed, & Mace, 1981).

To anticipate, my ultimate concern is an understanding of PC in realist terms. To achieve this, I need to establish that possibilities for action are real or factual states of affairs (i.e., they exist independently of perceiving or conception) that are perceived directly. I need to establish that possibilities for action constitute an ontological category, not an epistemological category, and are not to be confused with conceptual possibility or uncertainty.

2. ECOLOGICAL ONTOLOGY AS MATERIALIST AND DYNAMICIST

As I interpret it, the ontology of the ecological approach to perceiving and acting is *materialist*—nothing exists but matter, and perceiving and acting are wholly attributable to material agency—and *dynamicist*—everything changes. Two important qualifications are in order, however. First, the ecological approach is materialist but not in the sense of classical reductionism (Kugler & Turvey, 1987; Turvey, 1990). This means that the ecological approach rejects the physicalist thesis that the only realities, the only true material objects, are physical systems of the kind made familiar in the various forms of mechanics, and holds instead to the view that material existing at all scales (e.g., living systems and the ecosystems to which they belong) are all equally as real and concrete (Swenson & Turvey, 1991). Second, the ecological approach is dynamicist, but not in the dialectical sense that everything is a synthesis or unity of opposites, or in the sense promoted by Whitehead (1929) that process is fundamental and that extension is derivative from process. The ecological approach holds that everything changes in some respects, but not in all respects. To elaborate, I note that change in some respects is possible only because of persistence in other respects and that whatever is invariant or persistent is so relative to some specific group of transformations. There are, as Gibson (1979/1986; Reed & Jones, 1982) would have put it, persistence–change pairings (Lombardo, 1987; Warren & Shaw, 1985). This stance counters the fundamental polarity in traditional metaphysics of being and becoming (Reed, 1987). Thus, traditionally, event is opposed to thing, process to substance, change to structure. Under the ecological view, every change is the transformation of something, and everything is undergoing change. More specifically:

2.1. There are no changeless things and there are no thingless changes; there are only changing things.

3. PROPERTY REALISM

Gibson (1979/1986, p. 129) denied that affordances are simply phenomenal qualities of subjective experience. To the contrary, he assumed that they are real properties of the environment relative to an animal; they are real properties that imply the complementarity of an animal and its surroundings. What is behind these assumptions? Answering this question requires detailing what counts as a property at the ecological scale.

Two classical metaphysical positions concerning properties can be rejected at the outset. One is the Platonic position that properties are real but exist

independently of individual things. The other is the nominalist position that properties are not real, only individual things are real. In the modern form of the nominalist view, properties are conceptual, with each identified through a collection of individuals. Whereas the former position advocates thingless properties, the latter advocates propertyless things. By contrast, the ontological position of the ecological approach is as follows:

3.1. There are only propertied things; neither properties nor individual things are real independently of one another.

Let me develop this position further:

3.2. All objects have properties. A conceptual or formal object has formal properties, attributes, or predicates. A substantial object has substantive properties.

3.3. A substantial property is a feature that some substantial individual possesses and does so whether one is aware of it. By contrast, an attribute or predicate is a feature one assigns to some object. In other words, an attribute or predicate is a concept, an epistemological entity without clear ontological status.

3.4. A predicate may represent a substantial property; alternatively, it may not or do so erroneously. By contrast, the possessing of a substantial property by a substantial thing is not a matter of truth or falsity. Truth and falsity apply only to one's formal knowledge of properties.

3.5. Some properties are inherent properties of individual things and can be represented sometimes by unary attributes. For example, radioactivity is a property of atoms. These properties are called intrinsic.

3.6. Some properties are properties of pairs or, in general, n-tuples of substantial individuals and must be represented by attributes of rank higher than one. For example, solubility is a property of solutes and solvents in juxtaposition (see Section 6). These properties are called mutual or relational. They exist only when the relevant n-tuple exists.

3.7. Intrinsic properties and mutual properties are equally substantial properties. Both are real.

4. LAW-BASED PERSPECTIVE ON REAL POSSIBILITY

With the detailed assumptions of property realism identified, a description of affordances as substantial properties rather than as attributes can now be approached. Standing in the way of an adequate description, however, is the question of the status of possibility—is it ontological or is it epistemological? (Recall, to perceive an affordance is to perceive what actions are possible.) The

route to determining the status of possibility is through the understanding of laws.

4.1. A law is an invariant relation between or among substantial properties of things. The substantial properties can be either intrinsic or mutual.

4.2. Laws are not reducible to law statements, which are conceptual reconstructions of the invariant patterns. The contrast between law and law statement parallels those between substantial property and attribute and between objective and subjective. Law statements, therefore, need not overlap perfectly with laws (and will not in the earliest stages of their formulations). They will consequently tend to apply only approximately and not to any arbitrarily established desired level of accuracy.

4.3. Some laws are causal and others are noncausal. Lawfulness is not reducible to causality.

These statements deserve comment, given their significance to the identification of laws at the ecological scale (Turvey et al., 1981). One expression of causation, of the causal principle, goes as follows: If C (cause) happens, then (and only then) E (effect) is always produced by it. Although some laws conform to this principle, the principle falls short of exhausting all that is meant by lawfulness. There is a rich assortment of types of lawful production or determination, and causal production is just one of these types. For example, thermodynamic laws (of conservation and of the time evolution of dynamical states) do not refer to any cause.

Another more important qualification on laws should now be added:

4.4. Laws prescribe what can possibly occur but not what must necessarily occur. For something to happen and to be (really) necessary, circumstances must be added to laws. Laws and circumstances (auxiliary conditions, boundary conditions, initial conditions) yield actual states of affairs. (It must be underscored that this is a claim about ontology, not about law statements.)

The latter can be rephrased in a manner more directly suited to affordances and PC:

4.5. Real possibility is identical to lawfulness.

5. CHARGE OF ECOLOGICAL APPROACH TO PC

I raised at the outset the need to establish that there are real possibles (not just conceptual possibles); Items 4.4 and 4.5 address that concern. The challenge of PC can now be articulated more precisely. In largest part, the ecological

approach to PC is the study of the real possibilities with respect to which PC is conducted. Because real possibility is equated with law, then research in the ecological approach to PC is ultimately the search for laws, specifically those underlying PC and the circumstances that actualize them. Note that this is a different charge from that governing most efforts to understand PC. Most commonly, it is assumed that PC is to be accounted for by case-specific anticipatory mechanisms such as plans, frames, programs, and so on, embodied neurally in brain mechanisms, in the discrete symbols of von Neuman machines, or in the subsymbolic dynamics of parallel distributed networks.

As anticipated, the real possibilities in question are affordances. To understand how affordances embody laws requires analysis of real possibilities as dispositional.

6. A SPECIAL CONCEPT OF REAL POSSIBILITY: DISPOSITION OR CAUSAL PROPENSITY

The common term for a property of a thing that is potential or latent or possible (i.e., not occurrent) is *disposition*. Dispositional properties are fundamental to affordances and have three primary characteristics:

6.1. The disposition to do Y is prior to doing Y. For example, a crystal will actually refract light provided that it is refractive to begin with. If it was refractive to begin with, then it was so regardless of whether it was exposed to light.

6.2. Dispositionals (or causal propensities) come in pairs. For example, (all) light rays are refracted if and only if (some) pieces of matter are refractive. Complementarity occurs in the very definition of a dispositional property.

6.3. Dispositionals never fail to be actualized when conjoined with suitable circumstances. Disposition and suitable circumstance equals actuality.

7. ACTUALIZING A DISPOSITION

I now raise the issue of what is required for a causal propensity to become manifest:

7.1. The circumstances actualizing a disposition or causal propensity of a thing Z involve some thing X, other than Z, forming part of Z's environment.

7.2. This X, the complement of Z, must have a disposition matching (in the mathematical sense of "dual to") Z, for Z's disposition to actualize (i.e., if Z is refractible—has a disposition to become refracted—then X must have a disposition to refract).

7.3. What exhibits an actual or manifest property is the unit formed by Z and its complement X. Thing Z with disposition q joins thing X with disposition p to form thing $W_{pq} = j(X_p, Z_q)$ with manifest property r (j is the joining or juxtaposition function). For example, light is refractible, a prism can refract, together they yield refraction or, synonymously, a light-bending-in-prism system. In truth, X and Z have multiple dispositions—m and n, respectively. To actualize W_{pq}, the juxtaposition function j must be such as to filter p and q from the array of $m \times n$ dispositions possessed by X and Z.

7.4. An actual or manifest property r is, according to Item 3.6, a mutual or relational property.

Returning to the equation of real possibility and lawfulness, it follows that a disposition is tantamount to an actual state of affairs minus particular conditions. When the missing conditions are provided, actuality ensues.

8. ONTOLOGICAL FEATURES OF AFFORDANCES

The ontological character of an affordance can now be identified.

8.1. An affordance is a real possibility.

8.2. An affordance is a disposition. (In the most general of cases, it will comprise a configuration of substantive properties.)

8.3. An affordance is complemented.

With respect to Item 8.3, the complementation is by an *effectivity* (Shaw et al., 1982; Turvey & Shaw, 1978). Whereas an affordance is a disposition of a particular surface layout, an effectivity is the complementing disposition of a particular animal. An effectivity, as the term suggests, is the causal propensity for an animal to effect or bring about a particular action, to manifest what is needed for $W_{pq} = j(X_p, Z_q)$ to be realized. Thus,

8.4. An affordance is a particular kind of disposition, one whose complement is a dispositional property of an organism.

Note that what is called a disposition and what is called its complement changes with focus. When the focus is the environment's capability to support a given activity, then the affordance is the disposition and the effectivity is the complement. Conversely, when the focus is an animal's capability to perform that activity, then the effectivity is the disposition and the affordance is the complement. Given that a dispositional property is not defined (i.e., it is a nonexistent property) when there is no complement, then an affordance is not defined (i.e., is nonexistent) without a complementing animal property and, in

like fashion, an effectivity is not defined (i.e., is nonexistent) without a complementing environment property. Gibson (1979/1986), remarked that an affordance is "equally a fact of the environment and a fact of behavior" and that it "points both ways, to the environment and to the observer" (p. 129). These profound qualities of affordances follow from generalizing to animals and their surroundings the basic ontological principle (see Item 6.2) that a causal disposition of a thing is infeasible without a disposition in some other thing. The next section reinforces this understanding.

Before proceeding, however, I should address the scope of Item 8.4. First, it does not delimit the dispositionals of significance to animal activity. There are significant dispositionals whose complements are not properties of organisms. Nest building, tool use, and the like, depend on the selection of propertied things (e.g., twigs of a certain range of magnitudes and pliability) that are functionally suited to other propertied things (e.g., a particular configuration of tree branches), neither of which may be in the class of organism. Second, Item 8.4 does not delimit the organism with the complementing property as the would-be actor. In the form stated, 8.4 encompasses both affordances for the self and affordances for another.

9. A DEFINITION OF AFFORDANCE

Lombardo (1987) identified the central insight of Gibson's ecological approach as the principle of reciprocity—distinguishable yet mutually supportive realities. This principle is manifest in Items 3.1, 4.4, 8.0, and 8.4, and it is at work in the following definition of affordances: Let W_{pq} (e.g., a person-climbing-stairs system) $= j(X_p, Z_q)$ be composed of different things Z (person) and X (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.

Thus, a person cannot execute locomotion in the highly particular manner of stair climbing unless a sloped surface is underfoot composed of adjacent steps with suitable dimensions (of rise and horizontal extent). When it is, then the disposition to locomote in this highly particular way is actualized. The actualizing engenders new locomotory dynamics that are not present in standing and walking, and new reactive forces from the supporting surfaces that are not present in the absence of being climbed on. Both classes of new properties are determined by the properties of the walker and the stairway. An appreciation of

what (ii) entails can be gained most easily from a physically well-understood disposition. The disposition *p* of salt to be soluble rests with the fact that it is a lattice of electrically charged ions bound by an electrical attraction between opposite charges that can be eliminated by a liquid with a high dielectric constant. The salt-dissolved-in-water system lacks the attraction between ions; it does not possess *p*.

10. REVEALING DISPOSITIONS (AFFORDANCES)

What conditions must be satisfied for affordances to be perceptible properties? Consider a surface of support for locomotion. To support standing upright by an animal Z, a surface X must have a microstructure so aligned that it generates a distributed macroscopic force in reaction to, and equal to, the resultant of the force imposed actively by the limbs. This is X's disposition *p*.

10.1. An invariant relation among *unobservable* substantial properties (the disposition *p*) is connected lawfully, within the scope of *q* (the complementing disposition of Z), with an invariant relation among *observable* surface properties, for example, extension, orientation to horizon, planarity, textural composition—all defined (scaled) relative to *q*.

10.2. The invariant relation among visible surface properties structures optical distributions. That is, there is an invariant molar property of the optic array unique and specific to the disposition *p*. In short, there is information about the affordance.

10.3. The disposition *p* is known by attunement to (i.e., detecting) the optical (informational) property that specifies *p*.

11. SPACE AND TIME

The scaling relative to *q* of Item 10.1 entails several major ontological assumptions. Patently, it entails assumptions about measurement; these, in turn, entail assumptions about space and time. I discuss the ontological assumptions relating to measurement in the next section, pursuant to the discussion of the ecological ontology of space and time. I begin by saying what space and time are not in ecological ontology.

11.1. Space and time are not absolute or autonomous, that is, they do not constitute (in the form of space–time) a self-existing container within which all things exist (contra Newton, 1729).

11.2. Space and time do not constitute (in the form of space–time) the elementary substance from which all else is composed (contra Wheeler, 1962).

From these general denials follow denials of a more specific nature that continue the ontological themes presented earlier (see Section 2):

11.3. There are no spaceless things and no thingless spaces.
11.4. There are no durationless things and no thingless durations.

With the foregoing denials in place, I can now identify what ecological ontology *does* say about space and time:

11.5. Space and time are relations among facts. What makes up space? Things, their mutual separations, and their mutual nestings. What makes up time? Changing things, their mutual sequencings, and their mutual nestings.

Gibson (1979/1986) saw the need to construct the notions of space and time out of the ecological realities, precisely, the layout of terrestrial surfaces and the embedding of terrestrial events. He shared with Mach (1893/1960) the understanding that standard references to space and time—in ordinary conversation, in mathematics, and in physical theories—were elliptical references to facts. For Gibson (1979/1986, p. 101), "the reality underlying the dimension of time is the sequential order of events, and the realities underlying the dimensions of space is the adjacent order of objects or surface parts" (p. 101). And further, "time and space are not empty receptacles to be filled; instead, they are simply the ghosts of events and surfaces" (Gibson, 1979/1986, p. 101).

The relational view of space identified in Item 11.5 must be taken a step further. Ecological ontology assumes that there are only changing things (see Item 2.1). Hence, both space and time in this ontology must be based in the notion of "changing thing" (but without adding, unnecessarily, the implication that changing thing is more fundamental than space and more fundamental than time). The following qualification of the notion of space is required.

11.6. The mutual separations and nestings of things are not fixed but changing, given that there are only changing things. Space, therefore, is dynamic.

The latter ontological understanding is essential for the theory of PC in developing systems. Included among its implications are the ontological hypotheses that an affordance of surface layout need not endure and that new affordances of surface layout can come into existence. When considered together with Item 8.4, it implies that the affordances bearing on PC for a developing animal are not frozen, either in number or in type.

12. FRAMES OF REFERENCE

Let me now turn to the issue of measurement, specifically, endowing space and time with metrics. In rejecting the absolute view of space and time in favor of the relational view, one discards universal meters and absolute units. This dismissal leads immediately to the following assumptions:

12.1. The states of any propertied thing are relative to a reference frame.
12.2. All reference frames are local.
12.3. All units are relative.

The notion of a frame of reference must be built from the ontological assumptions developed thus far.

12.4. A frame must be real not conceptual, that is, it must be another propertied thing. (Because all reference frames can be characterized by means of a coordinate system, a mesh with numbers, it has been commonplace to equate reference frames with coordinate systems, that is, with their conceptual representations. This latter move is rejected in ecological ontology.)

12.5. For one propertied thing to qualify as a frame of reference for another propertied thing, its states (a) cannot affect the states of the other (or vice versa) and (b) can be used to quantify the states of the other.

In PC, the organism is the propertied thing functioning as frame of reference for the surrounding layout of surfaces and immersing nesting of events. Its states (e.g., width, grip strength, wing frequency, glucogen production) are separable in significant degree from the states of surfaces and events. Furthermore, its states can be used to quantify the states of surfaces and events. Because there are many organisms engaged in many activities, there are multiple frames of reference. Any particular surface layout or event is therefore quantified in multiple ways, coordinate with the multiple reference frames.

To date, experimental inquiry into affordances and PC has emphasized an animal's body and its linear dimensions as the reference frame. For example, the stairs that an observer in Warren's (1984) experiment perceived as climbable had risers that were a particular fraction of the observer's leg length. The ruler measured riser of a stairway deemed climbable differed across observers, but the ratio of riser height to leg length was common to all observers. That is, the individual observer saw the surface layout in his or her own scale. Obviously, perceiving surface layout in one's own spatial dimensions will not encompass all affordances. From the perspective of constructing an ecologically appropriate ontology, however, the foregoing discussion of space, time, and measurement, highlights that scaling in body dimensions expresses the fundamental issues: All frames of reference are local, all units are relative. The latter, of course, is a major

understanding about physical states of affairs fostered by relativity theory. Its general significance, however, has gone largely unnoticed in the scientific domains in which it is most prominent: biology and psychology. Developing a general theory of reference frames under the relativistic umbrella appropriate to the facts of the ecological scale is a major scientific challenge (Turvey, 1986); it would have to identify the transformations that relate the frames and the dimensional and dimensionless constants that hold over them (Kugler & Turvey, 1987). Similarly challenging is the development of a general theory of units and meters appropriate to the facts of the ecological scale (Rosen, 1978; Shaw & Kinsella-Shaw, 1988); it would have to identify how locally varying units and meters can be functionally equivalent in constraining action.

13. A FUNDAMENTAL FORM OF PC: CONTROLLED COLLISION

The core ideas expressed earlier can be brought to bear on a most basic example of PC. Consider a bird Z flying at velocity v toward a tree branch X. Z has the disposition q to be fractured when v is such that the change in v with contact approximates 7.6 msec^{-1} (Kornhauser, 1964). X has the disposition p to effect fracture. W is the bird-in-collision-with-branch system. This system, given by $W_{pq} = j(X_p, Z_q)$, exhibits fracturing; momentum in the external coordinates of the environment is transferred to the internal coordinates of the animal. Is the actualization of the disposition p optically specified? The answer is yes. The inverse of the relative rate of expansion of the bounded optical contour generated by the branch specifies when contact will be made. This optical property is τ (Lee, 1980). The first derivative of τ specifies the intensity of the upcoming contact if the current conditions (v) continue. In particular, $d\tau/dt$ has a critical value of -0.5 that divides safe approaches (those likely to involve little or no momentum exchange, $d\tau/dt \geq -0.5$) from unsafe approaches (those likely to involve a significant momentum exchange, $d\tau/dt < -0.5$; Kim, Turvey, & Carello, in press; Lee, 1980).

14. PERCEPTUAL CONSTANCY OF AFFORDANCES

Let me finish with a comment on a topic that is more epistemological than ontological but one that relies on the proposed ontology for its full understanding. The comment is on the attunement referred to in Item 10.3. Successful PC requires that an affordance be perceived as such over the wide variety of circumstances in which it is encountered. The perceptual constancies of more traditional concerns are those of brightness, shape, and size (Boring, 1942; Koffka, 1935; Epstein, 1977). Size constancy presents a telling case. In the

classical investigation of Holway and Boring (1941), graded elimination of information about distance (e.g., by means of a reduction screen at the site of the observer, by means of drapes around the to-be-judged object) deflected size perception away from the "law of size constancy" and toward "the law of the retinal image." That is, veridical size perception deteriorated with the withdrawal of information about surface layout. Will effects analogous to those observed by Holway and Boring be witnessed in affordance experiments? Important pioneering research into the conditions of affordance constancy has been conducted by Mark, Balliett, Craver, Douglas, and Fox (1990). Restrictions on the ordinary but subtle maneuvers of inspecting a surface layout impaired affordance constancy. For example, fixing the posture of the head or imposing demands on upright stance sufficed to render inaccurate (in the sense of more variable) a person's perceptions of "sit-on-able." This leads back to the foundational dynamicist nature of the ecological perspective (Section 2): Whatever is perceived unchangingly is perceived as being relative to (or under) a very specific set of transformations.

15. CONCLUDING REMARKS

Research in any given scientific discipline is guided (or misguided) by metaphysical principles. Because these principles are articulated rarely, they tend to influence research only implicitly and to evade critical scrutiny. In this brief article I have outlined in explicit form what I see as the primary ontological concepts and hypotheses shaping an ecological realist treatment of PC. To a significant degree, I have drawn these concepts and hypotheses from Gibson (1979/1986) and Bunge (1977, 1979), but those scholars should not be held responsible for any misapplications on my part or for the incompleteness of my exposition. My hope is that the critical evaluation of the ontology outlined in this article will benefit the experimental and theoretical study of perception in the service of activity.

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