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Beyond Affordances: Closing the Generalization Gap Between Design and Cognitive Science

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Introduction

Traditionally, the focus of many design disciplines has been on the form and function of the "product" (e.g., consumer appliances, living/work spaces, software/interfaces). The past three decades have seen a substantial broadening toward the design of experiences, interactions, services, and larger systems perspectives,[1] but for many designers the product artifact is still the main deliverable of their profession.

Likewise, in the cognitive science discipline, which also is diverse, the focus of many researchers has been and continues to be on internal processes of mind or brain. Again, the properties of the external stimuli or ecology (e.g., the space, tools, products, information technologies, and work domains) and the importance of the physical body certainly have not been completely ignored, but these aspects typically have been considered secondary to the core interests of cognitive science and to the training requirements for cognitive scientists. And again, as in design, there are some who are interested in broadening the perspective to consider additional aspects of experience, including ecological psychology, ecological rationality, situated cognition, embodied cognition, and evolutionary psychology.[2]

Despite the broadening of perspectives in both disciplines, a gap remains in these perspectives, as depicted in Figure 1. This gap makes connecting the discoveries and insights in one discipline to those of the other discipline difficult. Thus, designers are challenged to apply the discoveries and theories from cognitive science to improve their product designs, and cognitive scientists are challenged to learn from the successes and failures of design innovations.

In this paper, we explore the gap between these two disciplinary perspectives with the goal of creating a common ground so that the two disciplines can work together to enrich our

1 See, e.g., B. Joseph Pine and James H. Gilmore, *The Experience Economy: Work is Theatre & Every Business a Stage* (Boston: Harvard Business Press, 1999); Bill Moggridge, *Designing Interactions* (Cambridge, MA: MIT Press, 2007); Froukje Sleeswijk Visser, ed., *Service Design by Industrial Designers,* 1st ed. (Delft, the Netherlands: Lulu, 2013); and Patrick E. Waterson, M.T.O Gray, and C. W. Clegg, "A Sociotechnical Method for Designing Work Systems," *Human Factors: The Journal of the Human Factors and Ergonomics Society* 44, no. 3 (2002): 376–91, respectively.

2 See, e.g., James J. Gibson, *The Ecological Approach to Visual Perception* (Boston: Houghton Mifflin, 1979); Peter M. Todd, Gerd Gigerenzer, and the ABC Research Group, *Ecological Rationality* (Oxford: Oxford University Press, 2012); Lucy A. Suchman, *Plans and Situated Actions* (Cambridge: Cambridge University Press, 1987); and George Lakoff and Mark Johnson, *Philosophy in the Flesh: The Embodied Mind and Its Challenge to Western Thought* (New York: Basic Books, 1999); and Leda Cosmides and John Tooby, "Beyond Intuition and Instinct Blindness: The Case for an Evolutionarily Rigorous Cognitive Science," *Cognition* 50 (1994): 41–77, respectively.
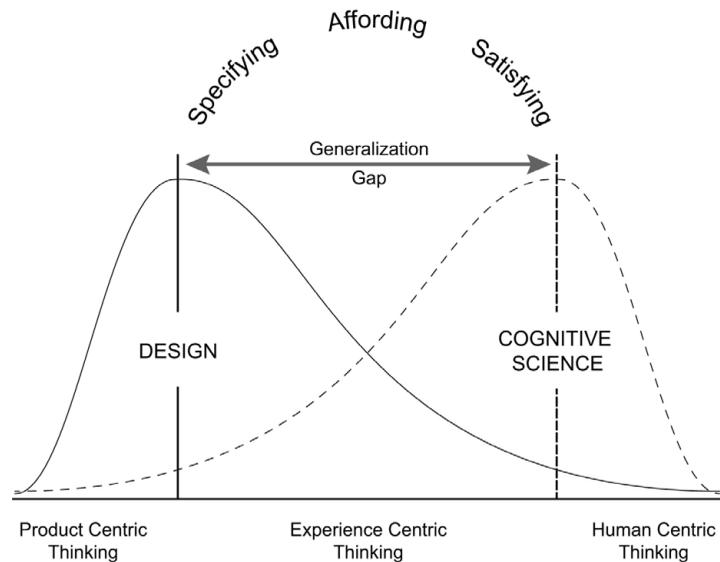
understanding of human experience. Although both disciplines contribute to our understanding of human experiences with products, integrating the separate contributions into a unified theory can be difficult because of their distinct perspectives and languages.

A first step in this exploration is to consider the notion of affordance, which Gibson formulated as a necessary construct for extending cognitive science to address people's ability to skillfully link perception and action.[3] Norman introduced the affordance construct to the design discourse, where it was adopted with some degree of success, as well as some confusion.[4] We argue that the affordance construct partially bridges the gap between a product-centered perspective and a human-centered perspective, but that alone it is not sufficient. Thus, we also suggest two additional dimensions and describe a framework that includes three axes for evaluating the human–product experience: affording, specifying, and satisfying.

The peaks in the simplified distributions in Figure 1 represent the typical, distinct disciplinary foci of design (product-centric) and cognitive science (human-centric). However, within each discipline, certain people (e.g., interaction designers and cognitive systems engineers) are specifically interested in the relations or emergent properties associated with interactions between people and products (or ecologies). In addition, a growing skepticism has questioned whether these emergent properties can be fully addressed from either a product-centric or a human-centric

3   See Gibson, *The Ecological Approach.*
4   See Donald A. Norman, *The Psychology of Everyday Things* (New York: Basic Books, 1988).

perspective. The alternative is an experience-centric perspective, which assumes that the coupling of mind and product cannot be fully described by adding together the constructs from the two different perspectives. Instead, the need is for constructs that directly reflect properties of the coupling or fit: holistic properties of experience.[5]

A Brief History of the Concept of Affordance
As noted, one construct that connects human and product and that has become popular with designers is that of *"affordances."*[6] The term was originally introduced by Gibson to amend the shortcomings of the construct of "stimulus" as it had been used in psychology.[7] Gibson identified the need to ground the construct in the ecology, or the meaningful objects (or products) in an environment and their functional significance for a human (or animal):

> First, the environment must be described, since what there is to be perceived has to be stipulated before one can even talk about perceiving it. This is not the world of physics but the world at the level of ecology.[8]

The construct of affordance largely was introduced as a way to describe the environment at the level of ecology. Thus, Gibson generated the following definition of affordances:

> The affordances of the environment are what it offers the animal, what it provides or furnishes, either for good or ill. The verb to afford is found in the dictionary, but the noun affordance is not. I have made it up. I mean by it something that refers to both the environment and the animal in a way that no existing term does. It implies the complementarity of the animal and the environment.[9]

The affordance construct provided a direct way to talk about the possibilities that a product's design offered to people (e.g., whether a door afforded opening, whether a software application afforded printing, or whether a smart phone afforded texting). When Norman introduced the term to designers, the new information technologies were beginning to create new challenges for design professionals. Previously, designers had dealt primarily with mechanical objects, where the functions were tightly coupled to the physical forms (e.g., hand tools or kitchen appliances). When they had to design information technologies, such as personal computers, designers were faced with two new challenges associated with the much looser coupling between form and function: First, the functions performed by the products were much more abstract, and the physical form of the computer did not provide

5   See, e.g., John M. Flach and Fred A. Voorhorst, *What Matters?* (Dayton, OH: Wright State University Library, 2016).

6   See, e.g., Norman, *The Psychology of Everyday Things;* and Donald A. Norman, "Affordances, Conventions, and Design," *Interactions* 6 (1999): 38–41. See also William Gaver, "Technology Affordances," Proceedings CHI 91 (New York: ACM Press, 1991): 79–84; Victor Kaptelinin, "Affordances," *The Encyclopedia of Human–Computer Interaction* (Aarhus, Denmark: Interaction Design Foundation, 2014).

7   James J. Gibson, "The Concept of the Stimuli in Psychology," in *Reasons for Realism,* ed. Edward Reed and Rebecca Jones (Hillsdale, NJ: Erlbaum, 1982), 333–48. Originally published in *American Psychologist* 15 (1972): 694–703.

8   Gibson, *The Ecological Approach,* 2.

9   Ibid., 127.

"hints toward use" in the way mechanical solutions often had. Second, designers had a broad new palette from which to create alternative representations to communicate the functions because of the innovations in visual and auditory display technologies (e.g., direct manipulation interfaces).[10]

Designers quickly appreciated that the affordances designed into a product would not be used unless they were made apparent to the human users. This realization led to confusion between the possibility of actions and the expression of those possibilities. For many designers, the term affordance meant a visual icon to express hidden functionality. This prompted Gaver to distinguish between "perceptible affordances" and "hidden affordances."[11] Later, Norman tried to address the confusion and introduced a new term, *signifiers,* to denote the expression of affordances.[12]

Relations Between Affordance and Information

The relationship between affordance and information had been core to Gibson's work—and it has been difficult to explain because both of these concepts are relations themselves: An affordance is a relation between an acting human (or animal) and (a part of) his or her environment (e.g., a product); information is a relation between perception and action in an environment. In fact, searching for the information basis underlying the skilled realization of affordances was central to Gibson's research program, leading to the study of ecological optics and the hypothesis of "direct perception."[13] Under this hypothesis, structure in optical flow fields can directly specify affordances associated with skilled performance, such as the control of locomotion.[14]

The importance of representing the affordances in a work domain as information accessible at the interface, which people can then learn to pick up and comprehend, was fully appreciated by both Gaver and Norman.[15] It also has been appreciated by engineers working on the design of interfaces for safety-critical systems, such as nuclear power plants and advanced aircraft (i.e., on cognitive systems engineering). For example, Woods notes that:

> There are no a priori neutral representations… The central question is what are the relative effects of different forms of representation on the cognitive activities involved in solving domain problems. HCI research then needs to investigate representational form as opposed to merely visual form, to investigate the referential functions that are performed by HCI tokens within a symbol system, and to investigate the interface as a coherent representational system rather than as a collection of independent parts, e.g., display pages.[16]

10 Ben Shneiderman, *Designing the User Interface: Strategies for Effective Human–Computer Interaction,* 2nd ed. (Reading, MA: Addison-Wesley, 1992).

11 Gaver, "Technology Affordances."

12 Donald A. Norman, "Signifiers, Not Affordances," *Interactions* 15, no. 6 (2008): 18–9 http://doi.acm.org/10.1145/1409040.1409044 (accessed July 18, 2016).

13 Gibson, *The Ecological Approach.*

14 James J. Gibson et al. "Parallax and Perspective During Landings," *American Journal of Psychology* 68 (1955): 372–85.

15 Gaver, "Technology Affordances"; Norman, "Signifiers, Not Affordances."

16 David D. Woods, "The Cognitive Engineering of Problem Representations," in *Human-Computer Interaction and Complex Systems,* ed. G.R.S. Weir and J. L. Alty, (London, UK: Academic Press, 1991), 175.

Rasmussen and Vicente have formalized an approach to representational design called ecological interface design (EID).[17] The "ecological" label is a direct recognition of the significance of Gibson's constructs of affordance and information on the framing of this approach to interface design. Thus, the thrust of EID is to discover and identify the affordances within a work domain through work domain analysis[18] and then to develop interfaces that help people to "see" and "explore" (e.g., through direct manipulation) the field of possibilities in order to manage complex processes safely and efficiently.[19]

A Third Facet: Value

The affordance dimension considers what actions are possible and the information dimension considers which actions can be recognized, but the question remains of what action should or will be chosen. Of the possibilities that are recognized, which possibilities are desirable, and which ones are hazardous? This third facet raises the issue of the potential value associated with the consequences of performing an action. For example, multiple ways for closing a computer document might be available, some of which save any changes made and some that do not save the changes. Depending on the intentions of the user, the consequence of saving changes might or might not be desirable. Thus, in designing a representation to support satisfying interactions with a computer, specifying the consequences of the possible actions also is important, so that people can choose actions that are compatible with their intentions (e.g., revising a document) and avoid actions that lead to undesirable consequences (e.g., inadvertently deleting hours of editing on a document). These consequences introduce the dimension of value.

The idea that consequences or values directly shape human experience actually predates the construct of affordance. As Gibson noted, Gestalt psychologists (e.g., Koffka and Lewin) recognized that "the meaning of a thing seems to be perceived just as immediately as its color."[20] Koffka used the term "demand character,"[21] and Lewin used a term that was translated to "valence."[22] Gibson writes:

> The concept of affordance is derived from these concepts of valence, invitation, and demand, but with a crucial difference. The affordance of something does not change as the need of the observer changes. The observer may or may not perceive or attend to the affordance, according to his [her] needs, but the affordance, being invariant, is always there to be perceived. An affordance is not bestowed upon an object by a need of an observer and his [her] act of perceiving it. The object offers what it does because it is what it is in terms of ecological physics instead

17 Jens Rasmussen and Kim J. Vicente, "Coping with Human Errors Through System Design: Implications for Ecological Interface Design," *International Journal of Man-Machine Studies* 31 (1989): 517–34; Kim J. Vicente and Jens Rasmussen," Ecological Interface Design: Theoretical Foundations," *IEEE Transactions on Systems, Man, and Cybernetics SMC-22* (1992): 589–606.

18 For example, Kim J. Vicente, *Cognitive Work Analysis* (Mahwah, NJ: Erlbaum, 1999); Neelam Naikar, *Work Domain Analysis* (Boca Raton, FL: CRC Press, 2013).

19 For more on interface design, see, e.g., Kevin B. Bennett and John M. Flach, *Display and Interface Design: Subtle Science, Exact Art* (London: Taylor & Francis, 2011); Catherine M. Burns and John Hajdukiewicz, *Ecological Interface Design* (Boca Raton, FL: CRC Press, 2004); Clark Borst, John M. Flach, and Joost Elerbroek, "Beyond Ecological Interface Design: Lessons from Concerns and Misconceptions," *IEEE: Systems, Man, and Cybernetics 99* (2015): 1–12.

20 Gibson, *The Ecological Approach,* 138.

21 Kurt Koffka, *Principles of Gestalt Psychology* (New York: Harcourt, Brace, 1935).

22 Junius F. Brown, "The Methods of Kurt Lewin in the Psychology of Action and Affection," *Psychological Review* 36 (1929): 200–21; and Alfred J. Marrow, *The Practical Theorist: The Life and Work of Kurt Lewin* (New York: Basic Books, 1969).

of physical physics, and it therefore possesses meaning and value to begin with. But this is meaning and value of a new sort.[23]

Gibson introduced the construct of affordance to avoid the dualistic trap that requires two objects—for example, an actual fire exit (the physical object) and a constructed mental image of the fire exit (the phenomenological object). His theory of direct perception argued that people directly interacted with the actual fire exit, not with a mental image of it. By including the qualifications "for good or ill" in his definition of affordance, Gibson subsumed the value dimension (e.g., the valence of an object) within the affordance construct. Thus, the affordance construct represented the meaning of an object in terms of what people could do with it and of why they might (or might not) want to use it.

However, we suggest that it may be useful to differentiate between what is possible (i.e., what can be done) and what is desirable (i.e., what will satisfy a need or attract attention) when describing human experience. For example, in the case of the fire exit, differentiating between the possibilities for action (e.g., is a door pass-through-able?); the value or potential benefits of that action (e.g., does it lead to safety?); and the information both that specifies the capacity for action (e.g., the relative visual angle) and that presages the consequences of that action (e.g., a flashing fire exit sign) might be useful. In designing an icon on a computer interface, considering what actions are afforded (e.g., is it clickable, drag-able?); what consequences result from each action (e.g., opening or closing an application, relocating a file); and what information specifies the action possibilities and the consequences to people interacting with the computer might be useful.

Thus, as illustrated in Figure 1, we suggest three constructs that are important for bridging the generalization gap to fully address the human experience of a product. The next section introduces these three constructs as affording, specifying, and satisfying.
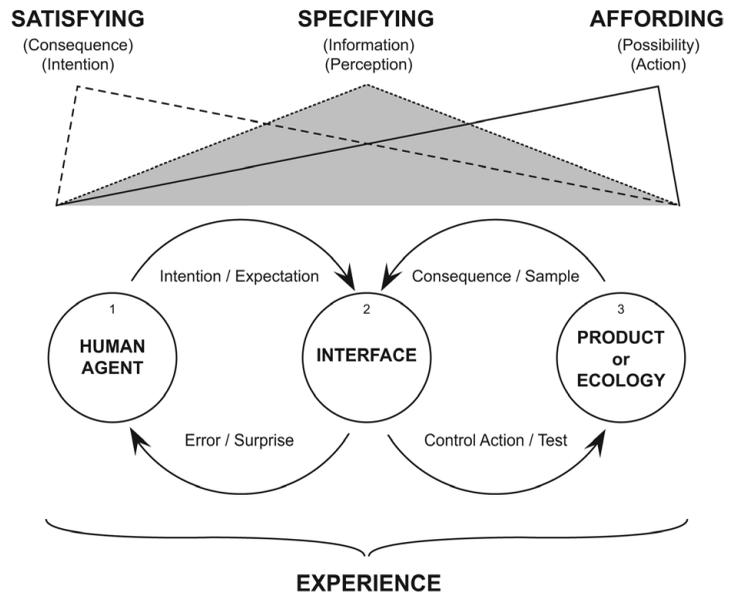
Three Dimensions of Experience
Figure 2 illustrates the three constructs of affording, specifying, and satisfying as overlapping perspectives on experience. Each perspective conveys a relation over a triad consisting of an agent (e.g., human), a representation (e.g., computer interface), and an ecology or object (e.g., a problem or work space). We chose to use verbs (i.e., action words) rather than nouns to label the perspectives. Nouns, like *affordance,* invite the reader to think of the construct as a property of a "thing" that exists apart from the relation to an acting agent. Much too easily, we can qualify a chair as having the affordance of "sit-able" without specifying *for whom.* But not all children or disabled people can comfortably sit on any

23   Gibson, *The Ecological Approach,* 138–39.

chair. Thus, the use of verbs makes more explicit the fact that these constructs refer to dynamic constraints associated with the agent–ecology (or subject–object) interaction, rather than to properties of any of the elements.[24] In the remainder of this section we elaborate on each of these three perspectives and discuss each with respect to two examples: a fire exit and the safe landing of an airplane (a situation that has been analyzed extensively in theory and experiment).

Affording
The construct of *affording* is intended to draw attention to relations that constrain action possibilities. This use is slightly different than Gibson's *affordance* because it does not differentiate between the possibilities as either "for good or for ill." Simply, the affording construct refers to possible actions, such as whether passing through an exit is possible, given its size and orientation, relative to the size and locomotion capabilities of an actor (e.g., in a wheel chair). These possibilities are "grounded" by constraints on action (e.g., size, mode of locomotion). Their description is given in terms that express the relationship (e.g., the width of the exit as 20% broader than an adult human), not in abstracted agent-independent terms, like centimeters or inches.

    For example, in describing the control of a vehicle's approach to an obstacle, the situation might be described in relation to constraints on braking and maneuvering capabilities in a way that can be coupled with both information (e.g., optical flow, as in its angular extent and rate of change) and values (e.g., the desire to avoid a collision or achieve soft contact).[25] Given a passage through a gap or up a stairway, the space might be described in

24   John M. Flach and Matthew R. H.
     Smith, "Right Strategy, Wrong Tactic,"
     Ecological Psychology 12 (2000): 43–51.
25   Brett R. Fajen, "Calibration, Information,
     and Control Strategies for Braking to
     Avoid Collision," *Journal of Experimental
     Psychology: Human Perception and
     Performance* 31 (2005): 480–501. See
     also John M. Flach, Matthew R. H.
     Smith, Terry Stanard, and Scott Dittman,
     "Collisions: Getting Them Under Control,"
     in *Theories of Time to Contact,* ed. H.
     Hecht and G.J.P. Savelsbergh, *Advances
     in Psychology Series* (Amsterdam: Else-
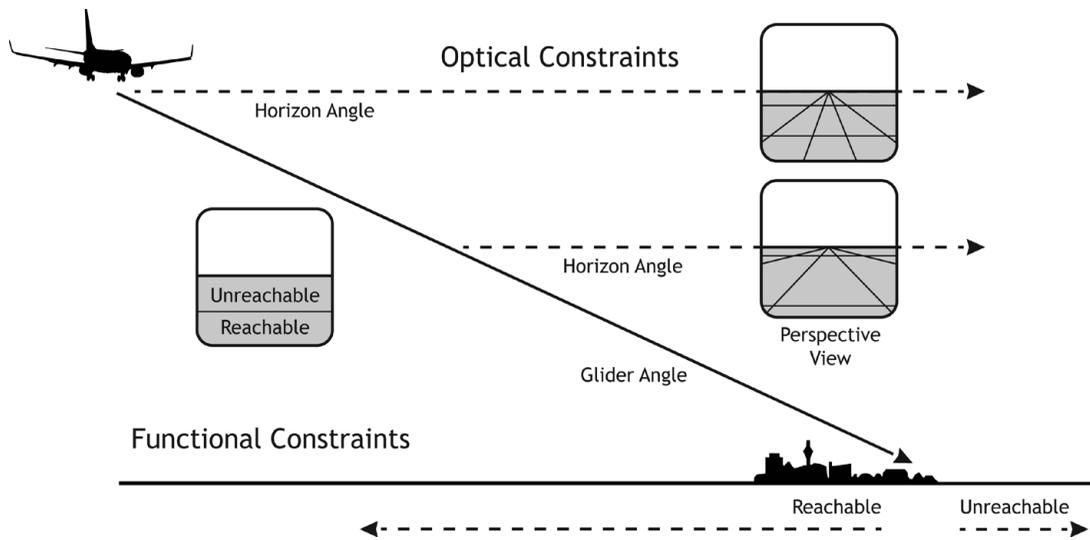   vier, 2004): 67–91.

Optical Constraints

Horizon Angle

Horizon Angle

Unreachable
Reachable

Perspective
View

Glider Angle

Functional Constraints

Reachable   Unreachable

experience-independent terms (e.g., referencing an observer-independent standard, such as a yardstick). Alternatively, the size can be described in observer-dependent terms (e.g., percent shoulder width or eye height). The use of observer-dependent terms makes the mapping to information (e.g., optical angle or flow) and to value (e.g., effort or ease of passage) much more obvious, leading to greater insight into the experience of the space.[26]

Specifying

The construct of specifying is intended to draw attention to the constraints on information that are grounded within the interface or representation. For example, in designing a fire escape, the appearance of the door is important: Emergency exits should not be camouflaged. (In times past, they were "hidden" in mental institutions to keep wandering patients from trying to leave, or were decorated in "fashionable," elegant circles with prints of book cabinets.) Specially lit symbols often are required by law in public spaces, so that the exit can be identified as a passage way (affordance) that leads to safety (desirable consequence), even when visibility is reduced by smoke.

Langewiesche elegantly describes the information needed for landing an aircraft safely (see Figure 3). He notes that the visual information available to a pilot about a position on the ground can be described either in terms of Euclidean coordinates (altitude, forward distance) or in terms of angular coordinates (degrees below the horizon). He describes why angular coordinates are preferable with respect to the function of controlling flight:

> …it is angle, rather than actual height and distance, that matters. Here is why. In a given ship, of given gliding angle, it is always the same point on the ground you can reach in a glide, regardless of your altitude; the same point,

26 William H. Warren, Jr., "Perceiving Affordances: Visual Guidance of Stair Climbing," *Journal of Experimental Psychology: Human Perception and Performance* 10, no. 5 (1984): 683–703; William H. Warren, Jr., and Suzanne Whang, "Visual Guidance of Walking Through Apertures: Body-Scaled Information for Affordances," *Journal of Experimental Psychology: Human Perception and Performance* 13, no. 3 (1987): 371–83.

that is, in terms of angle-under-the-horizon. Say your ship's gliding angle is 1:5; this means you can in a glide always reach any point that lies 10 degrees under your horizon, or steeper. This statement (true only in still air) must be thoroughly understood.[27]

And if you have understood what has been explained concerning angular vision, you will also understand this: How far the glide line lies below your horizon is entirely independent of your height; at any height, the glide line is the same distance (angular distance, in terms of degrees) below your horizon. As your height changes in the glide, both the horizon and the glide lines will be at different points on the terrain below you; but the horizon will always be at the same height as your eye; and the glide line will be the same number of degrees below the horizon; and the relation of horizon and glide line will not change.[28]

Langewiesche is describing what Gibson would later refer to as optical structure. That is, a fixed angular distance below the horizon specifies the glide capability of the aircraft (an affordance). This information allows the pilot to directly see or discriminate between positions that are reachable in a glide and positions that are beyond the glide capabilities of the aircraft and so cannot satisfy the goal of safe flight. Langewiesche's descriptions of piloting skills likely were one of the inspirations that led Gibson to imagine the possibility of direct specification of affordances.

Lee later argued that a purely optical property—for example, Tau, which is the optical expansion rate of an object one is approaching, such as the runway—specifies the time it takes to hit the goal (e.g., the runway), without the need for accurate judgment of the Euclidean dimensions of distance and speed.[29]

Satisfying

The satisfying dimension addresses the value or quality of the consequences of possible actions. One obvious aspect of satisfying is the goal or intention of the designer and/or human agent: To what extent does a design support the functions that the designer intended to provide or that the operator desires? For the fire exit, a door that makes possible a quick and easy passage to safety is "good"; a door that slows movement or that is difficult to pass through is "bad." A long, smooth, dry runway without obstructions allows for a comfortable and safe airplane landing while a rutted, wet surface with cross traffic is much less desirable.

The satisfying dimension draws attention to the quality of an experience relative to the intentions of an agent (e.g., the user or designer). Achieving the functional goals of the system often can

27 Wolfgang Langewiesche, *Stick and Rudder* (New York: McGraw Hill, 1944), 271–72.

28 Ibid., 273.

29 David N. Lee, "A Theory of Visual Control of Braking Based on Information About Time-to-Collision," *Perception* 5 (1976): 437–59. See also Matthew R. H. Smith, John M. Flach, Scott Dittman, and Terry Stanard, "Monocular Optical Constraints on Collision Control," *Journal of Experimental Psychology: Human Perception & Performance* 27, no. 2 (2001): 395–410; and Terry Stanard, John M. Flach, Matthew R. H. Smith, and Rik Warren, "Learning to Avoid Collisions: A Functional State Space Approach," *Ecological Psychology* 24, no. 4 (2012): 328–60.

be accomplished in multiple ways, and the satisfying dimension provides a basis for judging the relative attractiveness of the various options. This multiplicity raises questions of quality:[30] Is there a best way? Is one solution more efficient, more robust, more resilient, safer, or more elegant than another? The satisfying dimension concerns the criteria associated with any factor that might lead to a preference among the various alternatives.

In cognitive systems, satisfying might be the most important dimension with respect to predicting behavior.[31] For example, aerodynamics determines the possible trajectories a pilot might choose (i.e., what's afforded), and information determines which trajectories will be controllable (i.e., that provide the specific information feedback needed for stable control). Together, these two dimensions determine what the pilot *can* do skillfully, but they are not sufficient to predict what the pilot *will* do. Anticipating what a pilot *will* do requires the consideration of a value system. What is the pilot trying to accomplish? What are the potential payoffs and hazards? What are the pilot's preferences?

In addition to the purely utilitarian values typically associated with function, aesthetic qualities might also affect the quality of experience in terms of satisfying.[32] Research by Damasio suggests that adapting to the demands of everyday life might require cooperation between emotional and logical brain centers, such that emotional centers might shape experience by triggering actions and modulating attention to consequences.[33] Thus, aesthetic qualities might be important in engaging or inspiring people so that they do the things necessary to achieve success in a complex domain. For example, an aesthetic appreciation might be essential in sustaining the effort needed to learn how to fly or to play a musical instrument skillfully.

Combining the Three Perspectives for Designing
The three dimensions nicely align with the what, how, and why questions that recently have gained popularity in design narratives.[34] *What* possibilities are afforded, *how* can the possibilities be made apparent to a potential user, and *why* would one possibility be more desirable than another? Figure 4 expands Gaver's two-dimensional diagram, illustrating the interactions between affordances and perceptual information to include the satisfying dimension.[35] It illustrates how the three dimensions—affording, specifying, and satisfying—combine to determine peoples' abilities to control a system, where control reflects the ability to skillfully take advantage of opportunities and avoid hazards. For example, in the design of a fire exit, this matrix suggests potential directions for improvement.

30 Robert Pirsig, *Zen and the Art of Motorcycle Maintenance* (New York: Harper Collins, 1974).
31 See, e.g., Flach and Voorhorst, *What Matters;* and Simon Sinek, "Start with Why," https://www.youtube.com/watch?v=sioZd3AxmnE (accessed July 18, 2016).
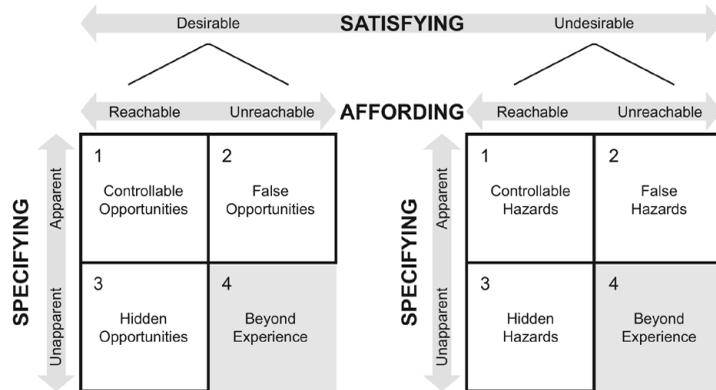32 Donald A. Norman, "Emotion & Design: Attractive Things Work Better," *Interactions* 9 no. 4 (2002): 36–42.
33 See, e.g. Antonio Damasio, *Descarte's Error: Emotion, Reason, and the Human Brain* (New York: Putnam, 1994).
34 Sinek, Start with Why.
35 Gaver, "Technology Affordances."

Skilled control requires that the opportunities and the hazards be well specified. For example, an efficient escape requires that people can discriminate between the exits that lead to safety and other potential passages that might lead to increased danger. This goal state is reflected in Cells 1 and 5 of the matrix. The other cells in the matrix suggest potential control problems.

Cells 2 and 6 reflect designs where the representations suggest or specify possibilities that are unattainable (False Opportunities) or where the representations suggest dangers that do not exist (False Hazards). For example, a door that appears to be an exit but that is locked would be a false opportunity; an apparent but ultimately nonfunctioning lock on a passable exit would be a false hazard. False opportunities are likely to frustrate users who try to accomplish things that simply are not possible with the technology that they have. False hazards might intimidate people so that they avoid using the system or might create unnecessary anxieties that interfere with the learning process or the pleasure in using a system.

Cells 3 and 7 reflect designs in which the system opportunities or hazards are not well represented in the interface. In the case of opportunities (Hidden Opportunities), people might be unaware that the capabilities or possibilities exist or they might be unable to skillfully achieve the opportunities because of inadequate feedback. For example, an exit that is disguised as a bookcase or that can't be seen because of smoke would be a hidden opportunity. In the case of hazards (Hidden Hazards), the lack of adequate representation means that the dangers are not well specified. That is, people do not have adequate information to recognize the potential for danger or the adequate feedback to avoid or recover from the danger. Thus, people can be trapped by these hidden dangers—for example, a door that appears to be a fire exit but that actually leads deeper into a burning building.

Cells 4 and 8 are indicated as being outside a person's possible experience: These cells reflect things that are impossible to do and for which no information is available. Cell 4 reflects a challenge to design in terms of potential but unrealized possibilities; planning to add fire exits where there were none is one example. Note that to realize this potential, the design must both afford exiting and provide information to specify it. Cell 8 reflects a challenge for designers because they have to recognize that new hazards might be introduced as a function of design innovations. For example, increased automation in aviation systems has resulted in new classes of errors (e.g., mode errors).[36] In the case of exit doors, doors that are activated automatically might lose functionality if power is lost during a fire. Thus, the loss of power creates a new hazard. Is the information required to manually open the exit provided? Anticipating this emergent hazard and then providing the information to discriminate between the automatic and manual modes and to operate the door in both the common (automatic) and rare (manual) modes is a new challenge for designers.

As a final example, consider the design of a drug delivery system. It should be able to deliver the drugs (affording) in safe and effective dosages (satisfying), and it should be clear to the operating nurse how delivery can be effected and what dosage levels are being delivered (specifying). This description provides the extent of the design considerations of 30 years ago, leaving to the nurse the responsibility for administering the proper dosage. Today, however, designers are beginning to go beyond usability to enable shared responsibility for patient safety. For example, can the design help the nurse to discriminate between safe and unsafe dosages? Should it make deliveries of unsafe dosage levels impossible (i.e., eliminate the hazard from the space of possibilities)? Should it at least require extra effort and confirmation (increasing the likelihood that a potential hazard will be apparent)?

Thus, our claim is that fully appreciating human experience in terms of either sensemaking or control requires that all three dimensions be considered. Affording reflects the constraints on action (e.g., the field of possibilities or the process dynamics). Specifying reflects the feedback that is available to control actions and anticipate consequences. Satisfying reflects the underlying value system in terms of functional significance (meaningfulness) or in terms of the criteria for success (e.g., payoff matrix or cost function or emotional satisfaction).

36   Charles Billings, *Aviation Automation: The Search for a Human-Centered Approach* (Mahwah, NJ: Erlbaum, 1997).

To Recapitulate: Affordances

The primary value of the affordance construct was that it brought physical action back into the field of cognitive psychology, which had framed problems of perception and cognition as "logical functions of mind" (i.e., as a symbol processing system), rather than as embodied functions that could enable successful adaptation to complex ecologies. The affordance construct forced scientists and designers to attend to the coupling of perception and action in service of achieving success in a world that includes both physical and logical constraints.

In the design context, confusion arose as the construct of affordance was stretched to cover the constraints not only on action, but also on information and value. However, preserving the distinctions between action constraints, perceptual constraints, and value constraints is valuable for both designers and cognitive scientists. At a theoretical level, these distinctions help to connect the dots between control theory, information theory, semiotics, ecological psychology, and functionalism. At a practical level, these distinctions suggest different categories of analysis and of intervention:

1. *Affording: Constraints on action.* What new actions or functions become possible with evolving technologies? What are the new opportunities? What are the new hazards?
2. *Specifying: Constraints on information.* How do we represent the opportunities/hazards and the possibilities/capabilities to people so that they can act properly/skillfully to achieve satisfying results? How do we close the loop (provide feedback) so that people are in control?
3. *Satisfying: Constraints on value.* Why are some actions preferred over others? Why are some consequences more desirable than others? Why are some products more attractive than others?

In sum, we propose that the constructs of affording, specifying, and satisfying provide a common ground to facilitate communications between designers and cognitive scientists so that designers can better apply the insights from cognitive science to improve how people experience their products and so that cognitive scientists can gain deeper insights into human experience from evaluations of design successes and failures. In other words, we hope that these constructs help to close the gap between a product-centric view of the world and a human-centric view of the world so that we can better understand and predict how people will experience a product or situation.

37 See, e.g., Donald A. Norman and Stephen W. Draper, ed., *User-Centered System Design* (Hillsdale, NJ: Erlbaum, 1986); Marc Hassenzhal, *Experience Design: Technology for All the Right Reasons* (San Rafael, CA: Morgan & Claypool, 2010) and Peter Wright and John McCarthy, *Experience-Centered Design: Designers, Users, and Communities in Dialog* (San Rafael, CA: Morgan & Claypool, 2010); and John M. Flach and Cynthia O. Dominguez, "Use-Centered Design," *Ergonomics in Design July* (1995): 19–24, respectively.

38 See, e.g., Todd et al., *Ecological Rationality;* and Ester Thelen and Linda B. Smith, *A Dynamical Systems Approach to the Development of Cognition and Action* (Cambridge, MA: MIT Press, 1995); Suchman, *Plans and Situated Actions;* and Edwin Hutchins, *Cognition in the Wild* (Cambridge, MA: MIT Press, 1995); and George Lakoff and Mark Johnson, *Philosophy in the Flesh;* and Andy Clark, *Being There: Putting Brain, Body, and World Together Again* (Cambridge, MA: MIT Press, 1997), respectively.

Some readers might argue that bridging the gap is not sufficient; rather, we should be striving to close the gap. From the design side, this desire is reflected in movements toward user-centered, experience-centered, and use-centered design.[37] On the cognitive science side, this desire is reflected in movements toward ecological psychology, situated cognition, and embodied cognition.[38] We certainly are very sympathetic with these initiatives and agree that when the distributions illustrated in Figure 1 move closer to the center, both disciplines benefit greatly. However, we also have a healthy respect for inertia and realize that this convergence needs to be accomplished one small step at a time. We hope that recognizing the value of shared constructs situated in the common ground of human experience not only facilitates communications between the disciplines of design and cognitive science, but also is a small step toward convergence of both disciplines toward an experience-centered perspective.

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