ECOLOGICAL PSYCHOLOGY, *12*(1), 65–69


# An Affordance-Based Perspective on Human–Machine Interface Design

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The distinction between events and affordances, as offered by Stoffregen (this issue) in the target article, parallels one that is useful for understanding issues of human-interface design. The emphasis within interface design has typically been on the representation of events, but the conceptual basis of this approach has lacked any coherent structure that can drive research or support design practice. In contrast, affordance theory has the potential to guide a research program that could provide a coherent basis for the practice of interface design. In this commentary, the need and the opportunities are illustrated with reference to examples from interface design issues for the modern aircraft cockpit.

Stoffregen (this issue), in the target article, argues that affordances are static or dynamic[1] properties of objects and surfaces specified with reference to behavior and scaled as action-relevant properties of the animal. Events are also static or dynamic properties of objects and surfaces but are not specified with reference to behavior and are not scaled as action-relevant properties of the animal. This distinction parallels one my colleagues and I (Lintern, Waite, & Talleur, 1999) made for human–machine interface design. The basis for this approach is a three-way classification: functional properties (affordances), properties that are not functional in isolation but can be used to derive functional properties via a computational or inferential process (events), and properties that are irrelevant to current functional goals (nonevents).

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[1]To remain consistent with Stoffregen's (this issue) target article, the term *dynamic* is used here to refer to motions and the forces that cause them. Other uses of this term refer to a trajectory as it unfolds over time or a vector field without reference to force.

The central theme of this approach, which we have characterized as *functional interface design,* is to make the affordances of the system apparent to the operator. In contrast, the usual approach is to represent eventlike properties at the interface. There are static events, such as fuel capacity, and dynamic properties, such as elapsed time or mass transfer. At best, reference to eventlike properties requires inference or judgment on the part of the operator. At worst, it requires demanding, error-prone calculations. An affordance-oriented design philosophy could eliminate much of that by direct depiction of the functional properties. There are essentially two issues: one relating to the nature of the properties that should be represented at the interface and the other relating to the organization of those property representations. Affordance theory can inform both of these issues, although Stoffregen's (this issue) contrast of events and affordances is relevant specifically to the first of them.

There is no dearth of information in the modern aircraft cockpit, but pilots somehow miss critical information at critical times. The loss of American Airlines flight 965 at Cali, Colombia, in December 1995 (Lintern et al., 1999) and the losses of China Airlines flight 140 at Nagoya, Japan, in April 1994 and American Eagle flight 4184 over Indiana in October 1994 (Lintern, 1995) offer examples of the tragic consequences. It appears that the new forms of computerized automation now used in modern aircraft induce high cognitive workload and specific types of errors (Sarter & Woods, 1994). More reliable and robust technology has ensured that commercial aviation is safer today than it ever has been, but embedded within that good news is a troubling increase in accidents that have resulted from a breakdown of information management. The accidents cited earlier, together with a host of others, have occurred because the aircrew could not find, could not remember, did not notice, or misinterpreted critical information. Often these failures occur because the critical information is hidden or its meaning is obscure. At other times, the aircrew is distracted by the obscure meaning of competing information that is consuming their attention.

Typically, information to be presented at an interface has been selected on the basis of characteristics of the sensor suite without reference to system capabilities and is organized at the interface in an arrangement that conforms to an engineering view of how the machine operates. That information is provided so that operators may ascertain selected static and dynamic properties of the machine to be controlled. Modern computerized machines have relieved designers of many of the physical constraints associated with the older style physical and mechanical displays, and there are now far fewer constraints on the amount and type of information that can be presented at an interface. Unfortunately, these technological developments have led to more problems than they have resolved, and this is specifically (although not especially) true in aviation.

It would be wrong, however, to blame technology. Rather, it is the way interface designers have exploited the possibilities offered by technology. New sensors might be designed and other forms of information might be computed from available sensor information to support an affordance-oriented interface that matches displayed information to system[2] capabilities that would support more robust and cognitively economical performance. That information might also be organized in a hierarchical manner compatible with the functional needs of operators, much in the manner that affordances appear to be organized in the natural world (Rasmussen, Petjersen, & Goodstein, 1994; Vicente, 1999).

The development of the part of our argument relevant to the event-affordance distinction was influenced by the research of Stanard, Flach, Smith, and Warren (1996), in which the information used for control of a virtual aircraft in a collision-avoidance task was determined by the nature of the dynamics to be controlled. Time-to-contact information was used by participants for a system in which the avoidance maneuver had to be initiated at a fixed time from collision, whereas distance information was used by participants who used a system in which the avoidance maneuver had to be initiated at a fixed distance from collision. This work suggests that for the design of information displays, the dynamic response of the system must be analyzed to identify the information that should be presented at the interface.

Dinadis and Vicente (1999) did that in the development of a range display for a military transport aircraft, the C130. Within aviation, fuel states are generally represented by weight or volume, which leaves the aircrew with the task of computing potential range to ensure that the destination is within reach. In the modern version of the C130 aircraft, those computations take up to 1 hr of demanding work in which there is the ever-present possibility for error (Skinner, 2000). Dinadis and Vicente developed an interface for which range was computed automatically and displayed as such to the aircrew, who could then confirm by perceptual comparison (Hutchins, 1995) that the desired destination fell within the potential range. This brings the notion of affordances into the arena of designed systems, where both the requirement for action and the capability for action are represented in the same units and can be perceived as a relation.

There are, however, complexities in the calculation of potential range that were not considered by Dinadis and Vicente (1999) and that have implications for how we might use research on natural affordances for insights into the interface-design problem. In calculating potential range, an aircrew is required by regulation to allow for unscheduled diversions in flight or for events such as a loss of power from one or more engines (Galanis, Sterling, & Lintern, 1999). In addition, there is a concern with precision in that even detailed calculations will require the use of a safety margin. Guidance on how to address some relevant issues is already available within the experimental literature on affordances. Mark (1987) and Warren and Whang (1987) showed that we can adapt readily to changed system requirements, provided the appropriate information is available. Warren and Whang further

[2]*System* is used here to refer to the human operator plus the machine as an extension of human capability.

demonstrated that the critical points for behavioral transitions include a comfort (or possibly a safety) margin. More generally, affordances are available at diverse temporal and spatial scales and are nested within and overlap each other, yet we normally move comfortably within that space. The insights regarding how that is possible are likely to be informative for interface design.

One specific area of interest is in Stoffregen's (target article, this issue) distinction of action boundaries for behavioral mode selection and patterns of ambient energy for continuous control of unfolding acts. Both forms of behavior are relevant to control of designed systems. A pilot, for example, must make sure that fuel does not fall below a minimum acceptable level prior to landing and also has to maintain continuous control of the aircraft during the landing. The first form of control is in reference to an action boundary, and the second is in reference to a pattern of ambient energy. A range display of the type designed by Dinadis and Vicente (1999) specifies an action boundary for a behavioral mode, whereas descent path indicators of the style developed by Lintern, Roscoe, and Sivier (1990) enhance patterns of ambient energy for continuous control.

Thus, Stoffregen's target article (this issue) captures some of the concerns of functional interface design. Human–machine interface design has typically been an atheoretical activity or, at best, one in which the more popular information-processing views have been used to justify design solutions without shaping then in any substantive way. A consistent theme recognizes that users can exploit the information made available at an interface by perceptual forms and changes in those forms (i.e., events), but that theme does not recognize any link between the nature of the information and the nature of the control requirements. Although it is sometimes said that system information must be written in the language of control action (Hutchins, Hollan, & Norman, 1986), it remains unclear what that means in general terms because of the lack of any integrative concept. As a result, interface design is a fragmented endeavor in which design solutions lack any substantive coherence within or across work domains. Affordance theory has the potential to change that by bringing to the endeavor a unifying theoretical structure.

## REFERENCES

Dinadis, N., & Vicente, K. J. (1999). Designing functional visualizations for aircraft system status displays. *International Journal of Aviation Psychology, 9,* 241–269.

Galanis, G., Sterling, G., & Lintern, G. (1999). Challenges facing interface design for safety critical systems. In R. S. Jensen, R. Lavis, B. Cox, & J. D. Callister (Eds.), *Proceedings of the tenth international symposium on aviation psychology* (pp. 421–426). Columbus: Ohio State University.

Hutchins, E. (1995). *Cognition in the wild*. Cambridge, MA: MIT Press.

Hutchins, E. L., Hollan, J. D., & Norman, D. A. (1986). Direct manipulation interfaces. In D. A. Norman & S. W. Draper (Eds.), *User centered system design: New perspectives on human–computer interaction* (pp. 87–124). Hillsdale, NJ: Lawrence Erlbaum Associates, Inc.

Lintern, G. (1995). Flight instruction: The challenge from situated cognition. *International Journal of Aviation Psychology, 5,* 327–350.

Lintern, G., Roscoe, S. N., & Sivier, J. E. (1990). Display principles, control dynamics, and environmental factors in pilot training and transfer. *Human Factors, 32,* 299–317.

Lintern, G., Waite, T., & Talleur, D. A. (1999). Functional interface design for the modern aircraft cockpit. *International Journal of Aviation Psychology, 9,* 225–240.

Mark, L. S. (1987). Eyeheight-scaled information about affordances: A study of sitting and stair climbing. *Journal of Experimental Psychology: Human Perception and Performance, 13,* 361–370.

Rasmussen, J., Petjersen, A. M., & Goodstein, L. P. (1994). *Cognitive systems engineering*. New York: Wiley.

Sarter, N. B., & Woods, D. D. (1994). Pilot interaction with cockpit automation. II: Operational experiences with the flight management system. *International Journal of Aviation Psychology, 4,* 1–28.

Skinner, M. (2000). *RAAF C-130J-30 strategic workload evaluation* (Client Rep. No. DSTO–CR–0139). Melbourne, Australia: Defence Science and Technology Organisation.

Stanard, T., Flach, J. M., Smith, M., & Warren, R. (1996). Visual information use in collision avoidance tasks: The importance of understanding the dynamics of action. In *Third Annual Symposium on Human Interaction with Complex Systems* (pp. 62–67). Los Alamitos, CA: IEEE Computer Society Press.

Vicente, K. H. (1999). *Cognitive work analysis: Towards safe, productive, and healthy computer-based work*. Mahwah, NJ: Lawrence Erlbaum Associates, Inc.

Warren, W. H., & Whang, S. (1987). Visual guidance of walking through apertures: Body-scaled information for affordances. *Journal of Experimental Psychology: Human Perception and Performance, 13,* 371–383.