The Exploratory Analysis of Spatial Perception in Augmented Reality with Gaze Path and Task Achievements

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Abstract

This study aims to examine spatial perception in an augmented reality (AR) application with a gaze path and a task achievement. This study utilized the Korean traditional style townhouse for a spatial experience in the AR application. Nine participants were divided into three groups; 2D-based picture material, 3D miniature AR material, and 3D real-size AR material. The task entailed elucidating the comparison of two different features of Korean traditional style townhouses. After gathering the participants' eye movements and recording their responses to the task, we examined the scan path of the participants and classified the task responses. According to the results, the 3D real-size AR material group scanned the townhouses horizontally and vertically longer than the other groups. In addition, their responses contained more words related to 'depth, height, width' for the spatial observation. These results show that 3D real-size AR material could increase spatial perception..

Keywords: AR application, Scan-path, spatial perception

Introduction

Recently, many learning materials using augmented reality (AR) have been developed in cultural history, science, and art education. AR is evaluated as an academically efficient learning tool based on multimedia learning theory (Wang et al., 2018). The technology is also capable of providing a specific context for the learning content by augmenting the visually three-dimensional data on the desk. Since spatial information is obtained through learners' visual information (Kiefer et al., 2017), spatial graphics provided by augmented reality can improve learners' understanding of learning materials.

Spatial information is obtained through visual sensors (Zheng, Chen & Wang, 2020). It is for this reason that eye-tracking has been employed in spatial cognitive relationship research. Furthermore, visual information can explicate the manner in which learners interact with spatial information and how spatial information is perceived in decision-making (Kiefer et al., 2017). For example, the spatial distribution of gaze and scan-path explain the gaze movement process for spatial perception.

Since visual information can explain the relationship between the learner's attention to visual data, eye tracking is used in research on AR learning data (Asan & Yang, 2015). Wang et al. (2018) confirmed the degree of cognitive load by comparing three different learning materials such as text data, augmented reality data, and real object data through eye-tracking. As a result, the augmented reality learning data provided a similar experience to the learner without much difference from the real object data (Wang et al., 2018; Weichbroth, 2020). However, there is insufficient

understanding of ways of perceiving three-dimensional space and buildings provided by AR-based learning materials. Rudimentary exploratory research is needed to understand how spatial perception appears in the learner's cognitive processing process.

To effectively develop AR-based learning materials, it is necessary to study how learners recognize and explore three-dimensional learning materials. Since the learner's gaze provides information about the cognitive process (Kiefer et al., 2017), it will enable the learners to explore ways of observing and processing the augmented three-dimensional learning material (Asan & Yang, 2015).

The purpose of this study is to examine the gaze information of learners who observe AR-based 3D spatial learning materials through eye-tracking. The learning material is an AR application about two traditional Korean townhouses. Via the utilization of eye-tracking, we seek to identify how the learners understand the places and how their cognitive processing occurs. The research questions are shown as follows.

Research Question 1: Is there a difference in the learner's gaze movement among 2D-based picture material, 3D miniature AR material, and 3D real-size AR material?
Research question 2: Is there a difference in the learners' spatial knowledge achievement among 2D-based picture material, 3D miniature AR material, and 3D real-size AR material?

Research Design & Method

Participants: The participants were nine undergraduate students.

Materials: The three-dimensional augmented traditional Korean townhouses were the experimental materials used in this study. To undertake comparison, 2D materials are provided to the control group, and 3D spatially augmented learning materials are provided to the treatment group. Participants were presented with the task of learning spatial recognition: Observing five differences between two different types of townhouses. The task will consist of questions asking about location, distance, direction, order, spatial arrangement, etc. so that the participants can focus on spatial awareness (Alemdag & Cagiltay, 2018).

Variables: The independent variable was 2D material, AR bird view material, or AR navigation material. The dependent variable was the scan path of eye information. The gaze path signifies data that visualizes time series data information. The larger the circle size in the gaze path information, the longer the gaze fixation stayed. Notably, the numbers in the circle denote the order of gaze movement.

Figure 1

The scan path analysis

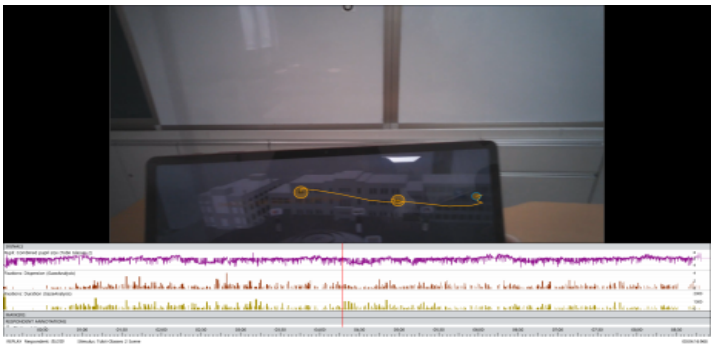
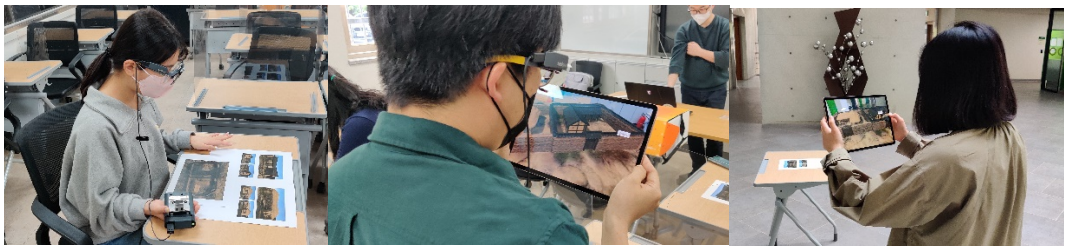


Figure 2

The scenes of the experiment (2D material, AR bird view material, and AR navigation material)



Results

The first group, the '2D picture material', can directly see the entire house, but detailed observation is impossible. Therefore, the gaze moves within a narrow area. The participants in the 2D picture material group mainly check for differences such as the presence or absence of specific objects or differences in materials. Detailed observation was possible through approaching, sitting, or moving because '3D miniatures AR material' can see the entire house. Their gaze was moved more frequently than the 2D picture material group. 3D miniature AR material group mainly observed the details and arrangement of the houses. In the '3D real-size AR material', it was impossible to watch the whole pictures of the two buildings at once, but a long gaze movement was observed up, down, left, and right while moving at a distance like the actual size. On this basis, it was ascertained that the 3D real-size AR material group did recognize the depth and height of the space. Accordingly, it can be inferred that 3D real-size AR learning materials could improve spatial perception by directly moving around the target contents.

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