Identifying Affordance Features in Virtual Reality: How Do Virtual Reality Games Reinforce User Experience?

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Abstract. In order to clarify the concepts of affordance, we reviewed the previous studies of presence, interactivity, and affordance. Then, we presented the three-step identifying affordance features (IAF) model, which were (1) to develop a stage-of-the-action model for VR game environment that defined behaviors in the VR space from the user's point of view, (2) to identify affordance features based on the-stage-of-action model, and (3) to identify dimensions and to ensure the affordance features with the two-dimension framework for VR games. The results of this study will provide a consistent and comprehensive academic approach to the role of affordance to enhance user experience in VR games. Also, it is expected that VR devices and applications will become a basis for understanding user-oriented design and service factors in the process of developing and distributing VR devices and applications.

Keywords: Virtual reality · Virtual reality games · Affordance
Presence · Interactivity

1 Introduction

The VR market was expected to grow at an annual average rate of 80% or more, reaching $ 40 billion by 2020 [39]. In particular, after 2018, VR applications were expected to exceed the hardware market size, and game content was expected to account for the largest portion at the beginning. As the prices of equipment dropped and the number of VR experience centers increased, the market seemed to expand rapidly and the more investment has been made. However, the market did not expand as expected. Market researcher Digi-Capital [8] predicts that the VR market will be worth $ 25 billion by 2021 from Augmented/Virtual Reality Report 2017. This is a significant downward revision from the April 2015 report. The company had expected the VR market to reach $ 30 billion by 2020.

VR applications provide users with the opportunity to experience a virtual presence through 3D computer graphics that react to user movement [36]. At the present time, there are insufficient virtual reality applications other than visual elements [27, 36], and unidirectional delivery of defined content rather than interaction. Due to these

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limitations, users do not experience sufficient affordance, and such restriction makes obstacles against users' virtual experience. In the end, it becomes a stumbling block to reuse VR application and to grow the VR industry.

In order to expand the market, we need more realistic and easy-to-use content that induce users who is willing to pay VR content in the early stage of the industry. Although VR market is growing, research on VR application still remained in conceptual stage base on reference reviews, experiments, and focus-group interviews without integrated framework. To overcome the limitation of previous research, this study proposed the three-step conceptual framework to identify right affordance features in the integrated point of view, which are key factors to enhance presence in VR and therefore strengthen users' virtual experience. We have focused on head mounted display (HMD)-based VR game environment which is state-of-the-art at present.

In order to clarify the concepts of affordance, we first reviewed previous studies of presence, interactivity, and affordance. Then, we presented the three-step identifying affordance features (IAF) model, which were (1) to develop a stage-of-the-action model for VR game environment that defined behaviors in the VR space from the user's point of view, (2) to identify affordance features based on the-stage-of-action model, and (3) to identify dimensions and to ensure the affordance features with the two-dimension framework for VR games. The results of this study will provide a consistent and comprehensive academic approach to the role of affordance to enhance user experience in VR games. Also, it is expected that VR devices and applications will become a basis for understanding user-oriented design and service factors in the process of developing and distributing VR devices and applications.

2 Literature Review

2.1 Presence in VR Game

When users put on HMD, they feel presence in virtual world. Presence was simply defined as the perception that nothing is between one's self and the virtual world. In that sense, Lombard and Ditton [24] said presence as the perceptual illusion of non-mediation. Lee [21] proposed that the presence was a psychological state in which virtual objects are experience as actual objects in either sensory or non-sensory ways. Presence is frequently presented as consisting of two phenomena: spatial presence and social presence [3]. Spatial presence is defined as the sense of "being there" including automatic responses to spatial cues and the mental models of mediated spaces that create the illusion of place [3, 4]. Spatial presence is influenced by technological determinants and user-based determinants. Typical technological determinants of spatial presence are the degree of interactivity of a mediated spatial environment, the breadth of human sensory channels addressed by the environment, and the naturalness of proved spatial information across sensory channels [3, 37]. Therefore, when you play a VR game, 360-degree body movements, perspective and 3D objects will help you feel spatial presence. With the technological determinants, typical user-based determinants are a person's interest in and attention to the mediated spatial environment, user's arousal level [2] and his or her cognitive spatial ability [41]. The user-based determinants are

difficult to handle by technology due to individual differences. However VR games convey additional information in a more visually or audibly emphasized way to increase arousal level and cognitive spatial ability.

Social presence is defined as a "sense of being together with another," including primitive responses to social cues, simulations of "other minds," and automatically generated models of the intentionality of others (people, animals, agents, gods, and so on). Social presence is studied to explore some aspects of technology or the effects of technology. Researchers in communication and human-computer interaction area are typically interested in social presence because it may mediate the effects of other central variables such as attitudes towards the mediated others, features of the interface, persuasion, illusions of reality, learning and memory, and mental health [1, 4]. Social presence in VR game include VR interface including game navigation and interaction with other things/persons/users. This social presence helps users enjoying and immersing the VR game.

2.2 Interactivity in VR Games

The interactivity of game system is known as an essential element of video games due to its influences on the uses of the video games [40] as well as of presence experiences [18]. Interactivity was defined as the degree to which a user can actively participate in certain experience by controlling the forms and/or contents [19, 37]. As a psychological variable, the concept of interactivity was developed based on two types of efficacy, which were internal and external [32]. That is, if interactivity can be perceived, one person can send a message to a receiver, who can send the feedback to the sender. In the online environment, the internal efficacy can be seen as users' perceived control over where they are and where they are going while external efficacy is viewed as "externally based system efficacy" which is users' sense of how responsive a Web site is to the users' actions [42].

As studies on interactivity in the new technology, information systems or new media, more dimensions of interactivity have been explored. Therefore this view of perceived interactivity as two dimensions has been extended to the arguments in which interactivity includes three dimensions, which are control (internal efficacy), responsiveness (external system efficacy) and communication (direction) [23, 30], or more dimensions (features) such as time sensitivity [29], speed of feedback [7], and complexity of choice available [15]. It is found that the very basic and common dimensions of interactivity are control and responsiveness.

Previous research noted that interactivity with the perception of control is one of the factors that boost the enjoyment of video games [17, 40]. Moreover, a video game gets many different people from many different places networked via online and engaged in the game. Therefore their plays are all different and unpredictable, which cause various random situations in the game and all the attentions from the players [20].

Even for the HMD-based VR games, which are up-to-dated format of video games, perceived interactivity is an important factor to feel presence. VR environment with HMD provides 'a 100% of virtual space' and the opportunity to experience a virtual presence, and therefore users can immerse into the space and feel presence [36].

Because of these features of VR, it is critical to provide perceived interactivity and presence, for which affordance becomes essential.

2.3 Affordance Theory

VR game should provide affordances that feel the presence of virtual world and affordances that allow you to immerse the game. Affordance describes the physical interaction between objects and users. Gibson [12], an ecological psychologist who first introduced the concept of Affordance, defined affordance as "everything that a human environment provides and stimulates." It means that the physical relationship between the user and the object reflects what is possible in the object, such as what things look like. For example, 'a knee-high object with a hard, horizontal, wide surface' is an object with affordance that induces the action 'sit'. The user perceives and behaves by observing the information of the subject without previous knowledge or instructions. That is, Gibson's affordance is a fixed characteristic and capability of the object [12].

On the other hand, Norman [33], who approaches affordance in terms of the perception of the user rather than an independent feature of the environment, describes affordance as "the perceived characteristics of things, or the actual characteristics of things." He distinguished *perceived affordance* with Gibson's *real affordance*. The interpretation of the object from each user's experience does not necessarily match the intended property or design of the object. His definition provided a foundation for attention to the affordance concept in mediated communication theories, especially human computer interaction (HCI) field, which studies the interaction between humans and computers,

In contrast to researchers who succeeded Gibson [12] and found affordance in fixed capabilities and features of the object [11, 28], Hartson [14] focused on what reaction process the user takes to relate to things in interaction design and extended and supplemented the perceived affordance concept of Norman [33]. He stated that "the concept of affordance is an instrument that focuses on the link between user, action, and design. The process of recognizing and acting from what the user feels shows how to learn and use things by each of the absences [14]." In other words, the reason for the importance of affordance is that the physical characteristics of the tool cause intuitive behavior of the user without using a high level of cognitive processing such as inference or prior knowledge when the user uses the tool.

He renamed Norman's perceived affordance [33] as *cognitive affordance* and real affordance as *physical affordance*. Cognitive affordance, also referred as perceptual information about (real) affordance helps users to think and/or know about the object and physical affordance facilitates users to do something physically. "Clear and precise words in a button label [14]" could be a cognitive affordance feature because it supports users to understand the function of the button. Reasonable size and accessible location of the button could be a physical affordance feature because it helps users to click the button easily. He added two more affordance concepts: *sensory affordance* and *functional affordance*. Sensory affordance is a design feature about user's sensory experience and includes some lexical and syntactic interpretation, but not about semantic interpretation. In addition, Hartson [14] included purpose in the definition of physical affordance and

suggested the concept of functional affordance. In terms of Human-computer interface (HCI), you can click anywhere on the screen but do not click just because it is possible. Users click buttons to accomplish a goal and systems will respond to the action. For example, a door is a physical affordance because it "can be grasped and turned", and also a functional affordance because it can be "grasped and turned in order to operate the door (that allows to pass)." In addition, Hartson [14] referred to Norman's 'Stage-of-Action' model [34] and explain the process which users interact with some machine.

2.4 Affordance in Application Area

In their social media affordance study to support continuous communication in a social media environment, Majchrzak et al. [25] found four affordances to engage in dialogue for knowledge sharing: *metavoicing, triggered attending, network-informed associating, and generative role -taking*. The research focused on engaging and associating relationships for online activities. In order to succeed the results of this study and to derive the affordance in the VR game environment, the technical characteristics of the VR different from the social media should be additionally considered. In the same vein, Lee and Shin [22] analyzed the product design and multi-media affordance cases of mobile games with high game rankings and *identified interaction, user experience, metaphor* and *simplicity* as the affordance of mobile game.

Although new concepts such as technology affordance [11], communication affordance [16], pedagogical affordance [38] and social affordance [10, 25] have emerged as a result of studying affordance in various fields, most studies that explored the interaction between users and computerized beings in augmented reality games and virtual reality games are mostly dependent on concepts Hartson [14] suggested.

The concept of affordance used in virtual reality research for a long time, but is still in the early stage of theory development based on specific products and environment [13, 31]. Each of the studies have different definition and classification of affordance concept [6, 9, 26]. A generally accepted definition of affordance and the relationship among diverse affordance concepts in VR game environment is needed to develop more sophisticated theory and research models for empirical studies.

3 Theoretical Framework for Affordance Development in VR Games

3.1 Three-Step IAF (Identifying Affordance Features) Model

To enhance users' experience, affordance are very basic key concepts and therefore it is important to identify affordance features for specific industry (here is VR games) to increase presence. Here this study presents the three-step IAF model. The three steps are (1) to develop a stage-of-the-action model for VR game environment that defines behaviors in the VR space from the user's point of view, (2) to identify affordance features based on the-stage-of-action model, and (3) to identify dimensions and to ensure the affordance features with the two-dimension framework for VR games.

3.2 Step 1: The Stage-of-Action Model of VR Games

Affordance is the first step in cognitively letting a user feel presence, technically being the starting point for making VR games sophisticated. In this regard, studies on the user's feeling of affordance in the virtual space under the VR environment [35] and on the significance of affordance in the degree of presence [13] have been done. The preconditions to understand the role of affordance in creating and maintaining a virtual reality is to believe that there is an alternative "place" where we can presence. When the user's viewpoint changes from observer to actor, it increases the feeling of "place". This means not only believing in the space the user can explore, but also feeling presence as if they are one of the objects in this space. Users perform actions in an environment full of tools to achieve goals. The time and space of action is limited by the environment and the affordance of the object [13].

Based on the concept of affordance and presence in the VR game environment discussed above, we have modified and improved the stage-of-action model of Norman [34] to fit the VR environment. The Norman [34] model is a chronological summary of the typical user activity that occurs when a user interacts with a machine ("some machine").

In the VR game environment, user behavior has different aspects from the case of using a general machine which Norman [34] suggested. First, an action takes place in a space separated from the real world as a way to enter 3D virtual space while a user act in the real world and the action applied into two-dimension monitor in a general machine. Second, movement in the virtual space is done not only through the manipulation of the device but also through user's movement. Third, the game is played through the player's initiative action and interaction with various objects. Especially for RPG games social factors should be considered because many people from different places log in to the game and play together. Forth, the user is continuously exposed to a plurality of various missions and feed-backs of the results to perform the next successive mission. Based on the above analysis, we derive a new state-of-action model in VR environment. Users will encounter affordance and presence on the process of experiencing VR games.

As seen in Fig. 1, gamers enter the virtual world when they wear HMD. After they put on HMD and see the virtual world, they perceive their presence in the virtual world (Perceiving Virtual World). Involuntary attention should be premised on the spatial presence. Various sensory factors and depth of presented information such as real image is critical. Second, in order to play the game, users should perceive every movement and line of sight as first-person position (Perceiving First-Person Position). When they go close to the object in virtual world, the objects should be close-up. When they turn their face and move gaze, the virtual world is changed along their eyes.

Third, the gamers recognize what they are doing based on beings and things around in virtual world (Interpreting the Perception). When they perceive virtual world and the role in the game, they decide to what to do in the game (Goal Setting). Goal setting stage is the beginning point of the real game. When they execute the actions such as moving, click, shaking, or stand up/down, cognitive, physical, and sensory affordance can support to execute in VR game. After the action, gamers see the results of the action. Physical and sensory affordance helps them to understand the feedback and

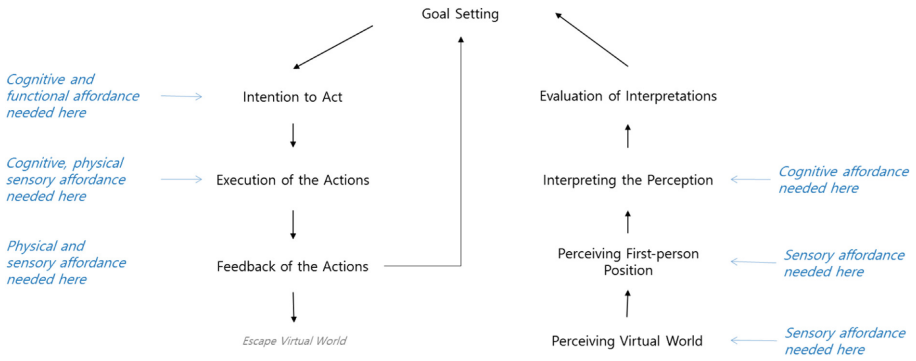

Fig. 1. Stage- of-action model for VR game environment (draft)

recognize the next step of the game. The loop from Goal Setting to Feedback of the actions continues before they stop the game and escape the virtual world.

In addition, we mapped four types of affordance, i.e. cognitive affordance, physical affordance, sensory affordance, and functional affordance from Hartson [14], to our stage-of-action model. The range of each affordance is extended in the VR environment. In cognitive affordance perspective, users are exposed to unfamiliar and diverse stimuli and must perform missions within them. Therefore, the cognitive affordance feature should be enhanced to guide the journey to perform the goal in the VR environment. In terms of physical affordance, the physical features of action itself and the results of actions should be proper and reasonable. The responses of VR world, background 3D image as well as mission-related images, should interact as expected to strengthen the reality of virtual environment. To support cognitive and physical affordance in the VR environment effectively, the design of the results and feedbacks should be realistic which is constituent of sensory affordance. In order to strengthen cognitive and physical affordance, more sensory aspects need to be considered than visual elements currently [36].

3.3 Step 2: Identifying Affordance Features

In step 2, affordance features are identified. Affordance feature is the components which should be considered to design affordance. The-stage-of-action model in step 1 is used to examine users' perspectives. Each stage in the model provides the ideas of users' specific actions and therefore the important features of objects, backgrounds, or agents in the VR game to display.

As seen in Table 1, the affordance features identified from previous research are insufficient for VR games. Minocha [31]'s affordance features fit to the learning in the VR environment, which did not cover the characteristics of the game. Bower [5] is missing the VR element by defining the elements of the overall media for the e-learning. Moreover previous studies did not consider the viewpoint of enhancing social presence.

Table 1. Affordance features

	Bower(2008)	Minocha et al(2017)	This rsearch(2018)
Environ-ment	e-learning	VR learning (Google Expedition)	HMD VR game
Features	*Media affordance*	*360-degree visual authenticity*	*First-person view*
	Spatial affordance	*360-degree navigation*	*3D journey*
	Temporal affordance	*3D view*	*Visual authenticity*
	Navigation affordance	*Emphasis*	*Stereoscopic 3D image*
	Emphasis affordance	*First-person perspective*	*Goal-oriented actions*
	Synthesis affordance	*In-situ contextual information*	*Emphasis*
	Access-control affordance	*Simulations*	*Action-based response*
	Technical affordance	*Single-user handling*	*Unintentional response*
	Usability	*Synthesis*	*Social environment*
	Aesthetics	*Visualization*	
	Reliability		

By describing the process by action from the users' perspectives with the stage-of-action model, following critical affordance features of VR game are driven:

(1) First person view: the VR game takes first person narrative. Therefore the background images and all the elements should be displayed along with the player's movement.
(2) 3D journey: Users are usually moving around to achieve a goal instead of staying at one place.
(3) Visual authenticity (3D): Background image should be realistic as much as possible. Authentic visualization such as high-fidelity pictures and 360-degree physical view of the space helps users to sense and experience the virtual space which hard to visit in real life.
(4) Stereoscopic 3D image: Things in the VR should be stereoscopic so that it looks real. This realism is about accurate representation of objects, events and people.
(5) Goal-oriented actions: In the VR game, a player move his/her head, arms, legs, and body to achieve goals. Goal-oriented actions should be reliably and quickly designed as the same as the player expect.
(6) Emphasis: Emphasis is some signs or things to highlight important information in the view. This additional information includes visually or audibly emphasized ways. It increases arousal level and cognitive spatial ability.
(7) Action-based response: The VR system should be designed to respond to the actions of player properly and quickly.
(8) Unintentional response: Except action-based response, VR environmental interaction depending on users' action such as looking around and touching things which are not directly related with game goals. This is more related interactivity to feel presence in VR environment.

(9) Social response: The VR environment is social-interaction friendly so that the player can be with other beings, play the same game with other players networked or interact with things in the VR.

3.4 Step 3: Two-Dimension Framework for Affordance Features of VR Game to Enhance Presence

In order to ensure all important affordance features are identified, we should consider what kinds of point of view we use to identify affordance features. Based on the previous literature review, two-dimension framework is induced. Axes of the framework are *Media Perspective* and *Interactivity Perspective*. Media Perspective is the key features which VR game should include: *VR Features* vs. *Game Features*. VR Features is related with the characteristics of VR media which is distinguish from other environment such as PC or mobile while Game Features are related with various game dependent factors. Interactive perspective is a key factor in VR game to support presence: *Interactive Control* and *Interactive Response* [42]. Among many other dimensions and features of interactivity, the two very basic components are used in this study. All the features should be implemented to enhance spatial presence or social presence of virtual world in VR.

The affordance features identified are categorized into each cell so that we can make sure the affordance features are identified enough to cover for every important aspect (See Table 2).

Table 2. Affordance feature categories based on media and interactivity perspectives

		Media	
		Game features	VR features
Interactivity	Interactive control	• Goal-oriented action • Emphasis	• First-person view • 3D journey • Visual authenticity (3D) • Stereoscopic 3D image
	Interactive response	• Action-based response • Social response	• Unintentional response

4 Discussion

This study clarified the concepts of presence, interactivity, and affordance which are critical to maximize user experience in VR game. Based on the conceptualization, we developed the three-step IAF model, which includes (1) a stage-of-the-action model for VR game environment that defines behaviors in the VR space from the user's point of view, (2) affordance features identified, and (3) a two-dimension framework to ensure that affordance features for VR games to cover all perspectives. Affordance features are required to enhance the VR effects of the action for each stage of the model. Two perspectives of the matrix are (1) VR game dimension which includes VR focused aspect and game focused aspect and (2) interactivity dimension which are control aspect and response aspect.

The results of our study will be able to bring a comprehensive and consistent academic approach towards the roles of affordance and presence, which strengthen user experiences in VR games. This approach will be developed further with the changes of detailed elements in compliance with the advance of VR technologies. In practice, the IAF framework will be useful to identify the key elements of user-oriented design and services for the VR market which has not been expanded as expected.

Perceived presence can be different based on person's attributes, interests, and attention to the mediated spatial environment and arousal level [2]. Wirth et al. [41] also noted that cognitive-spatial abilities of users influence perceptions of spatial presence. This study, however, only focused on the characteristics of VR, not on personal factors. As well, there are many different environments to experience VR games, but this study investigates HMD-based VR environment, which currently are most widely used. Further studies on various VR environments could be done based on the results of our study. Finally, empirical studies will be needed to hypothesize and verify the relationships between the concepts driven from the framework and stage-of-the action model in this study.

At this very moment, the VR technologies are advanced rapidly and therefore the concepts and the framework proposed in this study will shed light on exploring the VR technologies in diverse disciplines.

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