

# On the Evolution of a Radical Concept: Affordances According to Gibson and Their Subsequent Use and Development

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## Abstract

James J. Gibson, the founder of ecological psychology, introduced a radical empiricist approach to perception and action centered on direct perception in naturalistic environments that was counter to popular representational views of his time. This direct perception approach and the associated introduction of the affordance concept have been extremely influential in several fields of study. However, since its inception, the affordance concept has evolved in a manner such that it now deviates significantly from Gibson's original intention. This review follows use of the affordance concept by four sets of influential experimental psychologists: Gibson, Donald Norman, Mike Tucker and Rob Ellis, and Daniel Bub and Michael Masson. Particular attention is paid to the manner in which they applied the concept and the contributions provided by each set of researchers. The primary goal of this review is to determine what cognitive psychologists can take away from developments within the field and what considerations should be taken into account when using the term *affordance*. Having a more thorough understanding of the factors that led to the concept of affordance and its recent reformulations will better equip cognitive psychologists and, by extension, human factors researchers to further advance the study of perception–action relations.

## Keywords

affordances, cognitive psychology, ecological psychology, mental representation

Perhaps the composition and layout of surfaces *constitute* what they afford. If so, to perceive them is to perceive what they afford. This is a radical hypothesis, for it implies that the “values” and “meanings” of things in the environment can be directly perceived.

—James J. Gibson (1979, p. 127)

The human perceptual system has evolved in service of promoting survival, whereby humans can extract information from their environment to enable subsequent actions. A long history of research has been aimed at achieving an understanding of how visual perception is linked to action. As it stands, widespread evidence favors the view that perception and action are entangled with one another (e.g., Blake & Shiffrar, 2007; Creem-Regehr & Kunz, 2010; Elsner & Hommel, 2001).

Despite support for the notion that perception and action are interrelated, there is currently no consensus on how the perception of objects affects motor movements.

Consider perceiving and acting on a mug with a handle. Although this seems like a straightforward task, even a simple sequence may depend on several factors. For instance, in reaching for the aforementioned mug, would performing a reaching action be dependent on mental representations and prior experience with mugs, or would this sort of processing be unnecessary? Furthermore, would simply viewing the mug lead to automatic motor activation related to grasping the handle regardless of context? Or, alternatively, might processing be dependent on context, such as reaching for the mug to hand it to someone as opposed to reaching with the goal of taking a drink?

Over the past 40-odd years, researchers from different disciplines have attempted to answer these and other related questions. These efforts can be linked in

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part to the groundbreaking work of James J. Gibson (1979), who introduced the concept of *affordances* to describe the relationships that exist between organisms and their environments. J. J. Gibson presented the concept as “the *affordances* of the environment are what it *offers* the animal, what it *provides* or *furnishes*, either for good or ill” (p. 127). Given the popularity of the term, however, it is most likely that the current reader has come to understand affordances as the properties an object possesses that communicate possible actions to a user. Or perhaps there might be some familiarity with the term as it has been developed for use in architectural design, artificial intelligence, and social interactions, among others.

However, long before the widespread affordance concept was adopted across various disciplines, it was part of a framework that challenged how psychology itself should be approached. At the time of its creation and even to this day, Gibson’s thinking on affordances and, more broadly, his ecological approach to perception were novel and counter to commonly held opinions about perception. Thus, he has often been considered a revolutionary in the field (e.g., Reed & Jones, 1979). Since his revolutionary endeavors in the study of perception, others across disciplines have taken his concepts and developed their own lines of research. In some cases, Gibson’s influence is clearly evident, whereas in others, it is much more difficult to discern exactly what his contributions are. For this reason, it is important not only to delineate the most influential pieces of research that have stemmed from Gibson’s work but also to do so from the lens of cognitive psychology to determine what the field might learn more globally from use of the affordance concept. Although cognitive psychology is but one of several disciplines that have adopted concepts from Gibson (e.g., Wang, Lau, & Gerdes, 2018), attention is directed toward cognitive psychology because it is the dominant approach to human experimental psychology.

The current review follows a temporal sequence beginning with the work of Gibson. The factors that led to his development of the term *affordance* and what he originally intended by the term are discussed. After this discussion, the three most influential developments of the concept since its inception are considered: Donald Norman’s use of the term for the purposes of design (e.g., Norman, 1988), Mike Tucker and Rob Ellis’s use in stimulus-response (S-R) compatibility paradigms (e.g., Tucker & Ellis, 1998), and Michael E. J. Masson and Daniel N. Bub’s use and reintroduction of the role of context (e.g., Bub & Masson, 2010). Each set of psychologists has been selected carefully for heralding shifts in thinking with regard to the subject of affordance. Furthermore, the different reformulations

of the affordance concept are discussed in terms of their underlying assumptions about the role of mental representations and what the respective developments can ultimately contribute to the field of cognitive psychology. Finally, a discussion of the application of principles from both cognitive psychology and ecological psychology to the field of human factors is provided.

Here, it is important also to note what this review is not intended to address. First, the review is centered on behavioral data, and although neurological studies are referenced, findings related to brain activation patterns are discussed in a relatively cursory manner. Instead, more emphasis is paid to the more global role that neuroscience may play in understanding object perception. Second, discussion of motor activation is limited to an object’s visual representation and not its linguistic representation. After all, when discussing a Gibsonian approach to perception, evidence related to the processing of objects is of far greater import than that related to the processing of words. Finally, and most important, the review of the literature is focused on developments of the term *affordance* conducted specifically within cognitive psychology and thus outside of ecological psychology. The latter field has understandably already warranted multiple reviews (e.g., Barsingerhorn, Zaai, Smith, & Pepping, 2012).

The relevance of the present work does not lie in reviewing the current use of the term *affordance* or in the discussion of the different approaches used to study affordances. In fact, these issues have been heavily discussed by researchers across various disciplines (e.g., Chemero, 2003; Chemero & Turvey, 2007; Greeno, 1994; Proctor & Miles, 2014; Withagen, de Poel, Araújo, & Pepping, 2012). However, these reviews have not yet addressed how use of the term *affordance* has expanded past the purely psychophysical context in which it was founded to the world of motor activation. The primary contribution of this review resides in the systematic examination of how the *affordance* concept has evolved since its introduction approximately four decades ago and what subsequent iterations might contribute to our understanding of the perception–action relationship. In addition, on the basis of the most significant iterations of the term, we discuss what lessons researchers and practitioners alike might learn from the widespread adoption of a concept taken beyond its initial context.

## Gibson and the Ecological Approach to Perception

Before delving into what have come to be known as Gibson’s seminal contributions to perception and action, it is informative to first paint a picture of the factors that shaped his thinking on the subject and the

historical context in which he found himself. During World War II, Gibson joined the U.S. Army Air Force and was tasked with creating tests that would predict the performance of an Army Air Force Crew (E. J. Gibson, 2000). He was directed to predict how pilots and other service members would perform tasks such as landing planes and locating and firing at enemy planes. At the time of his assignment, psychologists were able to investigate perception through tests designed to assess depth perception and other static perceptual cues.

These testing efforts eventually led Gibson to believe that perception studied in a laboratory setting could not mirror the complexity of the real world. He expressed his frustration with how these issues were being investigated:

Nothing of any practical value was known by psychologists about the perception of motion, or of location in space itself. The classical cues for depth referred to paintings or parlour stereoscopes, whereas the practical problems of military aviation had to do with takeoff and landing. (J. J. Gibson, 1967, p. 135)

Gibson's remarks highlight what he believed to be a fundamental issue related to studying perception: Considering perception in a laboratory might ultimately diverge from the visual cues obtained when moving about in the natural world. These thoughts were echoed by some of his contemporaries who referred to the stimuli used in traditional laboratory settings as "non-sense" (Reed & Jones, 1979, p. 191)

Beyond his criticisms of the work being conducted in psychology laboratories, Gibson also disagreed with the theoretical framework that was then in vogue. At the time of the development of Gibson's ecological approach, most perceptual researchers subscribed to a representational approach stemming from the work of Herman von Helmholtz (1878/1971). This account was centered on the idea that perception involves a three-way relationship between a subject, an object, and an internal representation of the object (Dotov, Nie, & de Wit, 2012). Gibson was a vocal opponent of this approach and thus was deemed by Harry Levin, Thomas Ryan, and Ulrich Neisser in a memorial statement as being "simultaneously [psychology's] most eminent and most dissident member" (E. J. Gibson, 2002, p. 108).

### ***The ecological approach to perception***

The ecological approach to visual perception was developed with consideration for the different environments organisms might find themselves in and the manner in which they detected information. Instead of

focusing like his contemporaries on the anatomy of the eye and the limits it imposed on perception, Gibson was motivated by gaining an understanding of the properties that the eye evolved to detect (Golonka & Wilson, 2012). These considerations gave rise to Gibson's ecological approach to perception, which is centered on two components: direct perception and affordances.

**Direct perception.** Direct perception can be understood by contrasting the worldviews that would be adopted by a cognitive psychologist who takes an information-processing approach, broadly defined, and an ecological psychologist (Cutting, 1982). From an information-processing perspective, the human may be viewed as a system that processes information about its environment systematically. This representational view assumes that humans create mental representations that guide their actions. These mental representations may be based on past experiences or knowledge.

In contrast, an ecological psychologist would remove the mental computation component from the equation so that it would be free of mental representations. Instead, they would state that humans, similar to other organisms, are guided by their own biological constraints within a particular context (see Urcioli, 1990, for an example of counterevidence). In the strictest view of direct perception, perception is unaffected by inferential processes or computation and does not require mental structures and representations (Hochberg, 1994). Ecological psychologists have argued,

Perception... is not a process by which the senses, like some *itinerant* mailman, collects coded messages about world facts and tosses them into the mailbox of the mind to be deciphered, sorted, and stored in memorial pigeonholes by some mysterious little postal clerk and perused by him at some later time. (Shaw & Bransford, 1977, p. 7)

Researchers opposed to a representational view of perception have noted that even animals without complex nervous systems (and consequently without representations) retain the ability to navigate the world (Reed, 1996). Furthermore, they argue that even if an individual were to create mental representations for specific circumstances, he or she would have to select the correct representation relevant to the key components of a task. To do this, the individual would have to simultaneously already understand the relevant components of the environment and the task. Although these and other arguments do not themselves prove that humans do not create mental representations, they highlight possible shortcomings with adopting a representational stance.

**Affordances.** Gibson's introduction of the term affordance was crafted with much consideration (Cutting, 1982). In fact, the concept was in its nascent stages for over a decade before its formal introduction (E. J. Gibson, 2000). Recall that Gibson defined affordance as what the environment offers the animal, the implication being that not only perception but also possible actions are directly conveyed by the environment. Admittedly, the introduction of the concept left some ambiguity about its meaning (Chemero & Turvey, 2007). For example, Gibson (1979) stated that "an affordance is neither an objective property nor a subjective property; or it is both if you like" (p. 129).

According to Gibson, affordances are relationships that exist naturally that do not require preexisting knowledge or necessarily need to be perceived. Turner (2005) elegantly exemplified the unnecessary condition of preexisting knowledge about a specific object with the case of an orangutan who found a claw hammer inadvertently left in its enclosure. Although one would expect the orangutan's knowledge of the tool to be limited at best, the animal was nonetheless able to use the claw end to scratch at walls and the face end to pound at different surfaces.

Although the affordances themselves may be stable (J. J. Gibson, 1979; Warren, 1984), perception of those affordances is context dependent, allowing for different affordances to be perceived depending on the state of an animal (Chemero & Turvey, 2007). To continue with the example of the orangutan and its hammer in the enclosure, the relationships existing between the two would be modified if, for example, the orangutan were injured and unable to handle the hammer. The affordances available would also further vary for different animals. Given the strength needed for lifting the hammer, a capuchin monkey who found itself in the same enclosure might never be able to lift the hammer regardless of its health status.

In addition, affordances will continue to exist in the absence of the perceiver. As long as the animal exists, the natural world will continue to afford certain actions (Dotov et al., 2012). The orangutan's hammer will not cease to afford pounding or scratching simply because the orangutan has been moved to another enclosure.

To better understand how the concepts of affordance and direct perception relate to one another, consider an example presented by Mace (1977). In this example, one must consider a cellophane fig leaf that allows for optical information related to its transparency and size, among information provided to the other senses. Because affordances would be directly perceived, the cellophane fig leaf could be related to whether it can be seen through, hidden behind, and hammered with, among other actions that can be performed by an observer. According to ecological psychology, these

directly perceived affordances would do away with the necessity of mental representations, such as those related to the object's properties of hardness, opacity, and so on. These representations would be outside of the observer-object relationship and thus would not be a part of direct perception.

### ***Post-Gibson affordances***

It is important to emphasize that Gibson's main goal was to develop a psychophysical theory of perception (Epstein & Park, 1964; J. J. Gibson, 1960). His career revolved around understanding how higher order variables of physical stimuli correspond to perceptual experience. This focus on higher order variables led him to postulate how action might factor into perception through the direct perception of affordances. Stated differently, Gibson focused on perception even in his work on development of motion picture aptitude tests for pilot selection in World War II. He made assumptions about the action component, the concept of affordance, but left the details underdeveloped.

Consequently, the term *affordance* is one that has become simultaneously popular and increasingly diffuse in usage since its inception (Lobo, Heras-Escribano, & Travieso, 2018). A Google Scholar search performed by Lobo et al. (2018) in early 2018 revealed 23,500 results. However, one would be hard-pressed to find an overarching definition among all of the articles citing Gibson. The development of the affordance concept over time can best be understood through a metaphor relating to redwood fairy trees. In the case of natural disturbance(s) to a redwood tree, resprouting will occur in the form of a circle around the parent tree (i.e., fairy ring). On first glance, the fairy ring structures that arise look like clones of the original tree, and this was thought to be the case for some time (Rogers, 2000). However, a closer, more detailed inspection reveals that the trees surrounding the parent tree are not all identical. Despite having the exact same origin, when genotypes are compared between the trees in the fairy ring, these trees can be quite distinct from its parent.

Likewise, a cursory and shallow review of the affordance literature would initially suggest that the work based on Gibson's affordances has held close to his original definitions or is very close to "cloning" the original concept. However, on closer inspection, a search through the literature quickly shows that there is no singular definition of affordances and that discussions of the concept do not adhere strictly to the theoretical work conducted by Gibson (e.g., de Wit, de Vries, van der Kamp, & Withagen, 2017; Makris, Hadar, & Yarrow, 2013). Whether purposeful or not, the use of the term has now been oversimplified and modified



to fit the practical needs demanded by different disciplines (Norman, 2015). This divergence from Gibson's intended use is somewhat ironic because Gibson himself warned against concepts being used too broadly (e.g., J. J. Gibson, 1941) and was careful in the wordings he used (Cutting, 1982).

The most notable exceptions to the trend of significantly departing from Gibson's writings come from within ecological psychology. In fact, research tends to share similar features to what was advocated by Gibson: It is usually conducted in naturalistic settings with 3-D items, and participants are required to perform real-world actions and make judgments about the feasibility of certain actions (e.g., Petrucci, Horn, Rosengren, & Hsiao-Wecksler, 2016; Ye, Cardwell, & Mark, 2009). As an example, in an effort to better understand the factors that lead to firefighter injuries and fatalities, Petrucci et al. (2016) asked firefighters dressed in their typical gear to navigate obstacles that are commonly found in fire situations. The concept of affordance in the ecological tradition has also been the basis of studies of children and adults (e.g., Franchak, 2019), nonhuman species (e.g., Cabrera, Sanabria, Jiménez, & Covarrubias, 2013; Wagman, Langley, & Farmer-Dougan, 2017), and human interactions in virtual environments (e.g., Geuss, Stefanucci, Creem-Regehr, & Thompson, 2010; Lin, Rieser, & Bodenheimer, 2015). Ecological psychology studies share several similarities, which include using real or virtual objects instead of static images and adopting contexts that replicate realistic settings as much as possible (e.g., nonfire setting for firefighters).

In addition to the empirical work that has been undertaken, several ecological psychologists have sought to establish the ontological basis of affordances to more completely address the relation between perception and action. Turvey (1992) attempted to formalize affordances as dispositional properties of the environment, and Chemero (2003) developed a theory of affordances as relations between abilities of animals and environmental situations. Chemero and Turvey (2007) noted similarities in their dispositional and relational definitions because both take "affordances to be genuine features of animal-environment systems" (p. 33). In apparent contrast to Gibson, they described affordances from both perspectives as "exquisitely context-dependent and 'quicksilvery'" (p. 33). Recently, Shaw, Kinsella-Shaw, and Mace (2019) proposed a distinction between *affordance type* and *affordance token*, with the idea that the former refers to the stable environmental property and the latter to the context dependence of specific instances of affordances.

Chemero and Turvey (2007) noted a third approach, which views affordances as mental representations. This approach situates affordances within a cognitive

psychology framework and thus differs fundamentally from their "more properly Gibsonian definitions of affordances" (p. 33). Discussion of this representational approach is the topic of the sections that follow.

## Affordances in Design: Norman

After the introduction of the affordance concept by Gibson, its most notable reformulation was that presented by Donald Norman, a cognitive psychologist with a background in engineering. Similar to Gibson, Norman's use of the affordance concept was primarily fueled by a personal frustration. In Norman's case, he had become exasperated with the design of common objects. After having witnessed and personally experienced difficulty in using everyday products such as programming a watch or a video cassette recorder, Norman penned *The Psychology of Everyday Things* (POET; Norman, 1988) and subsequent editions titled *The Design of Everyday Things* (DOET; Norman, 2002, 2013). Norman (2008) stated, "The concept of 'affordance' has captured the imagination of designers" (p. 18), and his use of the affordance concept has been credited with being the catalyst for its widespread adoption across disciplines (Turner, 2005). It is probably how most individuals, whether they are in psychology or not, are introduced to the term. Consequently, a discussion of Norman's contributions can be informative for discussing how the term has evolved over the past several decades.

In his widely popular book, Norman stressed the importance of considering human cognition and perception during the design process. Without including clues for use such as affordances, for instance, users might ultimately struggle to use a device. Here, Norman (1988) deviated from the concept developed by J. J. Gibson (1979) and modified it for the purposes of discussing the design of products. Specifically, he used the concept of affordances to refer to the perceivable actionable properties of objects. For instance, a chair could be considered to afford sitting, a knob to afford turning, and so on. Unlike J. J. Gibson (1977), who stated that "affordances of the environments are facts of the environment, not appearances" (p. 70), Norman primarily focused on the visible properties that could communicate an object's canonical use. Gibson, on the other hand, might state that a large number of objects might afford sitting regardless of the intentions of any particular designer. However, Norman's use of the term affordance was geared specifically toward the design of common objects, and after its initial introduction, Norman came to refer to his reformulation as *perceived affordances*, as distinct from Gibson's original formulation, which Norman called *physical affordances*, in an

effort to reduce confusion in subsequent editions of his book (Norman, 2002). To exemplify Norman's (1999) view on the matter of perceived affordances, consider a computer with a mouse and keyboard. Independent of the digital interface of the computer, the mouse would allow for clicking and a keyboard for pressing on the keys. These would be considered physical affordances and would be inherent to the objects in question. The perceived affordances would instead be tied to the interface and would provide feedback on the digital actions available to a user.

Norman himself noted early on that his adoption of the term was in conflict with Gibson's use. In the first edition of *POET/DOET*, Norman (1988) paid very little attention to the conflicts between his definition and Gibson's and dismissed a discussion on this topic as being "of little relevance" (p. 219). However, his emphasis on memory and what he referred to as "knowledge in the head" shows a clear departure from Gibson's writings on direct perception.

The latest edition of his book (Norman, 2013) provided additional insight into how Norman's thinking on the subject differs from that of his predecessor. Norman (2013) offered the following humorous anecdote on discussing the topic of direct perception with Gibson himself:

He argued that the world contained the clues and that people simply picked them up through "direct perception." I argued that nothing could be direct: the brain had to process the information arriving at the sense organs to put together a coherent interpretation. "Nonsense," he loudly proclaimed; "it required no interpretation: it is directly perceived." And then he would put his hand to his ears, and with a triumphant flourish, turn off his hearing aids: my counterarguments would fall upon deaf ears—literally. (p. 12)

Although Norman disagreed with Gibson's thoughts about the role of cognition in perception, he readily acknowledged the significant contributions made by his predecessor (e.g., Lindsay & Norman, 1977) and highlighted differences between their approaches. Unfortunately, recognizing the difference between these two views of affordances is not a practice that has carried over to present day. Norman's use of the term affordance has also come to be misapplied and misunderstood (Norman, 2008). For instance, many user experience researchers or human factors professionals fall into the trap of claiming that by including a new component to a website (e.g., an icon), they have "afforded" clicking. However, given that users can click anywhere they want regardless of the interface setup,

the aforementioned designer is not doing much beyond providing information about the significance of clicking in a certain location.

### **Activation Regardless of Context: Tucker and Ellis**

After Norman's reformulation of the affordance concept, subsequent interpretations have come to describe objects as possessing properties that afford actions associated with their use and that these affordances in turn lead to the automatic activation of a mental representation regardless of context (e.g., Kourtis & Vingerhoets, 2015; Roberts & Humphreys, 2011; Rounis, van Polanen, & Davare, 2018). *Properties* here refers to the manipulable aspects of an object that are associated with its canonical use (e.g., the handle of a mug for drinking; the handle of a spoon for eating). Although this is a clear departure from Gibson's definition of affordances for several reasons (e.g., he rejected the idea of mental representations), this interpretation has nonetheless been erroneously credited to his name. Unlike Norman, the differences between reformulations of the affordance concept are rarely discussed in relation to Gibson. Given the obvious divergence of this interpretation from that of Gibson, these properties will *not* be referred to as affordances, both to reduce any possible confusion on the use of the term and further highlight the distancing from the Gibsonian tradition.

The notion of automatic activation by the manipulable properties of objects primarily stems from the field of cognitive neuroscience (e.g., Cisek, 2007; Cisek & Kalaska, 2010). Researchers have found that simply viewing images of objects or silently repeating their object name can lead to activation of brain regions related to motor activity (i.e., left ventral premotor cortex; Chao & Martin, 2000). These findings have spawned work both within neuroscience and outside of it and provide one of the main pieces of evidence offered by those aligned with the idea that an object's manipulable properties automatically activate mental representations—regardless of context, ultimately facilitating motor processes.

As mentioned previously, the concept of affordances was developed at a time in which the representational approach to perception was at odds with a more ecological approach (Dotov et al., 2012). The latter approach eschewed explaining perception in terms of mental representations. Despite this, the idea that perception is based on these very cognitive representations is still widely accepted. In general, mental representations have been argued to be a "necessary analytic tool for studying visual cognition" (Cooper & Hochberg, 1994, p. 223).

On the basis of the opposing worldviews that have been discussed thus far (i.e., those of the ecological and cognitive approaches), one might find it cumbersome to locate common ground between the two approaches. However, in the past two decades, researchers have championed combining the two. The draw in this union has primarily been to circumvent limitations inherent in the two approaches. Although a primary tenet of Gibson's ecological approach to perception was that of direct, unmediated perception, affordances based on mental representations have been adopted into action and motor control frameworks (e.g., Frith, Blakemore, & Wolpert, 2000; Vera & Simon, 1993). In what is perhaps one of the most widely cited articles on this topic, Tucker and Ellis (1998) freely acknowledged that theirs was "a representational account of affordances, and therefore very different from the use of the term in the ecological sense" (p. 833), though not specifically acknowledging Gibson.

Tucker and Ellis (1998) further contended that S-R compatibility methods lend themselves particularly well to the study of affordances and their subsequent automatic activation of motor responses. S-R compatibility effects refer to differences in performance (typically reaction time or accuracy) as a function of the pairings between stimulus sets and response sets. Although Tucker and Ellis proposed S-R compatibility paradigms as being suitable for the study of affordances, it is important to note that the explanations for compatibility effects have primarily focused on a central stage of information processing, often called *response selection*, in which actions are represented in terms of nonmotoric codes (e.g., Kornblum, Hasbroucq, & Osman, 1990; see Proctor & Vu, 2006b, for a review).

These issues aside, Tucker and Ellis's (1998) stance in favor of S-R compatibility paradigms seems to have since been adopted by many other researchers, and the methods employed originally by Tucker and Ellis are now the most commonly used in this area of study (e.g., Kourtis & Vingerhoets, 2015). In "affordance" studies using variations of their methods, stimuli are often images of manipulable objects (e.g., frying pan; teapot), most typically, of objects with handles facing to the left or right to which a discrete response is to be made via an assigned key press. Participants may have to perform an action that is either in agreement with an object (compatible or congruent) or in disagreement (incompatible or incongruent). Experiments using these paradigms typically show a benefit when the left or right response hand and the object handle correspond compared with when they do not (e.g., Grèzes, Tucker, Armony, Ellis, & Passingham, 2003). Authors have argued that unlike a typical S-R compatibility paradigm, which is guided by spatial compatibility, automatic

responses using handled items are guided by the "intrinsic properties of the objects" (Grèzes et al., 2003, p. 2738).

The studies using these paradigms to investigate affordances appear on the surface to suggest that the manipulable properties of objects automatically evoke action representations that in turn activate motor intentions. But, this cannot be definitively concluded without ruling out variants of customary accounts of S-R compatibility effects. In fact, numerous studies have found that findings initially attributed to grasping affordances on closer empirical inspection often are a result of spatial factors such as the location of a visually salient object property (e.g., Song, Chen, & Proctor, 2014; Xiong, Proctor, & Zelaznik, 2019). Thus, object-based compatibility effects have been obtained for situations in which they would not be expected to occur from the affordance view, such as with both broken handles (e.g., Ambrosecchia, Marino, Gawryszewski, & Riggio, 2015), disembodied objects (e.g., Cho & Proctor, 2010), and even when feet are used as effectors (e.g., Phillips & Ward, 2002; Symes, Ellis, & Tucker, 2005). These are but a select number of cases demonstrating that the viability of explanations in terms of automatic activation of mental representations of specific actions afforded by objects or their pictures has been overstated (Proctor & Miles, 2014) because of what Masson (2018, p. 222) called "insidious spatial correspondence effects."

In the past decade, efforts have been made to move toward more naturalistic response-item pairs and take the role of context into greater consideration. This trend stems from the idea that previously observed facilitation might be indicative of more general task-dependent factors such as the keypresses used to make the responses. Although the methods employed to date may still be some distance from what Gibson would consider appropriate for studying perception, they can nonetheless inform our understanding of the perception-action relationship.

## Activation in Context: Bub and Masson

Daniel Bub and Michael Masson can be credited with primarily leading efforts to give more extensive consideration to the context of object use. Before discussing their stance on automatic activation, it is important to note why they in particular are essential for the discussion of affordances, especially given that their work has not received the attention that Tucker and Ellis's has. For one, Bub and Masson studied aimed responses made toward a manipulandum instead of key presses and employed their "Graspasaurus" in several studies (e.g., Bub, Masson, & Cree, 2008). The Graspasaurus registers movement time the moment a participant

touches the instrument and consequently breaks a weak electrical current flowing through it. Second, of particular note for their approach is the meticulous manner in which they have used the term affordance. In their early works, Bub and Masson abstained from using the affordance concept, which demonstrated their understanding of the concept as it was proposed by Gibson and that its use may not be appropriate for laboratory studies that use pictures and words as stimuli.

More recently, they have come to refer to the notion of “motor affordances” for reach-and-grasp responses (Bub, Masson, & Kumar, 2018) and have done so carefully and systematically, after concerted efforts to rule out alternative accounts. They have noted that their findings of apparent grasp-related motor activation when making grasping responses to object pictures is contrary to Gibson’s use of affordances for interacting with actual objects. They have also shown differences in results obtained with object pictures and verbal descriptions, restricting their use of *motor affordance* to the former and referring to the latter as *motor representation* (Areshenkoff, Bub, & Masson, 2017). Their conscientiousness and meticulousness set the work of Bub and Masson apart from that of most others in the field.

Bub and Masson (2010) pointed out that when it comes to discussing the automaticity of object-handling behaviors, it is important to consider an individual’s goals or intentions in a particular context. The factors involved in passively viewing an object can differ from those recruited when actually making an aimed movement toward the same object. When planning to grab a handled object, for instance, a number of factors have to be considered that include but are not limited to one’s starting hand position, the end state hand position, and the end goal state of the object in question (e.g., Rounis, Zhang, Pizzamiglio, Duta, & Humphreys, 2017). In contrast, if one were simply responding to items with handles using discrete responses (e.g., key presses), these complexities, among others, are lost (Bub, Masson, & Lin, 2015). It is crucial not to overlook the importance that more naturalistic, aimed movements toward a graspable object may play. After all, “the action most strongly afforded by graspable objects is a grasping action, not a key press” (Suzuki, Takagi, & Sugawara, 2012, p. 882). The notion that simpler actions cannot be equated to grasp gestures is supported by neuropsychological investigations using nonhuman primates, which have suggested that pantomimed actions do not result in the same neural activation patterns as actual gestures (e.g., Umiltà et al., 2001). In addition, evoking more naturalistic actions (e.g., grasping 3-D items) is actually better aligned with the Gibsonian tradition.

One of the most compelling pieces of evidence suggesting that activation may be more nuanced than has been previously presented comes from Bub et al. (2008). Using object priming, Bub and colleagues were able to show that volumetric gestures (i.e., handling related to the volume of an object) and functional gestures (i.e., handling related to the conventional use of an object) could be elicited in different situations. To differentiate between the two, one might consider how they manipulate a calculator to move it versus when they intend to use it. In the former case, one might perform a unimanual action using all five fingers to pick up the calculator (volumetric gesture), whereas in the latter case, one might perform a bimanual action involving cradling the calculator in one hand and using the pointer finger of the other hand to punch the selected buttons (functional gesture). Critically, unlike the work of Bub and Masson, other discussions of automatic activation brought forth by the manipulable properties of items have tended to overlook these different types of manipulations. Although Bub and Masson can be considered to be the gold standard for their meticulousness when designing studies and drawing conclusions from their results, it should be noted that several others have also made efforts to better understand the role of context (e.g., Costantini, Ambrosini, Tieri, Sinigaglia, & Committeri, 2010; Jax & Buxbaum, 2010; Squires, Macdonald, Culham, & Snow, 2016).

As noted, Bub and Masson have, on several occasions, appropriately avoided use of the term affordance when discussing actions made toward objects. In fact, in a recent summary of their work, Masson (2018) used the term *action representation* and stated, “Because we are considering action representations that something as abstract as a photograph of an object can elicit, these representations cannot be considered to be affordances in the sense that J. J. Gibson (1979) intended” (p. 220). Although Bub et al. (2018) used the term *motor affordances* instead, they emphasized the rapid time course of activation and the difference in results from those obtained when responding to object names in their reasons for using the term. This fluctuation on the part of Bub and Masson highlights their understanding of the issues associated with the use of the term, which have only been alluded to thus far in this article. The ecological approach to perception and action, on which the affordance concept is based, fundamentally disagrees with the cognitive approach. Therefore, Gibson should not be invoked to justify representational affordance explanations. Although Gibson has come to be presented as an S-R theorist (see Costall & Morris, 2015, for select examples), this is far from the case (Costall, 2017). Reed (1996) argued that affordances “do not and



cannot cause even the behavior that utilizes them” (p. 18). Thus, even if results imply automatic activation of a motoric nature, care must be taken to differentiate the account from a Gibsonian affordance account either by abstaining from use of the term *affordance* or explicitly emphasizing the difference in usage.

## Discussion

We have traced the concept of affordance as it developed from its introduction by Gibson to subsequent reformulations by three sets of psychologists (i.e., Norman, Tucker and Ellis, Bub and Masson). This review has revolved around the study of object perception and the notion of automatic activation of mental representations. Although the manner in which this issue was addressed may be distinct from what a psychologist trained in ecological psychology might do, the aim was to summarize findings that can inform work in cognitive psychology.

The results obtained can be broken down into the common threads found among the different approaches summarized. For one, although Gibson developed his ecological theory of perception and action on the basis of claims of direct perception and affordances for action to circumvent the need for mental representations, those who have since adopted the concept of affordance have not adhered to the tenet of direct perception. In fact, all of the key researchers reviewed here outside of Gibson have readily embraced the idea of intervening mental representations. This trend is understandable, but as Dotov et al. (2012) noted, “Supposing that only the second claim [that of affordances] is true turns the affordance concept into a mere buzzword” (p. 30). The cognitive approach, with its emphasis on information processing, is far more widely accepted than the ecological approach. Admittedly, it can be difficult for cognitive psychologists to understand the idea of unmediated perception and action because it goes counter to the assumptions that form the foundation of their area of study. Ecological psychologists, whose foundations differ from those of cognitive psychologists given they are typically based in the work of Gibson, are far less likely to introduce mental representations into their work.

As result of the aforementioned inclinations that psychologists from different fields may have, it is important to understand that the methods and concepts used in one sphere of study may not easily cross over into another. Cognitive psychologists in particular need to take heed of this cautionary warning because they may be tempted to recycle commonly used methods for the purposes of studying object processing. As was

mentioned in this review, S-R compatibility paradigms, for instance, are most commonly misapplied, but other methods have also fared a similar fate (e.g., Skiba & Snow, 2016). Psychologists’ tendency to merge conflicting approaches was described elegantly by Neisser (1990):

Perhaps more than scientists in other fields, psychologists believe that there is nothing new under the sun. . . . Accustomed to this pattern, we try to understand each “new” proposal by mapping it on to some existing scheme. When an idea is really new, that strategy fails. (p. 749)

This review has ultimately come to support the conclusion reached by several other authors. The term *affordance* has become overused and in most cases has departed from the original intentions of Gibson (Costall & Morris, 2015). Affordances have now been invoked to explain myriads of research problems such as how different social situations *afford* certain leisure behaviors in powerful and powerless individuals (Guinote, 2008), *two-sided affordances* of interactions for different types of health care consultations (Islind et al., 2019), and security affordances of cyber-physical systems (Wang et al., 2018). It is impressive that a term created by one individual has sparked so many research works over the past several decades. However, in employing the term without much needed caveats referencing the departure from what Gibson originally wrote, many scientists inevitably contribute to a needlessly labyrinthine body of work. It is often the case that Gibson’s approach to perception is mentioned only in the introductory paragraphs of an article before shifting to a discussion of laboratory studies using keypresses without ever discussing the nuances of his approach (e.g., Gomez, Skiba, & Snow, 2018).

In addition to mirroring the conclusions that others have already drawn, the present review can uniquely attempt to comment on four issues that have not yet been addressed in the literature. The first issue pertains to the (a) possible reasons why the Gibsonian way of thinking never eclipsed the more prevalent cognitive approach. Next, there is the matter of what cognitive psychologists might glean from this review and (b) whether use of the term *affordance*, which was not intended for use outside of ecological psychology, should be abandoned altogether by cognitive psychologists. Finally, there remains the issue of (c) whether human factors specialists, who regularly apply theories and findings from cognitive psychology to system issues, should move toward embracing Gibsonian thinking, as has been suggested by some people within the field.

### ***Why are the majority of psychologists not Gibsonians?***

Gibson has been extremely influential and has rightfully changed thinking, not only in psychology but also beyond it. Nakayama (1994), who accorded Gibson the position as the most important perceptual psychologist of the 20th century, commented on his influence:

Spanning many levels—philosophy, physics, behavior, specifics of the stimulus—the sweep is without parallel. Then there is the obvious originality: surfaces, texture, invariance, motion, the moving observer, and ecological optics, to mention a few. Moreover, I would argue that Gibson's influence in perception, psychophysics, neurophysiology, and computer vision runs very deep, although not always fully acknowledged. (p. 333)

Considering the far-reaching influence of Gibson's work, one might naturally wonder why the Gibsonian line of thinking has not completely eclipsed today's more dominant approach. After all, the affordance concept has reached many areas of study, and its associated misuse might be related to the lack of familiarity with the ecological approach. Although this may seem tangential to the topic at hand, it can be fruitful to contemplate the possible reasons why we do not live in a world full of Gibsonians who subscribe solely to the ecological approach.

One reason why the ecological approach is not as popular as its cognitive counterpart may lie in the plausibility of its axioms. As a reminder, Gibson developed his thoughts on perception to counter popular Helmholtzian thinking. Key to the ecological approach is the idea that perception is unmediated and independent of mental representations, which are regarded as unnecessary. However, Hochberg (1981) commented that "stimulus information is often simply insufficient to specify the very phenomenon that the direct theory most confidently addresses" (p. 130). To exemplify this insufficiency, Hochberg presented the Ames trapezoid, which is a trapezoid that appears to oscillate even though it is spinning continuously. Here, direct perception is unable to explain a visual stimulus that should otherwise be invariant. It has been pointed out that these instances are relatively typical (Cutting, 1998) and that "even Gibson attributes the perception of the object, when based on the parts not occluded, to the operation of expectations, using language almost identical to that of Mill and Helmholtz" (Hochberg, 1981, p. 131). Given these issues, the field as a whole may be hesitant to embrace Gibsonian thinking.

Alternatively, it might be surmised that the issue instead rests within the way cognitive psychologists

have been painted by ecological psychologists. Cognitive psychologists are unlikely to embrace a field or consider the concepts presented therein when they are regularly dismissed with reproach. Early critics, for instance, stated that those aligned with the cognitive approach are "not only dead wrong both conceptually and empirically, but also retarding the development of adequate psychology" (Weimer, 1977, p. 269). It has also been stated that ecological psychologists, unlike their cognitive counterparts, view behavior as being self-initiated and modified by both internal and external factors and not simply as a result of passive processes (Reed, 1996). However, one would be hard-pressed to find *any* cognitive psychologist who views humans as passive entities waiting for external events to guide their behavior, going back at least as far as Miller, Galanter, and Pribram (1960). There are many other misrepresentations in the literature, but the greatest untruth might be that cognitive psychologists merely summarize and describe experiments instead of actively engaging in theory postulation and prediction (Golonka & Wilson, 2012).

Perhaps, on a much simpler level, the majority of the field simply does not align itself with a Gibsonian worldview because this approach would not be adequate for answering its questions. Consider the proverbial blind men who have never experienced an elephant. The manner in which they approach the elephant and the conclusions that they ultimately draw will be dependent on what questions they pose. A blind man considering locomotion, for instance, may be more concerned about the animal's limbs, whereas another blind man's interest in the animal's hide may not ultimately lead him anywhere near the legs. Evidently, one blind man's efforts do not necessarily negate the other's. Likewise, embracing one theoretical approach over the other does not necessarily negate the validity of the second. Moreover, it is important to note that ecological psychologists rely on the concepts of direct perception and affordances because they are essential to their approach to the study of perception and action, which is rooted in radical empiricism (Heft, 2001). Dispensing of these concepts would break down the foundations of their study. However, the aforementioned concepts are *not* essential for areas outside of ecological psychology that allow for mediation of perception and action by cognitive processes.

In fact, several approaches go beyond those discussed herein and have contributed to increased understanding of perception and deserve discussion. One popular and frequently cited framework, for instance, is theory of event coding (TEC; Hommel, 2019; Hommel, Müsseler, Aschersleben, & Prinz, 2001), which more thoroughly relates action to perception (stimulus identification). From its introduction, Hommel and colleagues

acknowledged being influenced by J. J. Gibson's (1979) thinking on the functional relationship between perception and action. Specifically, similar to Gibson, their framework considers perception to be an active process in which observers act to perceive and perceive to act. Thus, their framework begins with the goals of an observer instead of a particular stimulus. However, TEC nonetheless marries this approach with the notion of mental representations.

According to TEC, activated action goals will lead to the subsequent activation of codes related to visual features and actions. TEC can best be explained with an example modified from that used by Hommel, Brown, and Nattkemper (2016). Consider a Simon task, named after J. R. Simon (1990), in which individuals are instructed to respond to a red square with a left button and a green circle with a right button. Given these action goals, feature codes related to color and shape would be related to the activation of the motor programs for pressing the left and right buttons. Instances in which there is code overlap and multiple features are activated would allow for faster responses than cases in which multiple codes are tied to different actions. A thorough examination of TEC and its most recent iteration is outside the scope of the present review, but the primary takeaway is that TEC is an account considering both perception and action from a perspective distinct from the other approaches mentioned herein.

Finally, it is possible that the Gibsonian way of thinking has failed to reach popularity because it is too foreign to be embraced. Psychologists trained to consider mental representations may find it profoundly challenging, and perhaps even impossible, to think about the world in a different manner. Given that Gibson mostly speculated on the latter component of the perception–action dynamic and simultaneously eschewed mental representations, should psychologists nonetheless be attempting to tack on a representational approach to his sensorimotor one? It is not readily apparent how a bridge might be built between a representational account with one that inherently assumes that these representations are unnecessary (Mossio & Taraborelli, 2008). Furthermore, the necessity of doing so is not clear when the issues that researchers might attempt to address with each account would be at very different levels of granularity (Koenderink, 1980). More pragmatically, it appears that a great number of caveats would need to be adopted for marrying together these two accounts. Although the plausibility of a marriage between approaches is not obvious, the outright difficulty in doing so certainly is.

Whatever the reason behind the lack of widespread popularity of the ecological approach, however, there

is little doubt about Gibson's contributions to the study of perception and the field of psychology as a whole. In fact, different approaches are necessitated by such a complex research topic.

### ***How should cognitive psychologists approach the affordance concept?***

It is critical for researchers to be careful not only in the manner in which they use the term *affordance* but also in the conclusions stemming from their work if they wish to ultimately tie their results back to the natural world. After all, Gibson established the term *affordance* with a very specific use in mind in conjunction with his theory of direct perception. If researchers are intentionally shifting from Gibson's definition of the *affordance* concept, it can be useful to approach the term in the way done by Norman (1999) and Bub et al. (2018). By using the terms *perceived affordance* and *motoric affordance*, respectively, the deviation from Gibson is highlighted. Likewise, concepts such as “nested affordances” (Gaver, 1991) or “micro-affordances” (Ellis & Tucker, 2000) may help draw clearer lines between Gibson and the researchers that have followed him. At the very least, making these distinctions salient may prompt readers to investigate what the differences between various types of *affordances* are.

Although taking steps such as adopting appropriate terminology seems like a simple enough task, misuse of Gibsonian concepts runs deep. Being mindful of how terms such as *affordance* are used will require a concerted effort and to a certain degree, creativity. For instance, the current use of *affordances* has led researchers to suggest using novel terms that encompass more than the original concept. *Gib*, for example, has been claimed to introduce a mental component to the performance of actions (Lee, Shaw, & Jin, 2017). Whether concepts such as this one can serve as more effective tools in investigating the perception–action relationship, however, remains unclear. It can be useful to remember that Gibson himself created the term *affordance*, and without his theoretical ingenuity, it might not have otherwise come into existence.

We can only speculate as to what Gibson himself might have said about the widespread use of the term *affordance*. In 1941, he published a critique of the concept of “set” in experimental psychology and commented that “the underlying meaning [was] indefinite, the terminology chaotic, and usage by psychologists highly individualistic” (p. 781). Furthermore, he critiqued use of the term by stating that it “[denoted] a large and heterogeneous body of experimental facts and [connoted] rather different things to different

psychologists" (p. 782). Although Gibson passed away shortly after the term affordance was introduced widely to the scientific community, and thus was not able to see his work rise to popularity, it is reasonable to conclude that he would have similarly critiqued the widespread use of the affordance concept.

Although Gibson developed an extensive and thorough review on the concept of set, he was personally either unwilling or unable to provide a resolution to the issue of its use. This reluctance is understandable considering the different alternatives that exist. One alternative, for instance, might be to discontinue use of a popular term altogether and develop a more comprehensive term to encompass the many definitions within one field. Beyond the obvious difficulty in undertaking such a task, this action would not be an antidote to any potential (and probably inevitable) later misuses. Another alternative might be to accept the many uses of a term and simply become conversant in its many variations. These are only select possible alternatives, and it quickly becomes apparent that there is no one single solution.

In an ideal world, concepts would be created and operationalized in a very specific manner, and their adoption would be restricted to their intended uses only. However, it is difficult to find any term in psychology that has not experienced diffuseness in one way or another (e.g., compatibility; workload). This being said, the most productive path forward would be one in which cognitive psychologists avoid use of the term affordance altogether. Considering that the term affordance was founded in ecological psychology and derived its meaning from the concept of direct perception, it makes sense to leave it to those within ecological psychology to analyze the concept (e.g., Shaw et al., 2019). As alluded to in the previous section, researchers may be inspired to explain phenomena in concepts widely accepted within cognitive psychology or create new terms as Gibson himself did to avoid the overuse of *affordance*. This latter situation should, in practice, do away with issues in using overlapping terms. However, given how ingrained the term affordance might be in the collective lexicon of psychologists, it is probably more realistic to request that individuals modify the already existing term and have new terms and their underlying assumptions discussed meticulously. We maintain that moving forward, psychologists should use the term carefully and thoughtfully just as Gibson did in crafting it. Given that affordances are now studied by a vast majority of researchers from different backgrounds, our call for caution when using the affordance concept similarly applies to anyone attempting to embrace the Gibsonian approach.

### ***Should human factors be Gibsonian?***

Although the present review was created with the thought of evaluating the influence of the affordance concept and developing considerations for cognitive psychologists to take into account, we can also glean information on what might be learned for more applied work. After all, most individuals are introduced to the affordance concept in the context of designing products and technologies, as typified by Norman (2013). Application is particularly relevant to Gibson because he was motivated initially by human-centered issues in aviation and automotive domains (J. J. Gibson & Crooks, 1938).

We can first consider how traditional cognitive psychology and ecological psychology have influenced the study of how humans interact with technology, if at all. Although both approaches have been applied to human factors, the cognitive approach has been far more influential to the study of how humans interact with technology than the ecological approach has. The manner in which human factors professionals approach the investigation of human-system issues is undoubtedly reliant on mental representations. In human factors, critical concepts (e.g., situation awareness; cognitive workload) and common methods (e.g., cognitive task analysis; think-aloud protocol) are founded on the idea of mental representations. Early research in the field was reliant on the notion of mental representations (Fitts, 1958), and this has carried to present day (Meister, 1999; Proctor & Vu, 2006a).

Human factors researchers, however, have nonetheless embraced tenets of the ecological approach. Specifically, viewing behavior through a more holistic lens has been encouraged. Flach and Hancock (1992) argued in favor of approaching a more environmentally minded human factors in which researchers consider the context in which tasks are performed instead of humans in isolation. Undoubtedly, this is a necessary effort. For instance, a human factors specialist considering a console operator's performance and the design of the operator's workspace may extend their investigations to the way in which the operator's shifts are scheduled or the training received. By taking into consideration factors such as these (which could be considered outside of the original problem space), human factors specialists might be better equipped to design a workspace or task because they would be aware of the different factors that might affect human performance.

However, some human factors researchers have taken this situation to be a *carte blanche* to using terms from ecological psychology. In regard to their model of a cyber-physical system, Wang et al. (2018), for instance, noted that their efforts "make apparent to the



analysts the security processes and the features *afforded* [emphasis added] by different control system components . . . [and that analysts] can choose to increase security *affordances* [emphasis added]" (p. 715). In this case, the affordance-related terms could be circumvented altogether and replaced with *allowed* and *features allowed*, respectively. Admittedly, these word substitutions are based on supposition because Wang et al. did not provide detail on how they operationalized affordances. Unfortunately, this is only one recent example of injudicious use of the term affordance in the human factors field, of which there are many. It might be argued that the misuse of the affordance concept in human factors is particularly egregious when considering that the field is made up of both academics and industry professionals with a wide variety of backgrounds and education levels. Although people in academia might have the resources to sleuth out the intended use of a term, people in industry may not be as inclined to do so. Consequently, the ultimate success of design and implementation of human-centered systems may rest heavily on the misuse of a universal yet widely misunderstood term.

In sum, human factors professionals can embrace the *spirit* of ecological psychology by considering environmental context when exploring human behavior but do so without misusing terms unintended for the field. Researchers and designers must remember that Gibson created his approach to explain interacting with the natural world, not a designed one with buttons, knobs, and displays, which is the focus of much human factors work on emerging technologies.


## Conclusion

The goal of the present work was to review the evolution of the term affordance over the past approximately 40 years. Since its introduction, the affordance concept has been extremely influential and has fueled a significant body of work within cognitive psychology. However, use of the term affordance has deviated away from how it was first intended to be used, and it is undeniable that the research using the term affordance is vast and nuanced. Gaining a more thorough understanding of the factors that led to the conception of the affordance concept, more recent reformulations, and the limitations of different approaches might better equip cognitive psychologists and, by extension, human factors researchers to further advance the study of perception-action relations. Although we reviewed only a select number of studies with a focus on adults, readers are encouraged to go forth and choose their own path through the literature.

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