ASSESSING VISUAL PERCEPTION IN VIRTUAL REALITY ENVIRONMENTS

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ABSTRACT

Recent trends in cognitive psychology have highlighted the significance of the situated context with which individuals must carry out cognitive processes. Understanding the cognitive and biological mechanisms which permit people to negotiate their environment is therefore of paramount importance. Considering this with the widely establishing relationship between STEM educational success and spatial ability, this study aimed to develop authentic psychometric assessments of visual perception in virtual reality environments. It is envisioned that the development of such tests could be used in the determination of a potential relationship between visual perception and success in STEM. The findings of this study offer significant insight into the progression of this agenda from a methodological approach. The pertinent cognitive implications are discussed in relation to STEM education.

KEYWORDS: Visual Perception, Virtual Reality, Psychometric Assessment

1. INTRODUCTION

The learning environment created within engineering education affords students opportunities to develop a multitude of complex cognitive competencies. In particular, cognitive and external modelling skills are fostered which are foundational capacities for more general problem solving [1]. However, it is argued that learning is fundamentally situated and that the task environment has a significant influence on the espousal of cognitive skills [1]. The capacity to navigate this environment is predicated on a developed visual perceptual system. The ability of an individual to visually perceive stimuli has a direct impact on the way in which they interact with those stimuli. Therefore, it is important to attain a highly accurate visual perceptual ability.

The relationship between success in STEM education and spatial skills is widely established [2]. The cognitive faculty of spatial ability however consists of a dichotomy between spatial skills and perceptual factors and considering the reliance on visual perception for the successful negotiation of a task environment, this suggests merit in investigating the potential relationship between STEM and visual perception. A number of psychometric tests for cognitive factors pertinent to visual illusions have been developed using illusory stimuli as they have the capacity to elicit perceptual sensitivities [3]. However, these tests are typically constructed in a paper and pencil format which is misaligned with the constructs of situated cognition and task environments. Therefore, this study aims to instigate the creation of a battery of valid and reliable psychometric tests of visual perception within immersive virtual reality (VR) environments with the envisioned agenda of investigating the potential relationship between visual perception and STEM educational success.

2. METHOD

2.1. Approach and Participants

This study aimed to explore the use of virtual reality in the assessment of visual perception. For this study two separate experiments were designed. In the first experiment participants were asked to make perceptual judgements on eleven stimuli presented within a 3-dimensional VR environment. The stimuli were designed to create an illusory effect with the intent of the experiment being to elicit the participants' sensitivity to the effects. The illusory factors included in this experiment were *overestimation illusions*, *underestimation illusions*, *size contrast illusions*, *shape and direction illusions*, and *frame of reference illusions* and each of the included stimuli are recognised as a valid representations of these categories [4, 5].The aim of this experiment was to determine the reliability of VR as a tool for measuring perceptual sensitivity.

In the second experiment the participants repeated this process under the same conditions with eight new stimuli replacing the original eleven. Four of these stimuli were representative of length estimation illusions with two being of overestimation and two of underestimation conditions. The other four stimuli were representative of directional illusions. This time task related feedback was given as participants saw the correct response after making a judgement. A think-aloud protocol was also implemented at this stage. The purpose of this experiment was to determine the nature of strategies participants would use in making perceptual judgments in VR to provide insight as to whether immersive VR tests have the potential to be valid assessment instruments.

Due to the nature of the tests they needed to be administered individually to participants within the cohort (n=11). The study cohort consisted of 9 males and 2 females. The mean age was 22.27 with a standard deviation of 1.79. The participants consisted of undergraduate university students from a variety of disciplines including Initial Technology Teacher Education (n=5), Physics and Chemistry Teacher Education (n=2), Technology Management (n=1), Business Studies (n=1), Mathematics and Economics (n=1), and Arts (Joint Honours) (n=1).

2.2. Design and Implementation of Experiment 1

The test items were designed based on valid and reliable visual illusion tests described in the pertinent literature [3, 4, 6, 7]. A 3-dimensional environment for each stimulus was created to serve as a test of sensitivity to each illusory effect. The Unity 5.3.2f1 game development software was used to create the environments with a Google Cardboard software package incorporated into each to allow the tests to be run on an android mobile device. A Sony Xperia Z2 was utilised with a VIGICA headset as a device with a gyroscope was required in order for the successful implementation. The controller used for the manipulation of objects in the environment was connected to the device via

Bluetooth and had both joystick and D-pad specifications. During this experiment, each participant would use the wireless controller to manipulate a virtual stimulus. The stimuli for this experiment included:

- Muller-Lyer effect – vertical orientation – overestimation
- Muller-Lyer effect – horizontal orientation – overestimation
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- Muller-Lyer effect – horizontal orientation – underestimation
- Poggendorff effect – vertical interrupting bar – line at 30°
- Poggendorff effect – vertical interrupting bar – line at 45°
- Poggendorff effect – vertical interrupting bar – line at 60°
- Ebbinghaus effect – six contextual spheres – overestimation
- Ebbinghaus effect – six contextual spheres – underestimation
- Ebbinghaus effect – four contextual spheres – overestimation
- Ebbinghaus effect – four contextual spheres – underestimation
- Frame of Reference effect – grating-frame inducer and test rod
- Frame of Reference – double frame inducer and test rod
- Frame of Reference – frame-plaid inducer and test rod

Depending on the test item, the goal was to either match the size of a stimulus with a target size or to align a stimulus in a specific orientation. A sample of the stimuli used in the experiment is presented in Figure 1. When the participant has manipulated the variable geometry to their desired estimation the researcher would note the variance between the actual answer and the participant's response.

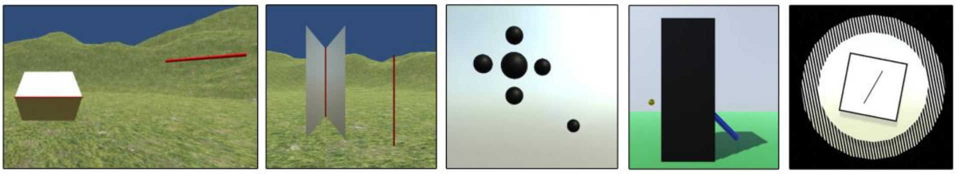

Figure 1. Sample stimuli used in experiment 1. From left to right: Muller-Lyer effect (Horizontal), Muller-Lyer effect (Vertical), Ebbinghaus effect, Poggendorff effect, Frame of Reference effect.

2.3. Design and Implementation of Experiment 2

The design of the second experiment was identical to the first experiment except that alternative stimuli were utilised. The stimuli used in this experiment included:

- Poggendorff effect – horizontal interrupting bar – line at 30°
- Poggendorff effect – horizontal interrupting bar – line at 45°
- Poggendorff effect – horizontal interrupting bar – line at 60°
- Poggendorff effect – horizontal interrupting bar – line at 150°
- Vertical-Horizontal effect – inverted 'T' – manipulate horizontal line

- Vertical-Horizontal effect – inverted ‘T’ – manipulate horizontal line
- Vertical-Horizontal effect – inverted ‘T’ – manipulate vertical line
- Vertical-Horizontal effect – ‘L’ – manipulate horizontal line

This experiment was differentiated from experiment 1 in that a feedback system was built into each item. When a participant made a judgement the researcher would note the variance but this time the correct response was identified (Figure 2). For the Poggendorff effect, the participant moved a sphere horizontally until they perceived it as collinear with the given line. The full line was then shown as feedback. For the vertical-horizontal effect, the participant adjusted the length of one line (blue) until they perceived is as equal in length to its perpendicular line (black). The correct length was then identified (red). A think-aloud protocol was implemented to elicit any potential strategies adopted by the participants.

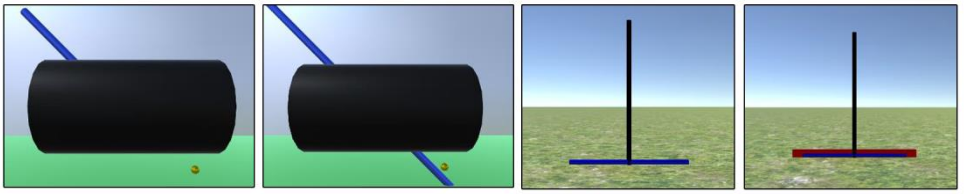

Figure 2. Sample stimuli used in experiment 2. From left to right: The Poggendorff effect at 45°,feedback received by participant, the vertical-horizontal effect (inverted ‘T’), feedback received by participant.

3. FINDINGS

To determine if there is merit in the progression of the use of VR in the assessment of visual perception, the reliability of the test items from the first experiment was determined. The Cronbach’s Alpha values for each of the illusory factors were; overestimation illusions (α = .864), underestimation illusions (α = .450), size contrast illusions (α = .546), shape and direction illusions (α = .713), and frame of reference illusions (α = .647). While the reliability is relatively high for some factors it is quite low for others. Interestingly, the highest and lowest values are seen for overestimation and underestimation factors respectively. As these stimuli present the same effect except are represented in different orientations this brings the methodological design of these items into question.

The transcriptions from the think-aloud protocol utilised in the second experiment were analysed using a codex deduced form the participants responses. Each participant (n=11) engaged with 8 test items resulting in a total of 88 responses. The codes used, the percentage of responses assigned to these codes and examples of responses are presented in Table 1.

Table 1. Analysis of think-aloud protocol responses from experiment 2

Code	Example item	% of items coded
Tilting Head	It's way easier if you turn your head	4.55
Adjustment based on previous result	I went to where I thought it was and I went over even further	13.64
Paying more attention	I'm more careful this time I'm judging it better I'd say	5.68
Visualising stimulus movement	I'm trying to visualise it going through the black cylinder	14.77
Making hand gestures	Using gestures by rotating arm with thumb as the pivot point (Researcher observation)	2.27
Comparing with the environment	I'm trying to rotate half it up until I feel it's half way using the horizon as a guide	3.41

Despite being instructed to verbally externalise all thoughts, many of the participants did not do this for all items and exhibited high levels of concentration. While the experiment included a total of 88 items, participants only spoke during 32 of these which accounts for the low percentage of items coded in Table 1.

4. DISCUSSION AND CONCLUSION

The findings of this study have presented some interesting results for the progression of this research agenda and for STEM education. Interestingly, participants identified that items could be made easier by adjusting their head. As a gyroscope was built into the mobile device this movement would affect the perception of the stimulus meaning items were not necessarily consistent for all participants. This may account for the variances in reliability scores from the first experiment and presents a methodological consideration for future studies. The use of the environment in aiding the participants suggests that the use of VR is an ecologically appropriate method for the assessment of perception as the comparison of cues of relative size is a biological strategy used naturally within the visual perceptual system. The inclusion of a feedback system in this experiment clearly highlights the effect it can have on the validity of a psychometric test in that the cognitive factors that are the focus of the test can be circumvented by analytical strategy. However it is an interesting example of how people can adapt their perception to their environment. This phenomenon is also observable in the development of a perceptual system as a child [8] and in how the perceptual system can adapt with the environment is inverted [9]. Finally, the use of gestures within the task is particularly interesting when considered in terms of *grounded* or *embodied* cognition. These theories suggest that thinking can enact a form of motor response and considering the close proximity of the thumb to the eye on a somatosensory map (Figure 3) the interplay between visual and kinesthetic capacities is an interesting research focus within STEM education.

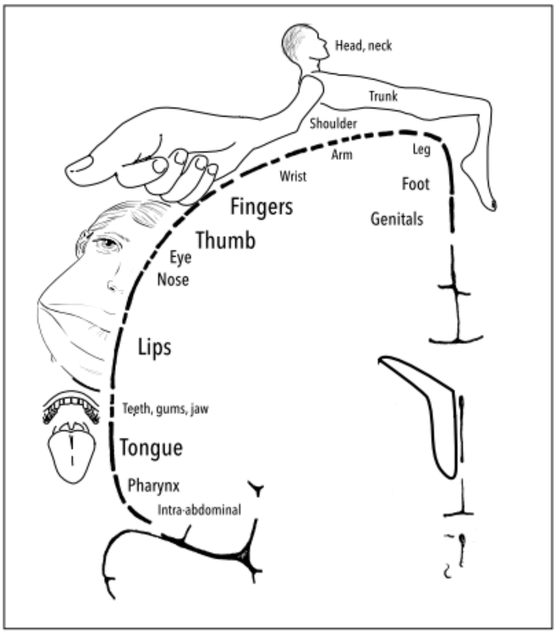

Figure 3. Somatosensory map [10]

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