Virtual Affordances: pliable user expectations

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Abstract

The experience of virtual environments is often based on contradictions: the user should perceive the environment and objects as real, and yet the behavior of the environment is typically unreal; the user should accept the world as a temporary reality, yet at the same time interact with it magically. At the core of these differences is affordances and the question: Are virtual affordances the same as real affordances? This is important, as perception of a "real" environment implies that the affordances are those of the real world, and conversely, magical interactions and environment behaviors are "un-real." By understanding that perceptual differences may exist and what they are, we can to leverage this knowledge to improve the experience of virtual environments. In this position paper, we lay out the issue of virtual affordances, why they are critical, and what we believe are the core factors that effect the user's expectations of virtual content.

Index Terms: H.1.2 [Information Systems]: Models and Principles—User/Machine Systems I.3.7 [Computing Methodologies]: Computer Graphics—Three-Dimensional Graphics and Realism

1 Introduction

The *experience* of virtual environments (VE) is one of the most important aspects of VE applications; yet, it is also one of the least understood aspects. This is demonstrated by various commonly held beliefs about user perception of VEs that are in direct contradiction. When creating virtual environments, the explicit goal is often invoking a feeling of "presence," the feeling of actually being in the VE or at least accepting it as a temporary reality. This implies that the VE is perceived the same as the real world. At the same time, the behavior of the environment is rarely physically correct - perhaps simple collision response and gravity - and interactions are almost always abstracted or even magical in nature. Flying or walking off a bridge is something few will experience in real life, but in VEs they are often performed. Even "direct manipulation" methods like the classic ray based method are not really natural. This desire to have users accept worlds that do not follow the behavior familiar from reality implies that the user should perceive the world as something virtual, i.e. not real. Such contradictions show a fundamental gap in our understanding of the perception of VEs.

We propose that one of the ways we can investigate the user experience of a VE is via its *affordances*. Affordances are the action potentials of an object and are briefly introduced in the box insert on the next page. Important questions that creators of virtual environments should ask about affordances are:

- *What does the virtual content afford to the user?*
- *Are virtual affordances the same as their real counterparts?*
- *What happens when the actual behavior does not match those affordances?*

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2 Virtual Affordances

Virtual affordances *are* different than real affordances, at least under particular conditions. This has been shown in two recent studies. A study by de Kort et al. indicates that there are differences in how users perceive scenes in terms of what activities they associate with that space [5]. A study by Albrecht et al. indicates that the affordances of simple objects are, in some respects, different than those of real objects [1].

de Kort et al. present a study with a primary goal of comparing the differences of performance in evaluation of and cognitive mapping of virtual and real worlds. A virtual version of a entrance hall was compared with the real hall. In their study, they considered a wide spectrum of factors. They examined approximation of heights (doors and hight of rooms), cognitive mapping (sketching of the test environment), self reported factors based on "Bipolar adjectives" (evaluation, ambience, arousal, privacy and security) and perceived affordances. Their study supports existing results to height underestimation and poorer cognitive mapping in the VE. The results also show a difference between virtual and real for all the self-reported factors, excepting arousal. The participants rated the real environment more positively than the virtual for evaluation, ambience, privacy and security. In addition, the users were questioned on their perceptions of the environment in regards to what activities where afforded by the locations. Their results showed that the real world was more frequently associated with social activities, while the virtual was tied to formal activities more often.

The study by Albrecht et al. differed in its explicit focus on the perceived affordances of singular objects. In this study, users were presented twenty (20) objects, ten (10) each in virtual and real spaces. The virtual space was a reproduction of the physical room used. Using a "think aloud" method, the user's perceptions of the objects were captured. Additionally any actions performed with were captured. Those perceptions and actions were then encoded and categorized. The results indicate that the affordances of simple objects are largely the same, but with important differences on certain concepts. The differences follow two main directions, what we call "playfulness" and destructive tendencies. Both occurred more often in the virtual setting. Examples of playfulness were perceiving (often performing) actions that do not fit the social norm for adults, such as using a cooking pot as a hat. Destructive tendencies involved both using the objects to damage other objects in the environment and damaging the objects themselves. The study also indicated gender differences and differences between users with different levels of experience with computer games.

That differences exist is also supported by informal observations, like the willingness to fly through an environment or walk off a virtual bridge. However, the extent of the differences are is not yet clear. The existing studies only touch on the subject and indicate that important differences are present. Many further studies will be required to gain an understanding of the extents of the differences and their significance.

3 Why We Should Care

Affordances of virtual spaces and objects should be of interest to us, particularly when they do not always match those of the equivalent real spaces and objects. Perceived affordances indicate what the user expects to be possible to do in an environment and with

Affordances

The term *affordance* originates from Gibson [6]. Affordance theory is familiar in the areas of Cognitive Science, Human Computer Interaction (HCI), and beyond. The theory of affordances says that objects innately provide certain action potentials, affordances, to the "user." Perceiving these affordances is one of the mechanisms that cognitive psychologist say is how we deal with the manifold objects we encounter every day, including novel objects and new versions of familiar objects. Affordances come to us in a natural and automatic process. Just glancing at an object, we automatically come to an understanding of what we expect can be performed with an object and how.

Examples of perceived affordances are door handles and objects for "hammering". Door handles are very interesting, because after reading Norman's book which discusses them extensively, one rarely experiences doors the same [8]. Under affordance theory, the door handles afford humans certain action potentials, e.g. the way to open the door. This means we see the door/handle and know whether we should push, pull, or slide the door. Simple examples are horizontal bars which afford pushing and vertical bars/grips that afford pulling. Each of us has experienced coming to a door and finding that it won't budge. Generally, by reversing the force we are applying we get the door open (potentially requiring a change in grip). The power of affordances can also be experienced in Europe, where one often sees color coded signs that say whether to push or pull. The affordance of the physical object almost always wins our attention and perception, rendering the signs ineffective for the first attempt. A different example is the affordance of hammering. Hammering is afforded, obviously, by a hammer. However, when a hammer is not at hand, many other objects afford hammering. For instance, a screwdriver (handle) or a shoe (the sole at the heel) has often been used when the need is present. The question is whether those affordances are perceived by the user and in what contexts.

Unfortunately, there are many differences in the meaning of the word affordances and different understanding among various groups. We use a definition of affordances that stems from Donald Norman, who has suggested renaming his concept as "Perceived Affordances." *Perceived affordances* are the actions that the user perceives to be possible with/to an object [7, 8]. The original meaning of affordances from Gibson, summed up in his own words, is: "The affordances of the environment are what it offers the animal, what it provides or furnishes, either for good or ill" [6]. This means that affordances exist between an organism and objects, independently from an individual being. As soon as a being exists, which can perform a specific action, the affordance exists, independently of whether the possibility is perceived or not [2]. Here we see a major difference between perceived affordances and Gibson's affordances. Perceived affordances are only those potentials that are perceived by a person. The other important difference between Norman's and Gibson's ideas is that Norman allows for the persons experience, culture, etc. to shape the affordances, where Gibson's are an innate part of the object independent of any observer.

a particular object. They can and should inform environment design, individual object design, and interaction design. Usually, perceived affordances also capture the how of that interaction. A classic example is a hammer. The hammer has an action potential of "hammering." It is also clear how this should happen. The handle "affords" holding in a *power grip* and through wrist and arm movements being accelerated forward.

We believe virtual affordances are important for another reason: **if the user's expectations of objects and the environment (i.e. their affordances) are not met in a reasonable way, then the user experience is going to suffer**. The core to this is the feeling of *agency*. We believe that if the perceived affordances of an object or environment are not met, then the user's sense of agency is going to be lowered. This in turn affects other aspects of experience, like presence. A theory to this relationship is presented in [3]. Perceived affordances that are not met are also likely to have other related effects on the users, like increasing frustration and increasing the cognitive load (as they have to actively consider what can be done instead of just reacting).

4 Influential Factors

All the factors that influence whether and what differences exist in virtual and real perceived affordances are not yet clear, but we can already identify some of the factors involved and how they will affect virtual affordances. **The factors we expect to influence virtual affordances come from three main areas: content, presentation, and personal demographics.**

4.1 Content

We believe that the virtual content itself influences the affordances perceived. Here, we use content to mean all aspects of the environment that "virtually" exists as perceived by the user. This is not equivalent a set of geometry that is visually displayed; though the typical representation of objects in VEs is visual. Content could also be sounds like "mood music." It might also be the story of a world/game.

The foremost realization of importance is that content that is familiar to the user from the real world will be initially and *automatically* considered the same as a real object. For instance, a hammer seen in the environment is quickly perceived as a "hammer." Just hearing the sound of hammering implies the hammer object exists. Having perceived a hammer, the user will, without cognitively registering it, perceive the afforded actions of picking the hammer up (by the handle) and hitting other objects with it. They will also perceive the afforded action of the hammer causing damage to those hit objects.

Content that the user cannot quickly identify may lead to any number of affordances. The Albrecht et al. study showed differences in affordance perception existed between recognized and unrecognized objects [1]. Some of these differences occurred in both the real and virtual settings; others were only present in the virtual. Users are likely to be quite creative, or playful, in what they find for perceived affordances of objects they do not recognize. If the object is not recognized, other factors of the environment will probably influence the affordances perceived more profoundly.

Objects that are defined by other media are likely to have the affordances provided in that media. For instance, many people initially perceive a virtual ray as a "light saber" and wish to cut objects into pieces and complain that the "sound effects" are missing. A more formal example is the Stargate portal that Steinicke et al. used to teleport users from a virtual version of the real environment to a completely virtual space [10]. This gradual transition was shown to improve the user's presence. Because the object followed the expected affordances, teleportation, it seems this is acceptable to the user. We have also successfully used this idea for teleportation.

We believe other content factors may also exist. For instance, we believe that dynamic objects are likely to increase the user's playfulness. There seems to be a pull (an affordance) to moving virtual objects that indicates that these objects can be interacted with. While the interactions themselves may not be creative, they may be unlikely for that object. An example is the desire to interact with the massive stone pendulum in the "Cuevo de Feugo" (the Fire Cave) [11]. Users express this desire often less than a minute after they ducked, so they would not be "hit" by the pendulum. Another example from that environment is the desire to stand on the visually bubbling lava.

This brings up another point that many will have experienced: interaction with objects that would not be possible in the real world. If we accept that a virtual couch is a couch, then how could we simply "pick it up and move it around" with a wand. What's more, wouldn't the leverage from a long pole, i.e. the perception of the virtual ray coming out of the wand, make the couch even heavier and more immovable? Do virtual couches have no weight? Do such interactions break perceived affordances? Affordances that are not matched by interaction may also be a factor effecting presence [3].

A final point to look at is the related question of physics in the environment. The perception of weight to virtual objects implies real physical properties. It seems very likely that the introduction of physics simulation to the virtual world will lead users to expect compliance with all real world affordances. As such simulations cannot yet be as complete as the physics of the real world, we believe its introduction might be more detrimental as helpful, since affordances will not be met. More importantly, we suspect including any single physical simulation component might be enough to induce this perception, thereby requiring a full physical simulation.

4.2 Presentation

We believe that how objects are presented influences how similar the perceived affordances are to those of the real world. How the user experiences the content is influenced by factors like displays or even priming via a good story told by the study/demo leaders [9].

As with the interrelated factors like presence, we expect that display fidelity will be a proportional factor to how close to real affordances the virtual affordances will be. On a desktop PC, such as a gaming situation, we would expect affordances to be more flexible and the user would perceive other actions than in the real world. In fully immersive displays, virtual and real affordances would be expected to be similar, as in the Albrecht et al. study [1]. This proportional relationship is expected to hold also for the other senses.

It is likewise to be expected that the introduction of multi-modal display (and input also) will make the user expectations more like the real world. Our ongoing study on virtual collision notification supports this idea [4]. However, we believe this is a very critical area. Including multi-modal cues requires also that they are appropriate. If they don't match the affordances, we believe the user experience will be significantly, negatively affected. In the Albrect et al. study, users often expressed a wish to have audio also; they desired it so they could drop unrecognized objects and how the material sounded when it hit the floor! Such a desire requires a high fidelity simulation. When multi-modal output and physics simulation are both present, we believe they will couple together, making affordance perception strongly reflect the real world. Again, when these affordances are not matched, it likely will be quite frustrating and detrimental to the experience.

Similar relationships are expected with other areas of presentation. For instance, changing the lighting model to more exact methods like ambient occlusion or adding shadows, is likely to make the perceived affordances become more like real world affordances. Conversely, computer graphics offer us an alternative, non-realistic rendering. With such techniques, we have the possibility to create environments that are high quality, but yet not realistic. In such an environment, we expect users to have less innate expectations on how objects should react; therefore, users will be willing to accept different behaviors, without having internal conflicts about them.

4.3 Demographics

Finally, there seems to be demographic differences in virtual affordance perception. One of the factors indicated in Albrecht et al. is the user's gaming experience. We expect gamers to have a different understanding of what is possible with virtual content than non-gamers. They have experience with objects that react differently than expected and with "magical" objects that don't exist in every day experience.

One of the most interesting findings of the Albrecht et al. study was the gender differences. They found that the affordance of destructive actions for virtual objects were not significantly different between the sexes; however, they were in the real environment (males perceiving destructive actions significantly more often). Such differences are critical and that study only looked at a small issue. These gender issues require extensive research to be understood.

5 Conclusion

The user perception of virtual content is important to consider in terms of design, but also in terms of usability. The affordances of virtual content are in many cases initially and intuitively perceived as real equivalents, but differences in perception have been shown to exist. Unfortunately, the usual behavior of and interaction with virtual content rarely matches those affordances. We believe this significantly and negatively impacts the user experience. We advocate that understanding the affordances of virtual content and differences in their perception is important in the development of VEs. These are important to inform design as well as behavioral programming. Supported by recent research, we argue that virtual affordances are pliable based on a number of factors. We proposed that three basic sets of factors influence perceived affordances: the content itself, the presentation, and certain demographics. By taking these factors into account in design VEs, we believe that better user experiences can be created.

Acknowledgements

The author wishes to thank Steffi Beckhaus for her support and influence on the development of the ideas in this work.

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