

# A Study on Utilization Plan for Affordance Theory-based Virtual Reality Contents

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## Abstract

**Background/Objectives:** Virtual reality content is changing into a form of pursuing experience and convenience as it gradually emphasizes user interaction, and user-centric designs and interfaces like UI/UX are performing important roles in creating a new communication and interaction. Thus, when designing content for a virtual environment, a design environment that allows users to focus within the virtual space, toward the cognitive factor, must be created by means of user comprehension and experience. **Methods/Statistical Analysis:** Current virtual reality content requires adaptive learning in terms of new device control, with various devices and interaction functions. Hence, studies, in accordance with the cognitive process from virtual reality, are necessary in order to achieve an effective experience based on virtual reality content, because user needs in regards to comprehension and convenience toward new environments are being generated. The present study analyzes virtual reality contents based on cognitive affordance theory through information and behavior detected by visual perception in order to achieve efficiency for convenient environments, utility, and user participation expansion, which is achieved by restricting contents to those only of the CAVE system type. **Findings:** The sub-elements of cognitive affordance theory are divided into perception, function, and behavior, and the data analyzing the correlation in accordance with each type of virtual reality content establishes a theory for an efficient virtual reality content usage plan, presenting a utilization model. Research on contents based on cognitive affordance has been positively affected by content understanding and focus, affected from the perception factor out of each cognitive affordance element. **Application/Improvements:** Such results show that more convenient environments for users will be built and content satisfaction will be increased, and may be presented as an efficient utilization plan for virtual reality content development.

**Keywords:** Action, Contents, Cognitive Affordance, Function, Perception, Virtual Reality

## 1. Introduction

### 1.1 Background and Necessity of Research

The virtual reality based contents enabled to provide various experiences to the users are structured with media environment that diversifies the interface according to the various usage of the virtual reality device and therefore, when designing contents that provide various experiences, the design environment enabled to immerse within the virtual reality space through the understanding and experiences of the user within the user's cognitive factor must be pursued<sup>1</sup>. Therefore in this study, the occurrence for user's desires towards level of immersion and convenience

as well as the understanding of users within the virtual reality environment must be grasped to provide effective experience of virtual reality based contents to the user. Also, continuous research is required for the immersion and cognitive process of virtual reality content interface.

### 1.2 Method and Structure of Research

The present study understands the concept of virtual reality and through the analysis of virtual reality device, it analyzed the satisfaction degree of interaction in the communication and virtual reality that is effective for the user through the factor of cognitive affordance within the

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virtual reality contents based on the virtual reality device of the CAVE method that is the immersive display based virtual reality system. Virtual reality contents of the CAVE method were classified as types of education, entertainment and technology in accordance with the different interaction functions and characteristics. The classified contents were measured for the degree of understanding, immersion and convenience through the operational definitions of perceptive factor, functional factor and action factor according to the user cognitive function based on the type of cognitive affordance. Moreover, the study hypothesis was verified based on the analysis results and the cognitive affordance utilization method for virtual reality were presented as well as proposing the direction for future studies.

## 2. Theoretical Consideration

### 2.1 Affordance within Virtual Reality Environment

With the definition of inducing a certain action, affordance is also used as a term to express 'to connect different concepts.' And this concept of affordance can be applied in the virtual reality environment. While the virtual reality system has been studied by providing new interactive experiences to the user with contents in various fields, the studies for the usability of virtual reality contents has not been conducted in various aspects and remains insufficient in comparison to the development of virtual reality based system and contents. Although the usability within virtual reality environment is emphasized as a significant factor in the development of interactive systems, in the existing usability evaluations, the issues regarding 3D interaction or navigation within virtual reality environments are not discussed. Furthermore, it does not include factors such as level of presence, side effects as well as navigation and operation of objects within the 3D space<sup>2</sup>. Gabbard, Hicks and Swan have stated that the usability evaluation for virtual environments must differ from the existing evaluation methods because the virtual reality is different from the 2D based interface such as the existing graphic user interface<sup>3</sup>. As the evaluations are conducted in the direction according to the distinct characteristics<sup>4</sup> of interface technology and contents within virtual reality environments, it can be concluded that it is close to the user-oriented evaluation and evaluation pattern and therefore, directly connected to affordance.

### 2.2 Relationship between Virtual Reality Contents and Cognitive Affordance

In order for users to understand and recognize the information within virtual reality covered in 4 sides, the present study must recognize the various factors perceived in the contents. Such environmental characteristics emphasize the significances of cognitive process and components of contents and the users continue to demand and apply convenience<sup>5</sup>. The cognitive process signifies the entire process of decision-making from perception to conducting physical actions and therefore, in cognitive affordance, the usability of how to operate an object must be designed directly by considering the human's cognitive aspects<sup>6</sup>. Hence, Norman explained the conditions related to how object are operated in the 'user-oriented design' with terms of affordance, restriction, response, visibility and feedback<sup>7</sup>. Through this process, the appropriate commands are properly conveyed by letting the significant parts in design operation for the usage of tools and environment and by restricting user's actions with restriction it only allows one action for proper operation or make the user naturally adapt by using characteristics of response and conclude whether the content operation was correct or incorrect through feedback. In other words, it is designed so that the user's actions lead to proper results<sup>8</sup>. The user interacts with all information and achieves communication within virtual space through visual stimulation and hearing and visual stimulation can lead to sense of touch. In accordance, the majority of information recognized in virtual reality contents is accomplished through vision and as displayed in Table 1, the visual information in the contents of virtual reality device environment can be divided as information transfer element and operation

**Table 1.** Visual perceptive factors in VR contents

| Factors constituting visual information |                 |             |
|-----------------------------------------|-----------------|-------------|
| Information delivery factors            | Static factors  | Image       |
|                                         |                 | Icon        |
|                                         |                 | Text        |
|                                         |                 | Color       |
|                                         |                 | Layout      |
|                                         | Dynamic factors | Animation   |
|                                         |                 | Navigation  |
|                                         |                 | Feedback    |
| Manipulative factors                    |                 | Input tools |
|                                         |                 | Gestures    |

element as interface elements. And such transfer elements were divided into static elements and dynamic elements.

Hence, the present study applied the appropriate affordance theory within virtual reality environments to the cognitive affordance proposed by Norman to study the cognitive affordance within virtual reality contents. Moreover, as the study on cognitive affordance elements in virtual reality contents, it conducts pilot study on affordance and virtual reality to analyze the affordance element that can be recognized by the user in virtual space in the virtual reality contents. And for the composition of the study, the cognitive function composition<sup>9</sup> of mobile contents analyzed by<sup>9</sup> in the pilot study was restructured to suit this study and defined as displayed in the following Table 2.

As the major elements of cognitive affordance, the elements of perception, function and action in the contents become the subjects of cognition for the users and for the virtual space, there are differences for each characteristic of contents and environmental properties of the device that directs the virtual space with cognitive methods that are different from the existing mobile environments. In accordance, the elements that influence the user's information recognition in graphic 3D videos were defined as the perceptive element while the elements that influence the information recognition according to user's actions required for system control were defined as functional elements. And lastly, the action elements related to environmental related gestures of the virtual space and the interactive elements for amicable usage of information in the virtual reality device by the user's actions were defined as the action elements.

## 3. Research Method and Analysis Result

### 3.1 Planning and Method of Research

Through the pilot research of affordance theory and the analysis on virtual reality based contents, this

**Table 2.** Perceptive affordance factors and item classification

| Perceptive affordance | Perceptive factors | Functional factors | Action factors |
|-----------------------|--------------------|--------------------|----------------|
| Item classification   | 3D effect          | Input tools        | Drag           |
|                       | Icon               | Limitation         | Choice         |
|                       | Animation          | Navigation         | Insertion      |
|                       | Color              | Feedback           | Gestures       |

study focused on the cognitive affordance elements of perception elements, functional elements and action elements by concentrating on the contents effectively used in the CAVE form among the types of virtual reality contents. And the evaluation items were prepared through operant definition and with this, the variables were found to set the study model and hypothesis. In accordance, the CAVE method-based education, entertainment and technology related contents enabled for maximized immersion were selected along with expanding user participation. Furthermore, the variables were found in the cognitive affordance types through theoretical consideration of affordance to propose the hypothesis. In this study, the research models of each variable were analyzed using the statistical analysis technique and ultimately, the hypotheses were verified.

#### 3.1.1 Hypothesis

Factors of perception, function, and behavior, in terms of experiencing virtual reality content, have set hypotheses indicated in Table 3, in accordance with variable analysis, in order to present a utilization plan for improving the usability of users based on cognitive function.

#### 3.1.2 Research Method

After the two hypotheses were set in the designed research model by analyzing the cognitive affordance elements for virtual reality, virtual reality contents were selected to be experienced to verify the hypotheses and results were surveyed using the self-report method.

#### 3.1.3 Research Process

To verify the research hypotheses, a questionnaire survey was composed and as shown in the following Figure 1, three different content experiences were conducted on the subjects. Moreover, the process for analyzing the

**Table 3.** Research hypothesis

| Hypothesis   |                                                                                                                                                      |
|--------------|------------------------------------------------------------------------------------------------------------------------------------------------------|
| Hypothesis 1 | There will be differences in recognizing affordance elements(Perception, Function, Action) according to the type of virtual reality content.         |
| Hypothesis 2 | There will be differences in recognizing affordance elements(Perception, Function, Action) according to the satisfaction of virtual reality content. |

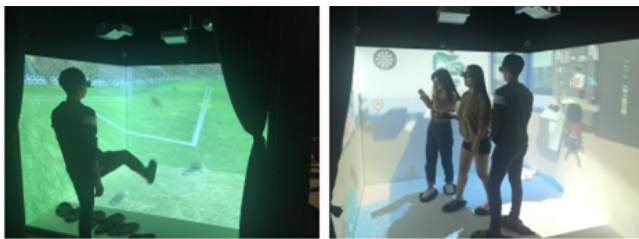
difference of cognitive affordance element according to the type and satisfaction of contents are as displayed in Table 4.

### 3.2 Survey Analysis and Hypothesis Verification

As methods of analysis, frequency analysis, reliability analysis and One-Way ANOVA were used to verify the research hypothesis and analyze the difference of affordance element in virtual reality contents. Prior to this, the reliability analysis was conducted for the reliability of research and as a result in this study, Cronbach's  $\alpha$  value for all questions were above 0.7 which showed that all can be accommodated without removal of any certain question. The results are indicated in Table 5.

#### 3.2.1 Hypothesis 1\_Verification Result

The result for the hypothesis “there will be differences in recognizing the affordance elements (perception,



**Figure 1.** Implementation of content experience on subjects of research.

**Table 4.** Research process for analysis of affordance elements

|                                                |               |            |
|------------------------------------------------|---------------|------------|
| Document research and experiment design        |               |            |
| ▼                                              |               |            |
| Pilot test and verification of survey items    |               |            |
| ▼                                              |               |            |
| Implementation of affordance survey            |               |            |
| ▼                                              |               |            |
| Research for each type of content              |               |            |
| Education                                      | Entertainment | Technology |
| Subjects of Research: 30 people                |               |            |
| Perception                                     | Perception    | Perception |
| Function                                       | Function      | Function   |
| Behavior                                       | Behavior      | Behavior   |
| ▼                                              |               |            |
| Analysis of survey responses and survey coding |               |            |
| ▼                                              |               |            |
| Survey analysis and hypothesis verification    |               |            |

**Table 5.** Analysis result and statistics of reliability

| Content       | Alpha of Cronbach | Chronbach's Alpha Based on Standardized Items | No. of Items |
|---------------|-------------------|-----------------------------------------------|--------------|
| Education     | .947              | .949                                          | 36           |
| Entertainment | .959              | .960                                          | 36           |
| Technology    | .925              | .928                                          | 36           |

function, action) in accordance with the type of virtual reality content” are as displayed in Table 6. In education contents, the animation element appeared to have higher influence in understanding and immersion compare to other contents. Also for entertainment contents, the three-dimensional effect, icon, animation and feedback elements appeared to have the lowest numbers in comparison to other contents and in opposite, in the technology content displayed the highest numbers to greatly influence the degree of immersion. In other words, the first hypothesis was verified and accepted through the analysis.

#### 3.2.2 Hypothesis 2\_Verification Result

The results for the hypothesis “there will be difference in recognizing the affordance elements (perception, function, action) according to the satisfaction of virtual reality content” are as displayed in Table 7. The selection element displays significant differences in education contents. Although it is lower than the average number, the selection elements under the action element for understanding the content was seen to be influenced by the satisfaction of content. In the entertainment content, navigation and drag elements influenced the understanding, immersion and convenience of contents to influence the degree of satisfaction. And overall, action and function elements were more influenced in degree of satisfaction for entertainment and technology contents than education contents. In the technology contents, the icon and selection elements displayed significant differences in immersion of content and the icon element of perception received the most influence in degree of satisfaction. In other words, the second hypothesis “there will be difference in recognizing the affordance elements (perception, function, action) according to the satisfaction of virtual reality content” was verified and accepted through analysis.

**Table 6.** Overall results for differences in cognitive affordance elements according to type of content

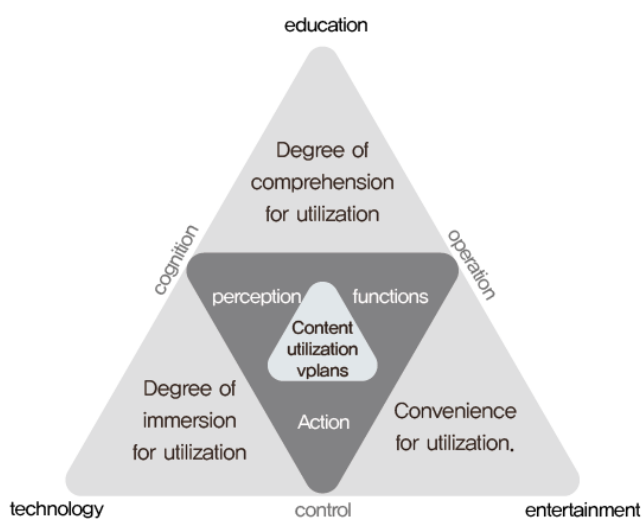
| Type          | N  | Cognitive Affordance Element |            | Item      | Contents | Average | Standard Deviation | F     | Significance Probability | Schfeffe |
|---------------|----|------------------------------|------------|-----------|----------|---------|--------------------|-------|--------------------------|----------|
| Education     | 30 | understanding                | Perception | Animation | A_edu    | 4.600   | .5164              | 3.343 | .050                     | A>C      |
|               |    |                              |            |           | B_Ent    | 4.000   | .8165              |       |                          |          |
|               |    |                              |            |           | C_Tec    | 3.800   | .7888              |       |                          |          |
|               |    | immersion                    | Perception | Animation | A_edu    | 4.500   | .7071              | 3.655 | .039                     | -        |
|               |    |                              |            |           | B_Ent    | 3.800   | .7888              |       |                          |          |
|               |    |                              |            |           | C_Tec    | 3.600   | .8433              |       |                          |          |
| Entertainment | 30 | immersion                    | Perception | 3D effect | A_edu    | 4.200   | .7888              | 4.081 | .028                     | C>B      |
|               |    |                              |            |           | B_Ent    | 3.400   | .6992              |       |                          |          |
|               |    |                              |            |           | C_Tec    | 4.300   | .8233              |       |                          |          |
|               |    |                              |            | Icon      | A_edu    | 3.900   | 1.1005             | 6.411 | .005                     | C>B      |
|               |    |                              |            |           | B_Ent    | 2.900   | .7379              |       |                          |          |
|               |    |                              |            |           | C_Tec    | 4.300   | .8233              |       |                          |          |
|               |    |                              |            | Animation | A_edu    | 4.200   | .7888              | 5.775 | .008                     | A,C>B    |
|               |    |                              |            |           | B_Ent    | 3.200   | .9189              |       |                          |          |
|               |    |                              |            |           | C_Tec    | 4.300   | .6749              |       |                          |          |
|               |    |                              | Function   | Feedback  | A_edu    | 3.800   | .9189              | 5.087 | .013                     | C>B      |
|               |    |                              |            |           | B_Ent    | 3.300   | .8233              |       |                          |          |
|               |    |                              |            |           | C_Tec    | 4.400   | .5164              |       |                          |          |
| Technology    | 30 | understanding                | Perception | 3D effect | A_edu    | 4.300   | .6749              | 3.685 | .038                     | C>B      |
|               |    |                              |            |           | B_Ent    | 3.700   | .8233              |       |                          |          |
|               |    |                              |            |           | C_Tec    | 4.500   | .5270              |       |                          |          |
|               |    | convenience                  | Perception | Icon      | A_edu    | 3.900   | .5676              | 3.538 | .043                     | -        |
|               |    |                              |            |           | B_Ent    | 3.200   | .9189              |       |                          |          |
|               |    |                              |            |           | C_Tec    | 4.000   | .6667              |       |                          |          |

**Table 7.** Overall result in differences of cognitive affordance elements in accordance with content satisfaction

| Type          | N  | Cognitive Affordance Element |            | Item       | Contents | Average | Standard Deviation | F     | Significance Probability | Schfeffe |
|---------------|----|------------------------------|------------|------------|----------|---------|--------------------|-------|--------------------------|----------|
| education     | 30 | understanding                | Action     | Choice     | A_edu    | 3.933   | .7988              | 4.987 | .014                     | B>C      |
|               |    |                              |            |            | B_Ent    | 4.417   | .5149              |       |                          |          |
|               |    |                              |            |            | C_Tec    | 3.000   | 1.0000             |       |                          |          |
| Entertainment | 30 | understanding                | Function   | Navigation | A_edu    | 3.133   | .8338              | 5.332 | .011                     | B>A      |
|               |    |                              |            |            | B_Ent    | 4.083   | .6686              |       |                          |          |
|               |    |                              |            |            | C_Tec    | 3.667   | .5774              |       |                          |          |
|               |    | immersion                    | Action     | Drag       | A_edu    | 3.133   | 1.1255             | 3.503 | .044                     | -        |
|               |    |                              |            |            | B_Ent    | 3.917   | .6686              |       |                          |          |
|               |    |                              |            |            | C_Tec    | 4.333   | .5774              |       |                          |          |
| Technology    | 30 | convenience                  | Function   | Navigation | A_edu    | 3.200   | .8619              | 3.522 | .044                     | B>A      |
|               |    |                              |            |            | B_Ent    | 4.000   | .7385              |       |                          |          |
|               |    |                              |            |            | C_Tec    | 4.000   | 1.0000             |       |                          |          |
|               |    | immersion                    | Perception | Icon       | A_edu    | 3.533   | .7432              | 3.531 | .043                     | -        |
|               |    |                              |            |            | B_Ent    | 3.917   | .6686              |       |                          |          |
|               |    |                              |            |            | C_Tec    | 4.667   | .5774              |       |                          |          |
|               |    |                              | Action     | Choice     | A_edu    | 4.267   | .5936              | 4.409 | .022                     | B>C      |
|               |    |                              |            |            | B_Ent    | 4.667   | .4924              |       |                          |          |
|               |    |                              |            |            | C_Tec    | 3.667   | .5774              |       |                          |          |

## 4. Application Plan for Cognitive Affordance in Virtual Reality Contents

Among the cognitive affordance elements for different types of virtual reality contents, the influences made by the perception element appeared the greatest and in education contents, the perception element seemed to cause connection between understanding and immersion of contents while in entertainment contents, it displayed correlation for degree of immersion. Also, in the technology contents, it appeared as though the understanding and convenience of contents were related due to the perception element and therefore, the results of this study states that the perception element of cognitive affordance can be displayed as effective model as the application plan of contents and through the survey method, it verified that cognitive affordance elements have differences in degrees of understanding, immersion and convenience through the survey method. In such a way, the cognitive affordance utilization plan model of virtual reality content, shown by Figure 2, is capable of presenting behavior within the basic model and virtual space, from interface designs of virtual reality content that enables researchers to understand the cognitive process of users in various content types. Moreover, the importance and preference of internal elements can be analyzed through the cognitive affordance element to influence content design or composition and satisfy the desires of users for understanding, immersion and convenience.



**Figure 2.** Application plan for cognitive affordance-based virtual reality contents.

## 5. Conclusion

This study analyzed the perception, function and action elements based on cognitive affordance in the education contents, entertainment contents and technology contents, which are the most used in virtual reality environments, and verified that there are differences according to type of content and satisfaction of content. Also, an application plan for virtual reality contents based on the analysis results was proposed. To achieve this, the elements were divided into fields of perception, function and action according to type of cognitive affordance and the detailed item of each element was derived in the virtual reality content element. Such studies based on cognitive affordance are able to suggest application plans as directions for effective interface that is user-oriented and utilization for each type of virtual reality content. Such application methods can be used positively when developing by providing interface direction of contents for the content planner, developer and designer. At the present time, virtual reality technology is rapidly evolving and processed to experience virtual reality contents with various devices. Also, it has influences that can be applied to all fields and this strength not only lets the user see and feel in the virtual reality content but induces the user's actions and therefore, the range of user's senses and various communication environments will be expanded. To understand such environments of virtual reality and for the content satisfaction of the user, the content application plan by cognitive affordance is significant and the influence of interface in virtual reality contents will further increase. And in order to achieve this, the research of interface in virtual reality contents must be conducted continuously and the research on the user's cognitive process and content utilization must be conducted.

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