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A study on the emotional changes of learners according to the emotions provided by virtual characters

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가상 캐릭터가 제공하는 감정에 따른 학습자의 감정적 반응에 관한 연구

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Abstract Considerable interest has been directed toward utilizing virtual environment-based simulations for teacher education which provide authentic experience of classroom environment and repetitive training. Emotional Interaction should be considered for more advanced simulation learning performance. Since emotion is important factors in creative thinking, inspiration, concentration, and learning motivation, identifying learners' emotional interactions and applying these results to teaching simulation is essential activities. In this context, this study aims to identify the objective data for the empathetic response through the movement of the learner's EEG (Electroencephalogram) and eye-tracking, and to provide clues for designing emotional teaching simulation. The results of this study indicated that intended empathetic response was provided and in terms of valence (positive and negative) states and situational interest played an important role in determining areas of interest. The results of this study are expected to provide guidelines for the design of emotional interactions in simulations for teacher education as follow; (a) the development of avatars capable of expressing sophisticated emotions and (b) the development of scenarios suitable for situations that cause emotional reactions.

Key Words : Simulation for Teacher Education, Emotional Interaction, Virtual character, EEG, Eye-tracking

요 약 실제 교실 환경과 반복 훈련을 제공하는 가상 환경 기반 시뮬레이션을 교사교육에 활용하는 데 상당한 관심이 집중되고 있다. 시뮬레이션 학습환경이 더욱 정교하게 학습에 적용되기 위해서는 감정적 상호작용을 고려할 필요가 있다. 감성은 창의적 사고, 영감, 집중력, 학습동기에 중요한 요소이기 학습자와의 정서적 상호작용을 파악하고 이를 교수 시뮬레이션에 적용하는 것은 필요한 활동이다. 본 연구는 학습자의 EEG(Electroencephalogram)와 시선추적을 통해 공감적 반응을 위한 객관적인 데이터를 확인하고, 감성교수 시뮬레이션 설계를 위한 단서를 제공하는 것을 목적으로 한다. 연구의 결과는 의도된 공감적 반응이 제공되었고, 상황적 감성이 학습자의 정서 반응을 결정하는 데 중요한 역할을 하고 있음을 확인하였다. 본 연구의 결과는 정교한 감정을 표현할 수 있는 아바타의 개발 및 감정적 반응을 일으키는 상황에 적합한 시나리오의 개발이라는 측면에서 교사교육 시뮬레이션의 설계에 시사점을 갖는다.

주제어 : 교사교육 시뮬레이션, 정서적 상호작용, 가상 캐릭터, 뇌파(EEG), 시선추적

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1. Introduction

Considerable interest has been directed toward utilizing virtual environment-based simulations that provide realistic experiences and enhance repetitive learning effects with level of difficulty controlled[1,2]. Especially, it has been reported that simulations for teacher education which provides authentic experience of classroom environment and repetitive training while controlling level of difficulty have been effective for improving teacher efficacy and instructional skills, which is why simulation for teacher education is becoming more and more common. With the development of 3D graphics technology, the development aspect of the virtual environment such as realization of a virtual avatar that acts and speaks like a human in a virtual space and realistic space has already reached the same level as that of real environment[3]. Beyond the realization of realistic simulation development, it is time to much emphasis should be placed on the consideration of how to develop a simulation that effectively improves learning performance. In this respect, the color of the emotional interaction between the learner and the simulation should be added to the picture of teacher education simulation. In immersive media-based simulations, in-depth learning activities will be possible if not only information exchange for learning but also emotional interaction can be shared[4].

In learning through virtual simulation, interaction with content plays an important role as a lens to confirm the effectiveness of the learning provided by the simulation. Previous interactions in virtual simulation have been focused on controlling virtual avatars by applying various multi-modal interfaces or allowing virtual avatars to react according to the way in which pre-service teachers use the class demonstration simulator in virtual classroom environment[5]. However, for more advanced learning performance, interactions should be able to interact emotionally and motivationally beyond the control of objects and avatars in virtual environments through simple interfaces. Since emotion and motivation are one of the most important factors in creative thinking, inspiration, and learning interest, both identifying learners' emotional and motivational interactions and applying these results to teaching simulation are essential activities[6]. Therefore, in order to apply the emotional and motivational interaction to the teaching simulation, it is a necessary process to identify the learner's emotional states and the area of interest in the simulation using the virtual student avatar with both objective and empirical way.

In this context, this study is an exploratory study to identify the objective data for the emotional reaction toward virtual characters through the movement of the learner's EEG (Electroencephalogram) and eye-tracking, and to provide clues for designing learning environment for emotional teaching simulation by using the results. The research questions are as follows.

1. What types of the emotional changes and eye-gazing movements do the learners have in their emotional interaction with the virtual characters?

2. What is the guide for emotional design for teacher education through the results of measured learner's physio-psychological reactions?

2. Theoretical Framework for this study

2.1 Simulation Based Learning

With the recent emphasis on diverse learning environments, the goals of education are shifting

from deriving applicable theories for students to exposing the learned skills and knowledge into the context in which they can be applied. In addition to the changes in the educational objectives, the use of simulations that simulate the real world and practice various skills and knowledge can be taken into consideration. Simulation positively affects the process of learning by providing an environment in which theory and conceptual knowledge can be applied realistically[7]. Simulation based learning is a learning environment that simulates the actual environment in which learning is to be performed by being provided controllably and simply. Simulation based learning has been utilized to provide assessments and training which have not been able to put into practice owing to risk and cost factors in real-world situations, like aviation, military training, medical, and construction sites[1].

In the Simulation based learning, the learner can make decisions in various repeated problem situations and perform the process of confirming the results of their decision making. One of the biggest advantages of simulation based learning is that the learners are not drawn to the elements of prudent threat, despite learning in these various problem situations. As an environment for training and learning, simulation based learning has been reported to have many advantages. First, learners can be provided longer repetitive training sessions than the real world allows, and also learners can immediately confirm the results of their learning through an elaborate evaluation system. Second, the simulation enables learners to master various risk training without the problems in the real world. Third, simulation based learning provides learners with an opportunity to make decisions about various problem situations and to develop the ability to present possible solutions. Fourth, simulations provide an effective way to increase learners' self-esteem and improve their conversational skills compared to case studies.[8]. The most important activity in learning through simulation is examining the results drawn by the decision making process and feedback about them.

2.2 Learner's physio-psychological reactions

2.1.1 EEG Measurement

Computers that have begun to be used for simple calculations have evolved into machines that interact with humans, examining the emotional states of human. There are two ways to find out the emotional state of a human being by a computer. The first way is to recognize emotions in a person's facial expressions and words.[9]. The second one is utilizing a physiological signals that are drawn by the automatic response of the brain[10]. Autonomic nervous system responses are closely related to valence and arousal dimensions of emotion. The attributes of the EEG closely related to the emotion are the frequency band of EEG, which classifies law EEG data into the theta wave (4-8 Hz), alpha wave (8-13 Hz), beta wave (13-30 Hz), and gamma waves (30-50 Hz), and another way is using brain asymmetry for identifying the gap between left and right hemisphere of brain[11]. EEG signals have been widely used for understanding mental state of human as well as for brain computer interface.

EEG signals have bands property that shift in time and space in terms of brain activity, measurement status, and spatial characteristics related to brain function. In observing brain waves, power spectral analysis is useful for classifying EEG signals in terms of frequency rather than of visual signals based on the time. In general, brain waves are divided into delta (0.2 to 4.00 Hz), theta (4.01 to 8.00 Hz), alpha

(8.01 to 13.00 Hz), beta (13.1 to 30.00 Hz), and gamma (30.01 to 50 Hz). Alpha waves has been associated with relaxation of mental and physical tension, relieving stress and improving concentration[11]. Beta waves represent the state of arousal and stress, affected by emotional stimuli such as hearing and feeling.

2.1.2 Eye-tracking

Eye tracking measurements provide an auxiliary means of measuring cognitive procedures at high resolution. Eye tracking technology makes it possible to capture visual behavioral information in real time[12]. In addition, it is possible to obtain a gazing position in the stimulus. Eye-tracking can collect data about visual attention by measuring the position and size of the pupil and tracking the immediate physiological response such as the fixation level and movement of the eyes. People's eye movements are classified into succade, fixation, and return sweep, and the eye movements that reflect the degree of attention vary according to the need for information acquisition. Among them, gaze fixation time refers to the amount of attention that is put into the information processing procedure. Eye movements have a purpose, and these movements are linked to the cognitive processes of the brain [12,13], which will allow the learner to identify what cognitive processes go through visual attention. This is why the eye movement is a factor that influences the process of environmental information processing and the result of spatial decision making process[13].

2.3 The Cognitive-affective Theory of Learning with Multimedia

Cognitive-affective Theory of Learning with Multimedia (CATLM), based on Cognitive Theory of Multimedia Learning[14], emphasizes cognitive and emotional processing in multimedia learning. That is, this theory adds both emotional and motivational consideration to the recent theory of multimedia learning. Most importantly, CATLM can provide learners with the opportunity to participate in various cognitive-affective situations beyond the limit of providing audio-visual material. This theory has a significant importance in confirming the influence of the motivational and emotional aspects on learners' concentration and academic achievement in learning using multimedia.

Reviewing studies on the application of motivational and emotional design principles to multimedia learning shows three main researches as follows. First, the study of D'Mello, Lehman, Pekrun, & Graesser[15] confirmed the learning effect of the emotional state (confused vs. calm) in multimedia learning environment. Magner, Schwonke, Aleven, Popescu, & Renkl[16] examined whether or not various visual data could enhance learners motivation for leaning in multimedia learning design. Finally, Plass, Heidig, Hayward, Homer, & Um[13] studied what factors are needed to induce positive emotion for learners in the design for multimedia learning, and how they facilitate the cognitive process. These prior studies can provide directions and clues for emotional design in multimedia learning environment.

3. Method

3.1 Participants

Participants for this study included 13 preservice teachers attending at Chonnam University in Gwangju, Korea in fall semester, 2017. The mean age of the sample was 20.56 years (SD = 2.3). A convenience sampling was conducted for this study. Participants were recruited by paid work through a part-time job site on campus.

3.2 Material and Tasks

The material for this study was video clips using the scenarios of both sad and angry situations applied by virtual student characters. Specifically, iClone was used to produce the overall video clips. Background music coincident with the sadness and angry videos were applied respectively (i.e., Spartacus for sad situation and crimson tide for angry situation). And another thing, to reflect the emotional elements of the virtual student characters, the gesture and expression were applied based on Ekman[16]'s research. The experimental task for this study was to present a solution for the situation of virtual characters after watching the video clips of virtual student characters.

Fig. 1. Example of sad (a) and angry (b) video clip for this study

3.3 Variables and research design

3.3.1 Independent variables

The independent variable of this study was the states of emotional atmosphere in the video clips provided. The emotional states provided by virtual student characters and background music were presented in two states (sad and angry). The contents of sad scenario is a lamentation about the difficulties and circumstances that a female student experiences in her life. As for that of angry Scenario, a boy is struggling with school violence (financial problems).

3.3.2 Dependent variables

There were two dependent variables in this study; (a) empathetic response and (b) eye fixation count. Specifically, arousal and valence states, which were the objective emotional variable of the participant watching the video, was examined for empathetic response through EEG. As for the eye fixation count, confirmation of the learner's interest in the virtual characters and objects in the presented learning material was identified by eye-tracking device. The dependent variable using the eye tracking device is the eye fixation count. In the eye-tracking analysis, a specific area called the AOI (Area Of Interest) is set, and then the gazing activity in the area is analyzed. In this study, AOI was set for the virtual student characters.

3.4 Measure

In this study, the equipment of Epoc+ (Emotiv) was used to measure the learner's emotional variables through EEG. To determine the state of arousal, the ratio of beta and alpha waves extracted from measured EEG signals was calculated. To determine the state of valence, the activation levels of the two cortical hemispheres in the brain were compared. Brain waves measured at the four positions (AF3, AF4, F3 and F4) of the frontal cortex were used. As for the eye-tracking, SMI (Sensor Motoric Instrument) iViewX was applied. The learner's AOI was confirmed during the video viewing. The overall experiment and the formula for examining the states of arousal and valence states through EEG measurements are shown in the Fig. 1 below.

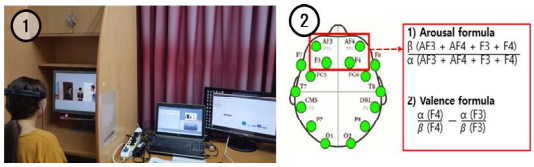

Fig. 2. Experimental conditions(①) and formula for EEG measurement (②)

3.5 Analysis

EEG was measured under two conditions according to the emotional situations presented by video clips. Since the measured EEG was the raw data, the FFT process was conducted using Telescan (LAXTHA) software. The sizes of alpha (8-12Hz) & beta (12-30Hz) bands were extracted by frequency units. The power values for the four channels (AF3, AF4, F3, F4) were derived from the temporal valence and arousal state according to the formula for calculating the valence and arousal presented in the previous session. The state of the valence and arousal on the video of the presented emotional state was presented according to the flow of time. As for AOI, the number of eye fixation count on AOI using a grid was visualized using heat map according to the result of analysis of eye-tracking data. A grid analysis on sad and angry videos was performed (sad: 4 rows x 7 columns, angry: 4 rows x 10 columns). Exposure time was set at 2 minutes, and the number of eye fixation counts on the AOI was presented as a heat map.

4. Result

4.1 Emotion response through EEG

4.1.1 Descriptive statistics on emotional responses

The learners' emotional responses were presented as mean value of arousal state and valence state respectively. In the case of arousal level, the case where the scenario of sadness was provided was slightly higher than that of being provided in the angry scenario. As for the case of valence state, the case of providing the sad scenario showed a slightly lower mean value than the case of angry one, but both cases showed a relatively low mean value. These results show that the learners experienced a similar level of excitement about the sad and angry scenarios and had a somewhat higher level of excitement. On the other hand, in the case of the emotional state representing positive and negative emotion, low mean value was shown, so that it could be interpreted as showing a relatively negative emotional state for presented scenarios.

4.1.2 Changes in emotional responses over time

The Fig. 2 and Fig. 3 represent the result of time series analysis of valence (positive and negative) and arousal (high and low) states of learners, the degree of hyperactivity of the left and right hemispheres of the brain of alpha waves (8-13 Hz) and beta waves (13-30 Hz), which are related to the emotional response, according to the emotional conditions of video clips.

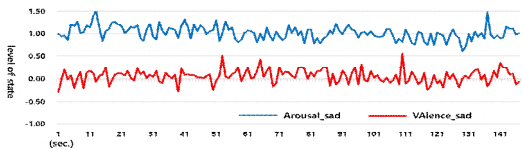

Fig. 3. Time series analysis of empathetic response to sad video clip

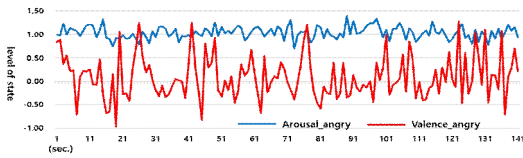

Fig. 4. Time series analysis of empathetic response to angry video clip

The states of valence which showed the positive and the negative states of learners'

empathetic response induced through the virtual student characters and scenario showed relatively low, which means negative empathetic response for sad and angry situations. On the other hand, the states of arousal indicating high and low emotional states were relatively high, which means there is no significant difference in terms of arousal (high and low) states. The states of valence which showed the positive and the negative states of learners' emotional response induced through the virtual student characters and scenario showed relatively low, which means negative emotional response for sad and angry situations. On the other hand, the states of arousal indicating high and low emotional states were relatively high, which means that learners continued to experience high level of excitement.

4.2 Results of eye fixation counts

The figures below is a graphical representation of the average number of eye-fixation count through grid analysis (4x7 for sad video and 4x10 for angry video). As shown in Figure 4, the highest eye-fixation count in the sad scenario was the face of the female student character experiencing sadness (92.2times / 2mins). Including the overall gesture of the female student character, the eye-fixation count focused on the female student character is the highest with a total of 136.9 times / mins. In the scenario of sadness, the male student character played a role of empathetic listening to the anxieties and lamentations of the female students character. At this time, there was a relatively large number of eye-fixation count for male student character (57.5 times / 2mins). Overall, the minimum number of eye-gaze times in a sad scenario was 0.1 times/2mins.

On the other hand, in the case of the angry scenario, the eye-fixation counts were most concentrated on the student character (43.4 times/2 mins) who was victim of bullying in the given situation. Next, a high eye-fixation count was shown to the offending student character (25.9 times/2mins) that triggered anger situation.

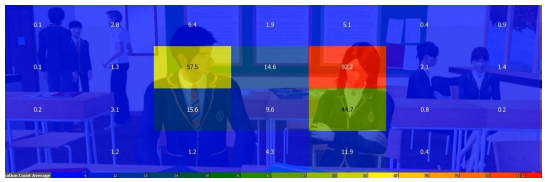

Fig. 5. Average eye-fixation count by grid analysis (sad situation)

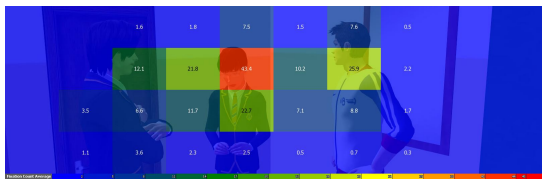

Fig. 6. Average eye-fixation count by grid analysis (angry situation)

Through the grid analysis of this eye-tracking, it can be confirmed that more eye-fixation is taking place in the object to which the emotion is to be input rather than to the causal factors of the emotion. When it comes to the results of the data on the learner's area of interest through eye-tracking, it was confirmed that learners selected the area of interest by the atmosphere provided by the situation rather than by the emotional judgment factors. It can be tentatively concluded that situational interest plays a predominant role in determining learner's area of interest.

5. Discussion

Recently, there has been a growing interest in the effectiveness of simulation-based learning environment and changes in educational environment. In addition, there is growing interest in empirical data for effective simulation-based learning environment design

using emotional and motivational factors. Therefore, this study collected the data of learners' emotional response and interest reaction to the scenario applying emotional and motivational factors to the simulation through EEG measurement and eye-tracking device. The results of this study were intended to draw implications for effective simulation-based learning and further simulation design for pre-service teacher education.

5.1 Implications

Through this study, it is possible to accumulate objective and empirical data for designing emotionally interactive simulation for teacher education. First, the valence state, which indicates whether the learner's emotional state is positive or negative, showed negative results in both the sad and the angry scenario. These results could be interpreted that the valence state is directly influenced by the context of the presented virtual avatar or the contents of the scenario itself. These results are consistent with previous studies that the learning environment that induces the personification through the virtual character and constitutes the contextual story could induce the high emotional reaction and the realness[13]. In addition, these results coincide with previous studies that the indirect experience based on the simulation also could promote cognitive and emotional response to the emotional stimulus presented by a specific situation[18]. In addition, when the state of valence is analyzed according to the flow of time for learning, it can be confirmed that the state of positiveness and negativeness change dynamically by the context and scenario provided by the virtual character. These results suggest that for designing simulation with emotional factors, it is necessary to consider the provision of various contextual simulations based on virtual characters and scenarios.

Second, the results of eye-tracking showed that situational interest plays an important role in determining areas of interest for learners. In order to make a cognitive or emotional judgment about a given situation, visual attention is inevitable. This result is consistent with previous studies that the learners' visual concentration occurs for the purpose of cognitive judgment, and that the movement of the eye is an important factor in processing decision-making process and environment information. Especially, in the emotional judgment, it was confirmed that the eye-fixation is focused on the object to which the emotion is transferred by the emotion created rather than the object which creates the specific emotion. These results show that when the emotional atmosphere should be judged without the need of cognitive information processing, the area of interest does not necessarily focus on the factors causing that emotion. This result is consistent with previous researches that the movement of eye represents various forms depending on the type and kind of information to be acquired[12,13].

Third, this study, which confirms emotional response and motivational result of learners, suggests a clue for the design of simulation taking emotional and motivational factors into consideration. When it comes to emotional responses, the results have it that, the proviso for the designing learning environment which can induce the intended emotional states in the terms of positive and negative situation can be prepared. Now that the sad and angry feeling represent negative valence states[18], the presented video materials could induce the intended empathetic response in terms of valence states. These results will enable the construction of simulation for classroom

environment, which can provide various emotional conditions that pre-service teachers will experience in the future. These results indicate the importance of elaborated scenarios in the design of simulations for teacher education[4]. The occurrence of area of interest means that motivation for learning is formed, which is why it is important to facilitate contextual scenarios for designing simulations for teacher education. In addition, the results of this study are expected to provide further guidelines for the design of emotional interactions in simulations for teacher education as follow; (a) the development of avatars capable of expressing sophisticated emotions and (b) the development of scenarios suitable for situations that cause emotional reactions.

5.2 Limitations and Future Research

The limitations of this study are as follows. This study, which is an exploratory study that confirms emotional and motivational level, is a development research to apply simulation using virtual character to teacher education. There is still room for technological advancement in realness and sophistication for the application in terms of applying virtual characters. In addition, there are some limitations in systematically analyzing the factors that might affect the research result because the variables and contents applied into this research are micro level.

Based on these limitations, some suggestions for future research are as follows. First, this study confirmed the emotional and attentional responses to sad and angry emotional situations. However, in order to confirm the application of simulation more deeply, future studies using various emotional situations are suggested. Second, in this study, only the empirical data for the situation provided by the virtual characters were collected and measured. However, in the simulation based learning, it is necessary to make decisions in various situations, suggest solutions, and examine the results. Therefore, further research is necessary to suggest both decision-making and learning tasks such as presenting possible solution for the problem situation of the simulation. Third, the classroom situation has various variables. In this study, background music was provided as a basic variables. However, in order for simulations to provide authenticity, it is necessary to provide various variables such as life noise and silent situation. Therefore, in order to develop a realistic simulation, a follow-up studies using scenarios that provide various contexts and cases are proposed.

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