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A Comparative Study on the Effectiveness of the Training System of an Augmented Reality-based Automated External Defibrillator with an added Tactile Sense

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Abstract*: This comparative study verifies the positive effects on learning by adding tactile senses to a training system for augmented reality (AR) automated external defibrillator (AED) using smart glasses. An AR-AED training system using HoloLense was developed. Then, differences on direct experiences between learning using simple gesture recognition and with added tactile senses using surrounding objects were compared. Vividness, presence, flow, and experientiality were analyzed as points capable of enhancing learning AR and virtual reality (VR). Two groups experienced the AR AED training system and the AED training system adding tactile senses. The vividness, presence, flow, and experientiality of the AR-AED training system with added tactile senses were higher than the AR-AED training system using gesture recognition. Thus, the participants of the tactile sense-added learning group perceive virtual objects to be realer than participants of the gesture recognition-based learning group, and felt that the virtual objects existed in actual environments. Enhanced flow directly related to enhanced learning, which concludes enhanced tactile senses using actual objects affect enhanced learning. Since gesture recognition-based AR-AED training is similar to a simulated stage experience, which is like indirect experiences in the experientiality stage, tactile sense-added learning is close to the exploratory stage and spectator stage of touching and seeing objects. Thus, it is concluded that learning effects would be enhanced by adding tactile senses by connecting the training system with actual objects based on prior studies indicating that vividness, presence, flow, and experientiality have a quantitative correlation with the learning effects. This comparative study verified that tactile interaction through physical interaction with virtual objects is important in education requiring physical training and practical experience, such as AED training.

***Index Terms*: Augmented Reality, Automated External Defibrillator Training, HoloLens, Smart Glasses, CPR**

I. INTRODUCTION

A heart attack patient reaches death in 5 minutes if not promptly treated, as oxygen is not supplied to the brain and heart when the heart stops. The survival rate decreases by 7-10% every minute that treatment is delayed after the heart attack. However, when a witness performs cardiopulmonary resuscitation (CPR), the reduction of the survival rate may be decreased by 2.5-5% every minute that defibrillation is delayed. An early use of the automated external defibrillator (AED) in an emergency situation of cardiac arrest may prevent damage to the heart and reduce the recovery period, minimizing side effects and possible saving a precious life. However, despite the rapidly increasing number of deaths from cardiac arrests caused by heart diseases and disasters, it is difficult to provide public education using realistic dummies due to the properties of AED training. Moreover, there is a lack of practical training that allows the user to intuitively understand the process. As a result, many people have lost their lives due to inexperienced use of AED upon occurrence of a cardiac arrest.

Based on the recognition of this problem, there have been many studies on AED so far. Nevertheless, most studies on the usage and recognition of AED are generally related to the effects and educational background of the existing method of educating on AED. However, studies on the development of the AED and CPR training system using virtual object is gradually increasing along with the rapid development of virtual reality (VR) and augmented reality (AR) technologies[1]–[3]. These training systems are predicted to provide education leading to high immersion at an affordable cost, which in turn raises expectations. However, learning using virtual objects that cannot be tactilely touched could cause problematic discrepancies from reality. In particular, CPR that must be conducted during the use of AED has restrictions in that people must be educated only in VR without the support of an actual interface. Upon use of the AED, two different pads must accurately be placed on the chest of the cardiac arrest patient, and the body of the user must not come in contact with the patient's body as not to cause error upon analysis of the heart. After recharging, the button is pressed to send an electric shock, during which the user and surrounding people must maintain a safe distance from the patient. Most importantly, CPR must be conducted while charging the AED, during which certain time intervals and a suitable force must be maintained on the chest of the patient. Thus, it is impossible to learn by accumulating such tactile senses without actually performing the action.

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Accordingly, the question arises as to whether a user who was educated through AR-AED education controlling the process through simple gestures or VR-AED education depending only visual and auditory senses using a controller in their hand without being able to touch an actual object are able to effectively handle a real-life situation. Therefore, this comparative study analyzed the difference between AR-AED education using simple gesture recognition and tactile sense-added AR-AED education.

II. AR-AED TRAINING SYSTEM OVERVIEW

The HoloLense was used as smart glasses for the AR-AED training system. The training content was realized using 3D studio Max and Unity, and C# was used as the programing language.

As shown in Fig. 1, the system was configured to allow consecutive learning in the order of using AED by displaying a virtual person on the floor realized by AR when the AR-AED training system is executed by wearing the HoloLense. There are two pads on the AED. When the pads are placed on the opposite side, the current flows in the opposite direction, which may cause a serious problem. Thus, it is important to attach each pad to the correct position. Accordingly, the content was composed to show the correct order of attaching the pads. When the user's body comes into contact with the patient's body upon operating the AED, the current also flows through the user's body, which could cause the user's heart to stop. To prevent such dangerous incidents, the user is instructed to keep a certain distance from the patient's body before pressing the defibrillator button when the AED is fully charged. The user must perform CPR while the AED charges. However, it is not easy to apply pressure at a constant depth by keeping the beat to accurate timing, even for a skilled professional. As the heartbeat of the person applying force increases, the beat of the CPR also gradually increases. To prevent this problem, the heart object and gauge bar are displayed to ascertain the beat and number of presses on the chest.

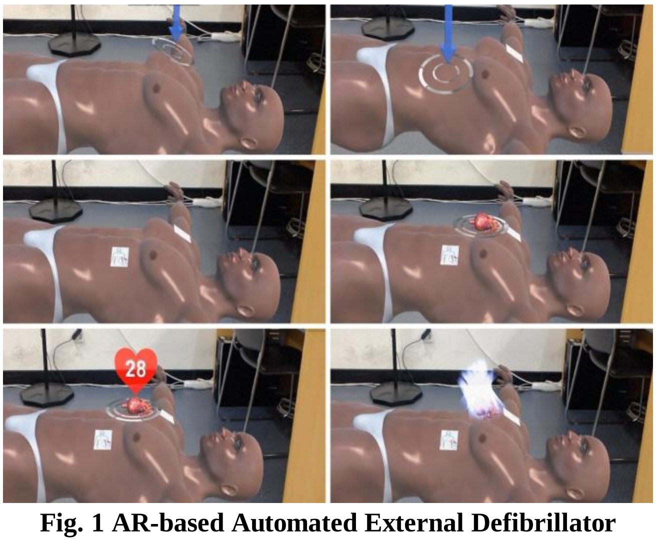

Fig. 1 AR-based Automated External Defibrillator Training System using HoloLense

III. COMPARATIVE STUDY

A. Experiment Procedure and participants

After establishing the research hypothesis that the user's direct experiential recognition would be higher in a tactile sense-added AR-AED training system than a gesture recognition-based AR-AED education system, and to verify this hypothesis, two groups of homogenous properties were composed to experience the systems and a survey was conducted on them. The first group experienced learning through the AR-AED training system in the basic format as shown in Fig. 2(a). The participants could operate virtual objects simply using finger gestures, but could not touch or come in contact with the objects. The second group could interact with the virtual objects using a cushion when learning through the AR-AED training system as shown in Fig. 2(b). When charging the AED, the participants were instructed to perform CPR on a virtual human, during which a cushion was placed on the chest of the virtual human to perform actual CPR.

Interest in AED education for adults is increasing for the practical handling of emergency situations. AED training programs, particularly for university students by school and regional groups, are gradually increasing. Based on these current trends, an experiment was conducted on university students (20 to 25 year olds).

A total of 24 students participated in the experiment, with 12 (9 male, 3 female) students in the experiment in AR-AED education using only finger gestures in the basic form, and 12 (8 male, 4 female) students in the experiment in AR-AED education directly performing CPR using a cushion. The participants of both groups were selected from a department of a university located in Busan, and the two groups were composed of students with homogenous properties. The participants had not experienced the AR-AED training system before, whereas only 25% (3 people) of the participants of each group had received AED education using a dummy. On November 15, 2018, the experiment was conducted in a school located in Busan. The experiment was conducted with the required safety measures prepared after passing the deliberation of the Institutional Review Board (IRB) in the event that an accident, such as an injury, occurred during the experiment. It took 5-10 minutes for each student to carry out the simulation education, and another 2-5 minutes to fill out the survey.

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Fig. 2 Experiential image, (a) Group 1: AR AED education using only finger gestures at the basic state, (b) Group 2: AR AED education by directly performing CPR using a cushion

B. Measures

Vividness, presence, flow, and experientiality were used for the experience recognition index verified in a prior study [4]. Vividness, presence, flow, and experientiality have a positive effect on learning effect [4], and thus, it can be concluded that the learning effects could be enhanced as well as the direct experience recognition if the measurement value of the group that received AR-AED education using a cushion is displayed as being higher than the measurement value of the group that received AR-AED education using just the gesture operation method.

Presence and flow were derived as the properties of VR in the Verification of the possibility and effectiveness of experiential learning using HMD-based immersive VR technologies study [4]. Moreover the study derived vividness, tactile interactivity, locomotive interactivity and simulator sickness as the subordinate elements contributing to presence. Furthermore, experientiality was derived in the prior study [5] as the property for measuring the degree of the experience. With the properties derived this way, the survey questions consisted of 7 measurement variables of vividness, tactile interactivity, locomotive interactivity, simulator sickness, presence, flow, and experientiality [4]. These VR properties are also the properties of AR for the reasons set forth below.

Presence is the core property of VR [6], [7]. This can be condensed into the two meanings of the ‘sense of being there [8]’ and ‘perceptual illusion of nonmediation [4], [9]. In this regard, the ‘sense of being there’ refers to the subject being present in a space made of virtual objects, which can be interpreted as virtual objects being present in an actual environment in front of the subject’s eyes from the view of AR. Furthermore, it means that the ‘perceptual illusion of nonmediation’ does not recognize the medium of the head-mounted display (HMD), which can be interpreted as the meaning that smart glasses, such as the HoloLense, cannot be recognized, in view of AR.

A prior study proposed vividness to refer to the representational abundance of the mediating environment of providing information to a person’s senses and interactivity to refer to the degree of participating in revising the form and content of the mediating environment in real time [4], [10], and when viewed in terms of AR, they may become the properties of AR in that they refer to the representational abundance of virtual objects existing in the actual environment, the degree of the possibility and ease of revision.

In general, it is understood that presence causes flow [11]–[13], and presence is a core property of AR, and thus, flow can also be considered a core property of AR. Flow refers to the state in which the user is completely immersed in the current activity [14], and flow has a positive effect on the overall learning effects [4], [15]–[17]. Accordingly, an enhanced learning effect can be assumed through the enhancement of flow.

Experientiality derived from the prior study [5] is composed of 3 stages: the simulated stage, spectator stage and exploratory stage. These act as an index measuring the steps of specific experience felt by the user [5]. The simulated stage is the stage of indirect experience generally speaking, whereas the spectator stage is the direct experience focused on vividness, such as directly visiting a site. The exploratory stage is the direct experience, such as directly visiting an actual site to directly interact with the surrounding environment [4]. In view of AR, it becomes the standard of determining whether it feels like virtual objects exist and can be touched in the actual environment.

However, simulator sickness is not a property of AR. Simulator sickness is caused by inconsistent information input from vestibular organs and the input from visual organs [18], which negatively contributes to presence [4], [19]. However, unlike VR realized in a virtual space isolated from reality, AR achieves an adjustment of the virtual objects in the actual environment, and thus, an inconsistency between information input from vestibular organs and the input from visual organs may not occur. Accordingly, it is difficult to view simulator sickness as a property of AR.

Although tactile interactivity and locomotive interactivity may be considered properties of AR, they were excluded from the survey in this comparative study for the following reasons. First, tactile interactivity is a subordinate aspect of vividness, which can be viewed as a property of AR associated with the degree of contact. However, in this experiment, it was determined that it would be unreasonable to compare the tactile interactivity of two experiment groups, because one group only uses gestures and the other group comes into contact with the actual object. Locomotive interactivity is also a subordinate aspect of vividness, which can be a standard of measuring the interaction of the user moving in a space made of virtual objects. However, it was determined that a comparison would be insignificant in this comparative study, as the two groups use the same AED training system.

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Table 1. Questions for the experiential cognition survey, by revising the prior research survey [4]

Variable	Question
Vividness	The events simulated through augmented reality felt like real-life events.
	The computer-implemented 3D person felt real to me.
	I felt like I was at the actual AED training site run by an educational institution.
Presence	In the computer-generated augmented reality situation, I had a sense of "being there."
	I have forgotten that "I am playing a simulated augmented reality".
	I felt like I was just perceiving pictures (virtual objects). (Reverse item)
Flow	I felt in total control of what I was doing.
	I was not concerned with what others might have been thinking of me.
	Time seemed to alter (either slowed down or speeded up).
Experientiality	It felt like I was watching a movie or TV show (Simulated stage).
	It felt like I was looking at an object in an actual environment (Spectator stage).
	It felt like I was walking in an actual space and touching real objects(Exploratory stage).

Accordingly, based on the above, this comparative study measured the direct experience recognition of the participants by composing the survey questions composed of the four variables of vividness, presence, flow, and experientiality. This also excluded tactile interactivity, locomotive interactivity, and simulator sickness. The survey questions were revised to suit the AR elements, and the questions are as shown in Table 1.

IV. RESULTS AND DISCUSSION

A reliability analysis was conducted to evaluate the accuracy and precision of the measured variables. Upon analysis, statistically reliable values were displayed by showing a Cronbach's α value above .6 in all elements as shown in Table 2.

Table 2. Reliability of factors

Factor	M	Cronbach's α
vividness	3.50	.63
presence	3.04	.63
flow	3.60	.81

A t-test was conducted on each aspect for a comparative analysis. Upon analysis, the 't' value of all variables displayed a positive (+) direction as shown in Table 3, and a statistically significant result was displayed. This met the research hypothesis that the user's direct experience recognition in a tactile sense-added AR AED training system would be higher than the user's direct experience recognition in gesture recognition-based AR-AED training system.

Table 3. Results of the t-test analysis for each variable with regard to the experiential characteristics of tactile sense-added AR-AED Training System and gesture recognition-based AR-AED Training System (one-tailed test)

Variable	Type of Learning	N	M	SD	T	P
Vividness	Tactile sense-added AR AED TS	12	3.75	0.45	2.25	0.02*
	Gesture recognition-based AR AED TS	12	3.25	0.62		
Presence	Tactile sense-added AR AED TS	12	3.28	0.47	2.20	0.02*
	Gesture recognition-based AR AED TS	12	2.80	0.58		
Flow	Tactile sense-added AR AED TS	12	3.83	0.64	1.95	0.03*
	Gesture recognition-based AR AED TS	12	3.36	0.54		
Experi-entiality	Tactile sense-added AR AED TS	12	2.25	0.62	4.01	0.00**
	Gesture recognition-based AR AED TS	12	1.33	0.49		

*p<0.05; **p<0.01

Upon comparison between the vividness value of the tactile sense-added AR-AED TS and gesture recognition-based AR-AED TS, the vividness was enhanced showing a notable result within a significant level of 0.05 ($t=2.25$, $p<0.05$). Accordingly, it was concluded that the participants of the tactile sense-added AR-AED training were able to feel the virtual objects in front of their eyes as being more realistic than the participants of gesture recognition-based AR-AED training.

The value of presence in tactile sense-added AR-AED TS displayed an enhancement with a notable result within a significant level of 0.05 ($t=2.20$, $p<0.05$) in comparison to the gesture recognition-based AR-AED TS. Accordingly, it was concluded that the participants of the tactile sense-added AR-AED training felt that the virtual objects in front of their eyes existed in the actual environment and had a lower recognition of the medium of HoloLense compared to the participants of gesture recognition-based AR-AED training.

The value of flow in tactile sense-added AR-AED TS displayed an enhancement with a positive result within a significant level of 0.05 ($t=1.95$, $p<0.05$) in comparison to gesture

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recognition-based AR AED TS. Consequently, the participants of the tactile sense-added AR-AED training were immersed much more deeply in the AED training compared to the participants of the gesture recognition-based AR-AED training. The enhancement of flow is directly related to the enhancement of learning effects [5], [16], [17], wherein the enhancement of tactile senses using actual objects affects not only the direct recognition of the experience, but also the learning effect.

The value of experientiality of tactile sense-added AR-AED TS displayed an enhancement with a notable result within a significant level of 0.01 ($t=4.01$, $p<0.01$), which met the research hypothesis. Accordingly, it can be concluded that the participants of the tactile sense-added AR-AED training had a stronger feeling of actually touching and operating virtual human objects compared to the participants of the gesture recognition-based AR-AED training. Upon analysis of the frequency of the survey questions as shown in Table 4, most of the participants (11 participants, 91.7%) of the tactile sense-added AR-AED training selected the spectator stage and exploratory stage, whereas 2/3 of the participants of the gesture recognition-based AR-AED training (8 participants, 66.7%) selected the simulated stage, a lower stage of experience. Furthermore, only one participant did not select the exploratory stage. Accordingly, if the experience of gesture recognition-based AR-AED training is viewed as the experientiality stage, it is closer to the experience of the simulated stage, which is an indirect experience. Moreover, the experience of the tactile sense-added AR-AED training can be considered closer to the exploratory stage of touching the actual object and the spectator stage of viewing the actual object.

Upon performing interviews after the survey, most of the participants of the tactile sense-added AR-AED training felt as if they were coming into contact with a real virtual human, and as if they were performing CPR when applying pressure to the cushion placed above the virtual human to the beat as guided in the training system. However, one participant indicated that it did not feel real because there were no changes in the body of the virtual human when applying pressure to the cushion during CPR. Accordingly, In order to provide a more realistic interaction with the virtual object realized with AR, it will be necessary to configure the 3D human body to modify and respond by recognizing the user's hand shape, movement and distance while performing CPR.

Table 4. Results of the frequency analysis of tactile sense-added AR-AED Training System and gesture recognition-based AR-AED Training System experiment participants' selection of the experientiality stage

Type (N)	Simulated Stage	Spectator Stage	Exploratory Stage
Tactile sense added AR AED TS (10)	1 (8.3%)	7 (58.4%)	4 (33.3%)
Gesture recognition based AR AED TS (12)	8 (66.7%)	4 (33.3%)	0 (0%)

V. CONCLUSION

This comparative study was conducted with the objective of verifying whether adding tactile senses to the AR-AED training system using smart glasses focused on visual and auditory senses would have a positive effect on the user's recognition of experience and overall learning effects. Upon experiment and analysis, when tactile senses are added to the AR AED training system, the user recognized the learning experience as being much closer to a direct experience than when compared to the AR-AED training using simple gesture recognition. As a result, the enhancement of the learning effects were confirmed. Accordingly, It is determined that interaction with the actual object is important in training that requires physical training and practical experience along with AED training. Moreover, it will be necessary to devise a means of physical interaction with the virtual object. However, it was also pointed out that the training system lacks a sense of reality, because the 3D human body realized in AR is unaffected when performing CPR. Accordingly, in future studies, the 3D human body is to be supplemented in order to respond by recognizing the user's hand shape, movement, and distance when performing CPR so as to verify the effect thereof.

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