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GUEST EDITORIAL

Affordances in design

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1. INTRODUCTION

This Special Issue of *AI EDAM* is devoted to invited papers concerned with affordances in design. Its goal is to examine the strengths and weaknesses of the concept of affordances, survey their use, predict future use, and consider their integration with other design methods.

The genesis of this Special Issue was at the ASME 2013 Design Theory and Methodology conference in Portland, Oregon, where one of the guest editors (D.C.B.) and the *AI EDAM* Editor in Chief were discussing possible topics for special issues with attendees. Several believed that it was time for a special issue about affordances, agreeing to participate, with one (J.R.A.M.) agreeing to co–guest edit. After that, we looked for a set of authors who had a wide range of research activities involving affordances in order to provide an overarching view of the active work. We also sought a contribution from Don Norman, an influential writer about affordances, and are happy to have his comments to open this Special Issue.

This editorial provides a brief, intuitive introduction to affordances and some of the issues that surround them, as well as a brief summary of the papers in this Special Issue. In the design area, affordances are usually considered to be *opportunities for action* that are provided by an artifact to a human. The classic example from interface design is that "a button affords pushing"; that is, it provides an opportunity for a pushing action.

Some authors make a distinction between "behavior" and "action," with the latter intended to mean behavior directed toward achieving some goal. Hence, in general, affordances are *opportunities for behavior*.

Affordances relevant to designing can be considered to arise from user–artifact interactions, as well as from artifact–artifact interactions: although the former is more commonly agreed upon. See Maier and Fadel (2003) and Burlamaqui and Dong (2014) for more discussion, pro and con. The argument revolves around whether devices as well as human users can "behave."

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Not all affordances can be seen as desirable: for example, very sharp edges that afford cutting built into artifacts intended for human manipulation. Designing using affordances centers on keeping and reinforcing the desired affordances while eliminating or hiding the undesired affordances (Maier & Fadel, 2001, 2003).

One challenge in this field is that researchers often mean slightly different things by the term *affordance*, so we have requested that authors try to be careful to characterize exactly what they mean by the term in their work. For those readers who are confused by the term, you are not alone! However, it does help to think of affordances as *opportunities*. As such, affordances are real and recognizable, but they are not physical things, nor are they actions.

Chemero (2003) argues that affordances are *relations* between "particular aspects of animals" and "particular aspects of situations." More colloquially, the environment affords a behavior to an animal because of the relationships between the environment and the animal. These relationships determine the compatibility between the environment and the animal, allowing the affordances to exist (Shaw et al., 1982).

For this Special Issue, we can assume the existence of a special part of the environment that is an actual or proposed designed artifact. Note that the physical configurations of the device, the environment, and the user play a role in the affordance (Shaw et al., 1982); they provide the "particular aspects" mentioned above, and play a part in determining "compatibility."

Discovering opportunities requires the animal to *perceive* features of situations (Shaw et al., 1982). The animal must be able to *recognize/notice* that a feature can be *associated* (i.e., the "relation") with a certain behavior (i.e., a way of acting). This association might be very direct, or might be reasoned out. Of course, the animal needs to currently have an "ability" to actually behave in that way.

Clearly, events can change the environment, leading to changes in the affordances, even if the abilities stay the same. Conversely, changes to the animal may change its abilities, so that the animal–situation relationship is different, and *potential* affordances may not be realizable (i.e., the animal cannot act). In addition, animals may have abilities, but may fail when attempting them (e.g., tripping when climbing stairs, or trying to open a locked door), so an affordance really is an opportunity, not a promise.

Brown and Blessing (2005) connect affordance to function (also see Vermaas, 2009; Ciavola et al., 2015, for extensions to that analysis). Brown and Blessing point out that when an artifact provides a function to a user, it has a set of interactions or relationships with the environment (where the environment includes the user) so that those interactions play a *desired* role for the user. The interactions may then satisfy preconditions for one or more actions in a plan to achieve a goal. Hence, the interactions are "desired" because the user is trying to reach a goal, and the user's actions are targeted toward that goal. However, it is still the case that the *relationship* between the user (the "animal") and the artifact in the environment (the "situation") affords a behavior.

However, detecting and recognizing features of situations that might afford a behavior is difficult. Affordances (and ultimately functions) depend on what features of the situation (more explicitly, the designed object) are recognized. Although this will depend on the relationship that is established, people tend to fixate on standard features that correspond to normal and useful affordances.

William James (1890) famously points out that features of situations that get noticed might vary depending on the current task and goal.

> There is no property ABSOLUTELY essential to one thing. The same property which figures as the essence of a thing on one occasion becomes a very inessential feature upon another. Now that I am writing, it is essential that I conceive my paper as a surface for inscription. . . . But if I wished to light a fire, and no other materials were by, the essential way of conceiving the paper would be as a combustible material. . . . The essence of a thing is that one of its properties which is so important for my interests that in comparison with it I may neglect the rest.

Hence, it should be clear that affordances may similarly be affected by goals. While in general an affordance is a goal-free concept, examples such as a knife affording pointing or a pencil affording piercing (e.g., punching a hole in paper) appear to be enabled by goal-driven reasoning about the opportunities for useful action that the artifact provides. In these cases, the preconditions for desired actions might be used to guide the recognition of features; that is, they are *desired* affordances. In general, to quote Jack Dixon (Brown, 2003), a feature is "anything about the thing being designed that's of interest."

The issue is made worse by the realization that it is possible that user action might be afforded by artifact behavior (e.g., vibration) or by material properties (e.g., flexibility): that is, not just the "form" of the artifact. Although features refer to form (including configuration) for most researchers, it is interesting to consider other possibilities, in order to extend the theory that relates features to affordances.

Thus, in summary, we have established that for affordances, the key aspect of the environment is a *feature*, and the key aspect of the animal is an *ability*. Hence, we have the relationship between the environment and the animal,

$$\text{Affords-f(feature, ability)},$$

where f is a behavior. Clearly, the affordances depend on this relation, as features change depending on the situation, and abilities change according to the animal and the condition of the animal (e.g., age or health). In order for the affordances to be recognized, the features must be detectable (i.e., perceivable) by the animal:

$$\text{Detects(animal, feature)},$$

and the features must be recognized as relevant:

$$\text{Recognizes(animal, Affords-f(feature, ability))}.$$

Some authors (Chemero included) argue that this is often much more direct such that there is no intermediate reasoning (or there does not appear to be):

$$\text{Detects(animal, affordance-of-f)}.$$

We need to be careful with the terms *perception of affordances, perceptible affordances,* or *perceived affordances*. Gaver (1991) argues that perceptible affordances are those "in which there is perceptual information available" that allows an association with an ability. However, it is hard to consider "perceiving" alone to be the recognition of an opportunity, because all that is being perceived is a feature: at least if perception is strictly about becoming aware of something due to the senses (Still & Dark, 2013). Unfortunately, dictionaries allow it to mean "realizing" as well, so there is ambiguity. However, the recognizing step where the animal finds the relationship between the perceived feature and the ability may well be highly "compiled" (like a skill) and very direct (Still & Dark, 2013).

The relationship between a feature and an ability depends on *detecting features* appropriately, as well as *characterizing abilities* correctly. Neither a human nor a computational design system might do these very well. In addition, the matches between a feature and an ability may be complex or even partial.

The idea of the *quality* of the affordance has been proposed, but it is complex. For example, from a negative point of view, the quality of "affords sitting" might be due to poor perception of the chair's structure or properties, it might be due to poor perception of some aspect of the environment, it might be due to an imprecise or incorrect estimation of the user's abilities, or it might be due to the inexact match between the features and the abilities (i.e., the strength of the association). There is also the possibility that the quality could be seen as "how well" the opportunity that affordance provides can be taken advantage of by actual action (McGrenere & Ho, 2000).

In the literature, we see affordances such as "affords sitting" and also "affords resting." Clearly, these affordances are related but different. To account for this difference, it has been proposed that affordances have levels and might be seen as hierarchically organized. This might be because abilities are related in some way and form hierarchies. For example, sitting is a kind of resting. In addition, the ability to walk is at a higher level than the ability to move a leg, due to the relationship between primitive and composed actions. It might also be because the features themselves are composed in a similar manner; for example, a handle is part of a door (Gaver, 1991). Maier and Fadel (2001) also propose additional structure on affordances by listing types of affordances, such as "affords sustainability" and "affords manufacture."

Another issue to introduce concerning affordances is a version of the "if a tree falls in a forest, does it make a sound" question. That answer depends on a definition: whether "a sound" is defined as vibrations in the air, or as what is perceived by an animal when these vibrations affect the eardrum.

For affordances, the question is what happens if there is no animal? Does an artifact still have affordances by itself? Chemero (2003) suggests that the "affordances do not disappear when there is no local animal to perceive and take advantage of them." Gaver (1991) makes a similar claim. In that case, they must be talking about "potential" relationships between features and animals, and hence they are *potential affordances*. A problem with that is that there are a very large number of potential relationships.

In general, it appears to make more sense to limit the existence of affordances to those due to specific, existing relationships between features and an animal. However, for practical purposes, it might be possible to know the potential users, and therefore the potential affordances could be cataloged.

However, one can talk about *intended* affordances of a designed object, because designed objects have built in functionality: their "designed purpose" (Burlamaqui & Dong, 2014). In that case, the object is considered to be capable of providing opportunities for specific actions to an intended future user. However, a designer may have inadvertently created a *phantom* affordance: that is, one that is not intended, and is not relevant (Still & Dark, 2013). A *false* affordance, in contrast, is one where a "nonexistent affordance" is recognized, "upon which people may mistakenly try to act" (Gaver, 1991).

A final issue concerns the naming of affordances. To name them, some writers have taken the name of the action afforded and added *ability* to it: for example, sitability, climbability, and throwability for chairs, stairs, and balls, respectively. Given this scheme, we need to be careful not to use "affords throwability," because we have already defined the format to require reference to an action: for example, "affords throwing." Even "affords sustainability" appears to be a problem because it is not in the "affords <action>" format; hence, it might be better written in a format such as "creates <affordance name>" (e.g., "creates sustainability").

Having given a brief overview of some of the issues that surround the concept of affordances we move to introducing the papers in this Special Issue.

2. THE CONTRIBUTIONS

By considering the role of use plans as a mitigating concept between function and affordance, Auke Pols presents a novel definition of the function of an artifact in terms of its affordances. His paper, "Affordances and Use Plans: An Analysis of Two Alternatives to Function-Based Design," builds on a considerable literature base from philosophers of technology, a community that engineering design researchers would do well to pay more attention to. Pols raises many philosophical questions pertaining to the implementation of affordances that remain as open research avenues.

Jonathan Maier's paper, "On the Computability of Affordances as Relations," presents a first attempt at forming a mathematical representation of affordances based on relations. He uses an existing notation to describe affordances, attempting to account for all aspects of their meaning, including the quality of an affordance relation. Maier continues by examining the computability of affordances, suggesting that Gibsonian direct perception should be computable. He concludes with examples, including analysis of the computability of the affordance of turnability of gears.

Thomas Stoffregen and Bruno Mantel bring a fresh perspective to this Special Issue with their paper, "Exploratory Movement and Affordances in Design." In this fascinating paper, Stoffregen and Mantel review the considerable literature and experimental evidence on the importance of how users explore artifacts in order to gather information about the available affordances. From this scientific basis, the authors go on to recommend practical advice for designers. In particular, they argue that designers should create artifacts that allow users to explore (or discover) all the affordances of the artifact, that is, all the ways in which the artifact should be used.

With the paper, "Three Methods for Identifying Novel Affordances," by L.H. Shu et al., this Special Issue turns away from higher level theoretical considerations and toward design practice. Because the design space opened up by affordance-based design is so large, methods such as those offered in this paper are particularly useful. Their method introduces the concept of "affordance of absence," an interesting idea with multiple dimensions that allows the designer to utilize empty physical space to add value to a product, among other applications. Shu et al. also describe how to identify novel affordances from lead users as well as from consumer product reviews.

Phillip Cormier and Kemper Lewis, in their paper, "An Affordance-Based Approach for Generating User-Specific Design Specifications," apply the concept of affordances in order to handle both consumer commonality and consumer variation. Cormier and Lewis propose a method to enable designers to capture individualized design specifications. This approach meshes beautifully with the overall affordance-based design framework, which suggests that the affordances of a product do depend upon individual users. Their method is demonstrated using a case study of a child stroller.

In their paper, "Toward Automating Affordance-Based Design," Ivan Mata et al. describe their efforts at generating an ontology to be used by software systems to automate the embodiment and detailed design phases of the affordance-based design process. Such automation, they argue, would enable designers to better share design knowledge and collaborate. Their work builds on previous attempts from the literature in ecological psychology at creating ontologies supporting affordances, but is tailored to implementation in a software environment.

Finally, in his paper, "A Methodology of Design for Affordances Using Affordance Feature Repositories," Yong Se Kim present research that implements an affordance-based design method in a computer-supported environment. Kim designs a database of the known affordances of typical part features (i.e., a feature repository), and then he proceeds to populate it. Kim then demonstrates several case studies showing how human designers can use the repository in order to guide their design of new products: by leveraging the captured knowledge of how previous designers have created similar affordances. Their case studies include a drink tumbler and a handcart, and involve both novice and experienced designers.

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