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Implementation of dynamic visual acuity testing system using optical see through head mounted display

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Abstract

Dynamic visual acuity is used as an important factor to measure athletic performance in sports field. A study on visual acuity testing system using non-see head mounted display (NST-HMD) was conducted recently. However, the NST-HMD has a problem that the sense of space felt by the subject differs from the actual environment. This is because the view is blocked so that it is only implemented in a virtual space. This paper proposes a dynamic visual acuity testing system using optical see through head mounted display (OST-HMD). To do this, OST-HMD and NST-HMD comparative tests were conducted using existing K-D (King-Devick) charts. Experiments were performed on 30 subjects and their visual acuity was measured and analyzed by parametric statistics and one-sample T-test. The results of the study demonstrate the effectiveness of the proposed OST-HMD. This study is expected to use the visual inspection and training equipment of OST-HMD.

Keywords: *Dynamic Visual Acuity, Optical see through display, Non see through display, Head Mounted Display, King-Devick Test*

1. Introduction

Dynamic visual acuity is the ability to see moving objects [1]. Dynamic visual acuity plays an important role in sports that must respond quickly to changes in the surrounding environment [2]. Therefore, dynamic visual acuity is an important factor for measuring athletic performance [3]. It has been demonstrated in many previous studies that visual function training affects the improvement of athletic performance [4, 5]. Recently, a dynamic visual acuity test system has been proposed [6] that uses a non-see-head-mounted display (NST-HMD). The NST-HMD is close to a real environment in which a user's movement reflects in a virtual space. However, there is a problem that the user's view is blocked. This paper proposes a dynamic visual acuity testing system using optical see through head mounted display (OST-HMD). By mixing virtual charts with the real world, we evaluate the effectiveness by implementing system close to actual environment. The composition of this paper is as follows. Chapter 2 describes the dynamic visual acuity, and Chapter 3 describes the OST-HMD and the

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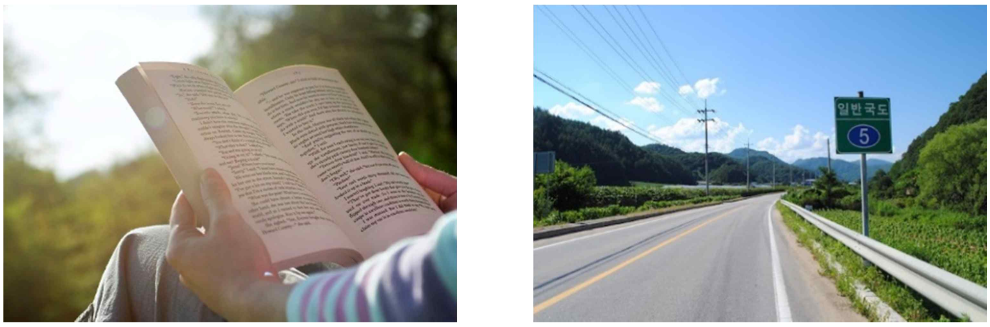
NST-HMD. Chapter 4 introduces the proposed system and experimental method, analyzes the correlation for utility verification, and concludes in Chapter 5.

2. Dynamic Visual Acuity

Dynamic visual acuity is the ability to see an object in motion with an observer or object moving [7]. Dynamic visual acuity is important in sports vision. It has been frequently measured in sports players such as baseball, soccer, and martial arts who watch more horizontal and vertical movements than static objects [8]. There are two factors that can affect the measurement of dynamic visual acuity. It is the physiological factor of the measurement object and the physical factor of the measurement system. The physiological factors of the subjects include eye movement ability, resolution of eyes, and perception ability. The physical factors of the measurement system are the brightness, size, irradiation time, and moving speed of the target [1].

2.1 Saccadic Eye Movement

Saccadic eye movement is the movement of the eyeball in order to place a moving object in the center of the retina [9]. The normal Saccadic eye movement speed is about 300 ° / s. If there is a problem with the saccadic eye movement, problems such as loss of reading, skipping a line, and omission of intermediate words may occur. In addition, the coordination of the eyes and hands is not done properly, so it may be difficult to match the balls in the ball games. Figure 1 shows an example of Saccadic eye movement.

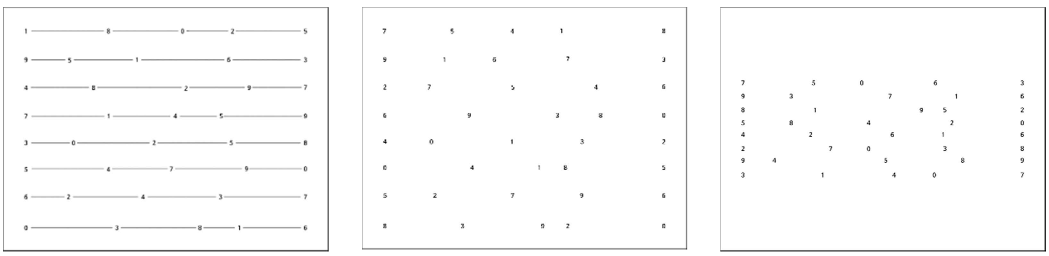


(a) Reading exercise (b) Driving exercise

Figure 1. Example of saccadic eye movement

2.2 King-Devick Test

The K-D (King-Devick) test was developed from Pierce Test and was developed for the microscopic saccadic eye movement test [10]. The chart consists of 8 lines consisting of 5 numbers on one line, total 40 numbers. Numerical intervals are arranged randomly within a single line. The K-D test consists of three tests: Test I, II, and III.



(a) Test I (b) Test II (c) Test III

Figure 2. K-D Test chart

The inspector instructs the examinee to read each digit as quickly as possible from left to right. Finally, measure the reading time and the error that occurred. The types of error are Omission error (o), Addition error (a), Transposition error (t), Substitution error (s). In order to calculate the reading time, we calculate the error affecting the time through Equation (1). Equation 1 is an equation based on Adjusted time (adt) of developmental eye movement. Figure 2 shows the K-D test chart.

$$adt = time \times \frac{40}{40 - o + a} \quad (1)$$

3. Head Mounted Display

The head mounted display (HMD) is an interface device that allows people to experience virtual environments through human senses such as vision and hearing. HMD is a device equipped with a high-resolution display, GPS, gyroscope, and wireless communication device [11]. Recognizes the motion of the user and outputs an image suitable for the motion. The HMD can be classified according to the display technology[12, 13].

3.1 Optical see through Head Mounted Display

Optical see through HMD (OST-HMD) transmits light through the display. It is a method of mixing transmitted light and computer generated image. In the early stage, since the half mirror is used, the transmitted light is reduced in half. The recently developed HMD uses mini projector and prism. Hololens of Microsoft is a representative example. The OST-HMD has the advantage that the image generated by the computer is displayed in a translucent state, so that the view is not blocked. Figure 3 shows the schematic diagram of the OST-HMD.

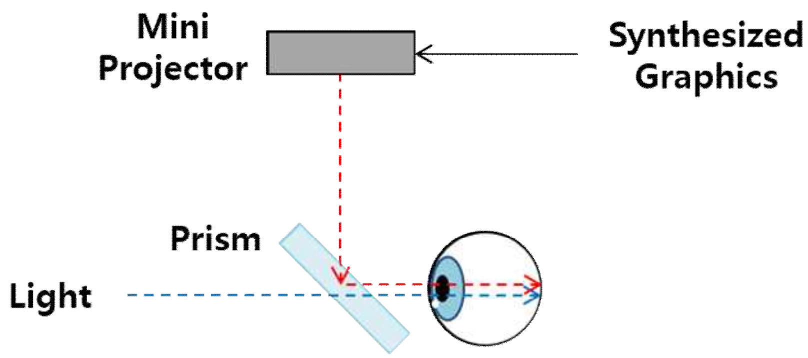


Figure 3. Schematic diagram of optical see through display

3.2 Non see through Head Mounted Display

Non see through HMD (NST-HMD) can only see the virtual world by blocking the view. The NST-HMD uses an effective optical system that uses a mobile display and a convex lens to magnify the display. As a result, it replaces the previous expensive HMD, and the HMD becomes popular. The NST-HMD tracks the position and orientation of the user through an infrared sensor or an IMU (Inertial Measurement Unit) sensor. Because of this, head tracking may not be accurate, resulting in latency or blur. This is also the cause of motion sickness. Figure 4 shows the schematic diagram of the NST-HMD.

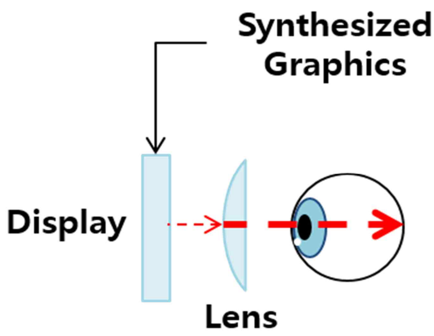
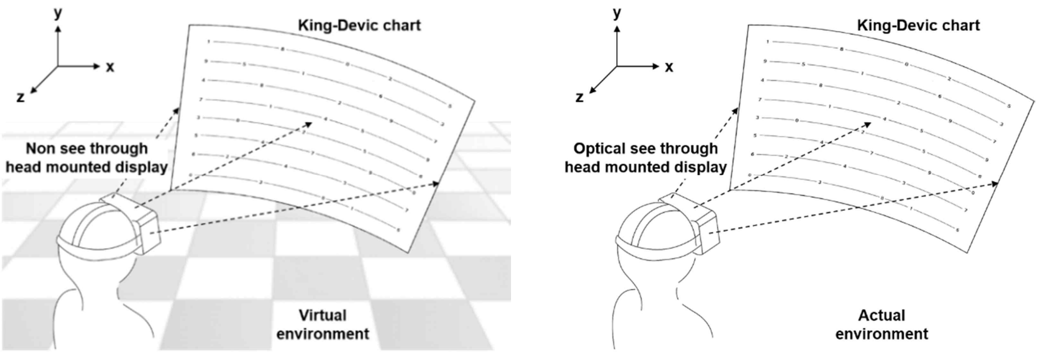


Figure 4. Schematic diagram of non see through display

4. Experiment and Result

4.1 Method of Experiment

Participants are 30 Taekwondo players (male 21, female 9) who understand and agree with the content of the experiment. Participants have a near-best corrected visual acuity of 0.8 or greater with no ophthalmic, mental or systemic disease. The size of the chart character was based on the Landolt C index [14]. The fonts of the chart characters utilized Nanum-bareun gothic (bold), which is a san-serif with excellent readability in the display environment [15]. Figure 5 shows the K-D test chart applied to the HMD.



(a) NST-HMD (b) OST-HMD

Figure 5. K-D test chart applied to the HMD

Data were analyzed using SPSS (Statistical package for social science, Ver. 18.0 for Window, SPSS Inc, Chicago, IL, USA). Paired sample T-test was used to check the significance between each experiment of the same Participants. We use parametric statistics assuming normal distribution. Statistical significance was determined by 95% ($p < 0.05$) reference. Experiments were performed to compare the error occurrence frequency and the measurement time of the OST HMD K-D chart and the NST-HMD K-D chart.

4.2 Results of Experiment and Discussion

Test 1, Test 2, and Test 3 of the K-D test were conducted with OST-HMD and NST-HMD. The records of the NST-HMD K-D test chart were measured in Test 1 (22.24 ± 3.27 sec), Test 2 (23.23 ± 3.80 sec) and Test 3 (24.04 ± 3.88 sec). The records of the NST-HMD K-D test chart were measured with Test 1 (14.50 ± 2.80 sec), Test 2 (14.61 ± 2.90 sec) and Test 3 (15.50 ± 3.08 sec). The measurement records of each chart were statistically significant. Table 1 and Fig. 6 show the measurement results of OST-HMD K-D chart and NST-HMD K-D chart.

Table 1. Measurement results of OST-HMD K-D chart and NST-HMD K-D chart

Test chart	NST-HMD K-D chart	OST-HMD K-D chart	t	p-value
	M±SD	M±SD		
Test 1	22.24±3.27	14.50±2.80	13.649	p<0.001
Test 2	23.23±3.80	14.61±2.90	12.878	p<0.001
Test 3	24.04±3.08	15.50±3.08	15.055	p<0.001

unit: sec

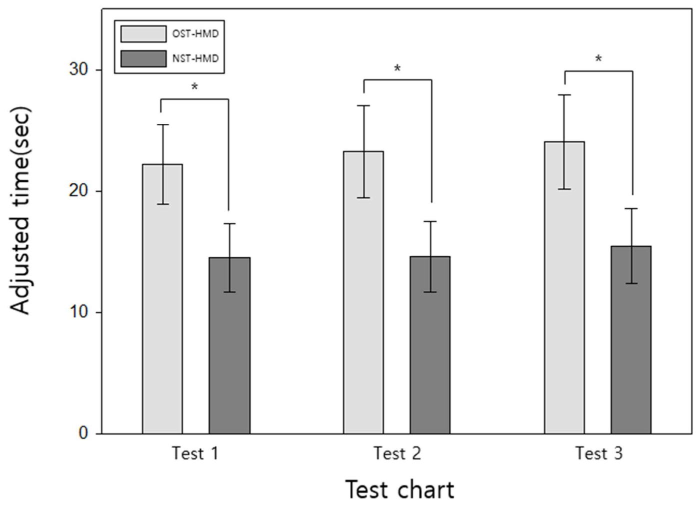


Figure 6. Measurement results of OST-HMD K-D chart and NST-HMD K-D chart (*: p<0.05)

The error frequency of the NST-HMD KD TEST 1 chart was measured as o error (0.07 ± 0.37 numbers), a error (1.00 ± 1.34 numbers), t error (0.00 ± 0.00 numbers) , s error (0.00 ± 0.00 numbers). The frequency of errors in the OST-HMD KD TEST 1 chart is measured by o error (0.10 ± 0.31 numbers), a error (0.47 ± 0.90 numbers), t error (0.07 ± 0.25 numbers), s error (0.07 ± 0.37 numbers). The frequency of error occurrence among each error type in Test 1 was not significant.

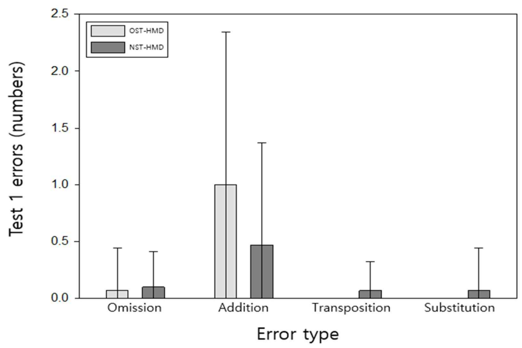
The error frequency of the NST-HMD KD TEST 2 chart was measured as o error (0.03 ± 0.18 numbers), a error (0.60 ± 1.00 numbers), t error (0.00 ± 0.00 numbers), s error (0.10 ± 0.31 numbers). The frequency of errors in the OST-HMD KD TEST 2 chart is measured by o error (0.27 ± 1.11 numbers), a error (0.37 ± 0.56 numbers), t error (0.07 ± 0.25 numbers), s error (0.10 ± 0.40 numbers). The frequency of error occurrence among each error type in Test 2 was not significant.

The error frequency of the NST-HMD KD TEST 3 chart was measured as o error (0.37 ± 1.40 numbers), a error (0.70 ± 1.29 numbers), t error (0.03 ± 0.18 numbers), s error (0.10 ± 0.31 numbers). The frequency of errors in the OST-HMD KD TEST 3 chart is measured by o error (0.17 ± 0.91 numbers), a error (0.43 ± 0.86 numbers), t error (0.03 ± 0.18 numbers), s error (0.07 ± 0.25 numbers). The frequency of error occurrence among each error type in Test 3 was not significant. Table 2 and Figure 7 show the error occurrence frequency of OST-HMD K-D chart and NST-HMD K-D chart.

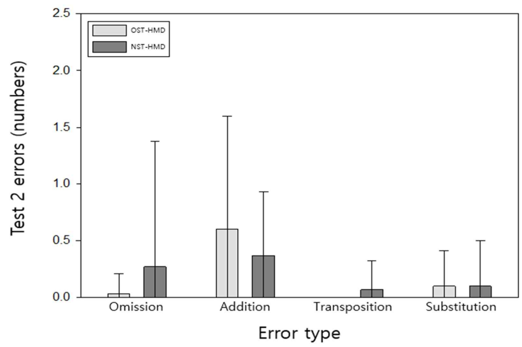
Table 2. Error occurrence frequency of OST-HMD K-D chart and NST-HMD K-D chart

Test Chart	Error type	NST-HMD K-D chart	OST-HMD K-D chart	T	p-value
		M±SD	M±SD		
Test 1	Omission	0.07±0.37	0.10±0.31	-0.372	0.712
	Addition	1.00±1.34	0.47±0.90	2.006	0.054
	Traspostion	0.00±0.00	0.07±0.25	-1.439	0.161
	Subsitution	0.00±0.00	0.07±0.37	-1.000	0.326
Test 2	Omission	0.03±0.18	0.27±1.11	-1.126	0.269
	Addition	0.60±1.00	0.37±0.56	1.045	0.305
	Traspostion	0.00±0.00	0.07±0.25	-1.439	0.161
	Subsitution	0.10±0.31	0.10±0.40	0.000	1.000
Test 3	Omission	0.37±1.40	0.17±0.91	0.641	0.527
	Addition	0.70±1.29	0.43±0.86	0.859	0.397
	Traspostion	0.03±0.18	0.03±0.18	0.000	1.000
	Subsitution	0.10±0.31	0.07±0.25	0.571	0.573

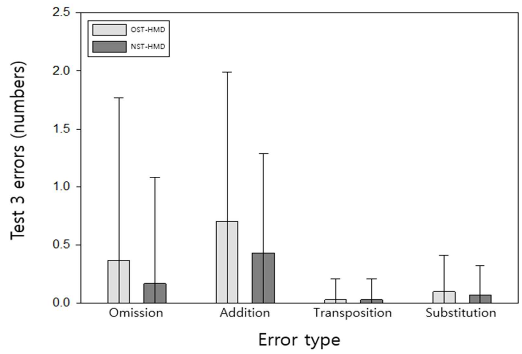
unit: numbers



(a) Test 1 errors



(b) Test 2 errors



(c) Test 3 errors

Figure 7. Error occurrence frequency of OST-HMD K-D chart and NST-HMD K-D chart

(*: p<0.05)

The results of OST-HMD K-D chart and NST-HMD K-D chart were statistically significant. In general, OST-HMD test records were faster than NST-HMD. It is considered that the difference of the recording is due to the fact that the OST-HMD is closer to the actual environment than the NST-HMD whose view is blocked. The frequency of error occurrence was not statistically significant. The occurrence frequency of error did not appear to be more dependent on the specific chart and HMD. There was no significant difference in the type and frequency of error. The average frequency of all errors was less than one and showed very little error occurrence. As a result of the occurrence frequency of error, the difference of HMD did not affect the error occurrence.

5. Conclusion

In this paper, K-D test chart was applied to OST-HMD and NST-HMD. The effectiveness of the OST-HMD K-D test chart was evaluated by comparing the correlation of the measurement time with the NST-HMD K-D chart and the frequency of error occurrence. There was a significant correlation between measurement time and K-D test of each HMD, but the error was not significant. This is because the characteristics of the HMD can affect the time it takes to read the chart. However, it is judged that no error occurs due to the specific HMD. This study demonstrated the possibility of performing dynamic visual acuity test and training near real environment by using OST-HMD. It will be necessary to develop contents that can increase the training effect by inducing interest of the participants in the future.

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