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Assessment criteria for nonverbal interaction contents in r-learning

CHOI Jong-hong[1], LEE Jong-yun[1], YOON Heung-seob[2]

1. Department of Computer Education, Chungbuk National University, Chungbuk 361-763, Korea;
2. Department of English Education, Chungbuk National University, Chungbuk 361-763, Korea

Abstract: r-learning, which is based on e-learning and u-learning, is defined as a learning support system that intelligent robots serve verbal and nonverbal interactions on ubiquitous computing environment. In order to guarantee the advantages of r-learning contents with no limits of time and place and with nonverbal interaction which are not in e-learning contents, in recent years, assessment criteria for r-learning contents are urgently required. Therefore, the reliable and valid assessment criteria were developed for nonverbal interaction contents in r-learning, and its detailed research content is as follows. First, assessment criteria for nonverbal interaction in r-learning contents will be specified into gesture, facial expression, semi-verbal message, distance, physical contact and time. Second, the validity of the developed assessment criteria will be proved by statistics. Consequently, the assessment criteria for nonverbal interaction contents will be helpful when choosing the better r-learning content and producing the better r-learning content, and the reliability of school education is improved ultimately.

Key words: r-learning,; r-learning contents; assessment criteria; nonverbal interaction contents; confirmatory factor analysis; construct validity

1 Introduction

After the term “robot” was used in Rossum’s Universal Robots, which was written by the Czech writer, Karel Capek in 1921, the robot has been widely applied into various fields such as education, medicine, silver, defense, transportation and construction, and affects our life deeply. With the development of robot technique and market, intelligent robot as a tool of teaching and learning in the education area has been applied and its educational effects has been reported as follows. In Japan, it was reported that robot, PARO, had an effect on the psychical cures for a dotard and an autism child [1]. KIESLER and GOETE [2] proved that the exercise quantity of old men comes differently by the appearance, features and used languages of silver robot. It was also reported that emotional interaction can be made to students by using the nonverbal message of teacher-aided robots and it was very effective in affective domains such as concentration, confidence, interest induction as well as cognitive domains such as positive learning achievement [2−8]. The r-learning has been introduced into a new paradigm in the education area because of the positive effects of r-learning, but so far the assessment criteria for e-learning contents have been applied into r-learning contents intact. The reason is that the traditional types of education robots were equipped with touch panel and then provided the services of e-learning contents. That is, it provided contents though screen, or provided services through beam project or large-size TV for the whole class in the teaching and learning environment.

However, there are some problems that assessment criteria for e-learning cannot be applied to those for r-learning directly. First, r-learning provides services with robot for education, while e-learning with computers. Second, it is not enough to substitute assessment criteria for e-learning with those for r-learning. In other words, assessment criteria for nonverbal interaction by robots such as gesture, facial expression, semi-verbal message, distance, physical contact, time and convenience or fun of using robot, are not included in those for e-learning. In order to overcome the above problems, valid and trusty assessment criteria of nonverbal interaction contents for r-learning should be required.

Therefore, the purpose of this work is to develop the assessment criteria for r-learning contents that can be used validly and objectively, and its contents consist of the follows. First, the assessment criteria for nonverbal interaction of r-learning contents will be classified into gesture, facial expression, semi-verbal message, distance, physical contact and time. Second, in order to verify the validity of the assessment criteria for r-learning,

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Corresponding author: LEE Jong-yun, Professor, PhD; Tel: +82−43−261−27289; E-mail: jongyun@chungbuk.ac.kr

construct validity will be inspected through analyzing content validity and confirmatory factor. In order to identify the inter-item consistency and homogeneity of assessment items, the reliability of assessment criteria will be verified by using Cronbach-α factor.

2 Related work

2.1 r-Learning

The change of paradigm in the area of multimedia learning and teaching is closely related with the development of information communication and technology, called ICT. CHENG et al [9] defined the steps of development for learning support system as follows. After 1980s, stand alone computer-aided instruction (called CAI) system was introduced, internet was popular to ordinary people, web-based learning was developed, PDA and mobile became the main tools for communication, and with the development of embedded technique, u-learning was developed as a new type of learning. The steps of development for learning support system are outlined, including the old styles and the concept of the progress [9].

In this work, the m-learning was integrated into the range of u-learning in the steps of ICT developments for learning support system by CHENG et al [9] and then r-learning is regarded as more advanced learning support system. First, CAI is defined as a type of learning by the interaction between an individual learner and off-line PC. That is, it is limited as the interaction between a learner and a computer in the aspect of the individual learning. Second, e-learning is defined as a type of learning by the internet-based bidirectional interaction by using electronic tool, information communication and electric wave, broadcasting technique, etc. That is, e-learning can provide all the learning sources that a learner wants to learn anywhere, anytime, and it means a learning system that many interactions between a learner and PC, a learner and a learner, and a learner and a teacher can occur. Third, u-learning is a type of learning that a learner can learn what he/she wants to learn, regardless of anywhere, anytime, and any device. That is, it means a learning system that links with all kinds of terminal devices which can communicate, without limits on time and place. The e-learning is regarded as a learning and teaching system based on online communication in the given class environment, while u-learning is regarded as a learning and teaching system based on online and offline communications in the movable environment, and an education model that makes intelligence learning possible by the interaction among learners. Fourth, r-learning has been progressed, integrating with intelligent robot techniques and based on u-learning education environment. The range of using education equipment has been extended from the integration of ubiquitous education environment and robot technique, because of extending intelligence interaction as well as emotion interaction like nonverbal communication. Consequently, r-learning is based on both e-learning and u-learning, as shown in Fig. 1.

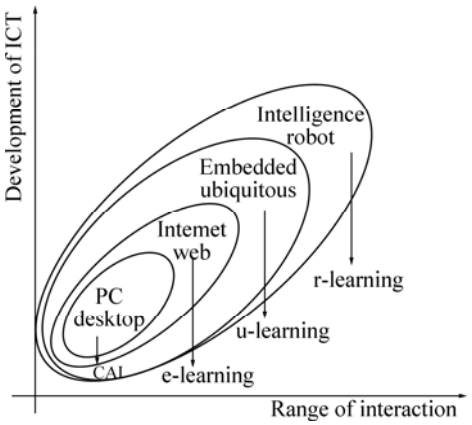

Fig. 1 Concept of r-learning

As above, we define r-learning as a learning support system that intelligent robot serves verbal and nonverbal interactions, based on ubiquitous computing environment. HAN and JO [10] defined a robot-aided learning as a type of learning that personified education service robots help the interaction between a learner and a teacher that can response the outside environments and the situation of a learner, and classified it into a type of other-directed intelligence, a type of self-intelligence and a type of blended intelligence depending on the position of intelligence.

We classify the use types of r-learning into other-directed intelligence robot-aided learning, self-intelligence robot-aided learning and blended intelligence robot-aided learning, depending on the position of intelligence and the presence of contents, as described in Table 1. First, other-directed intelligence robot-aided learning is defined as a type of learning that supports the verbal and nonverbal interactions between a learner and a teacher with the distant control toward intelligence robot by a distant learner or teacher. Second, self-intelligence robot-aided learning is defined as a type of learning that supports the verbal and nonverbal interactions between a learner and a teacher by intelligence robot that has either contents with artificial intelligence or servers linked with a network. Third, blended intelligence robot-aided learning is defined as a type of learning that supports the verbal and nonverbal interactions between a learner and a teacher by the distant control toward intelligence robot equipped with contents by a distant learner or teacher.

Table 1 Types and characters of r-learning

Type of r-Learning	Position of intelligence	Presence of contents
Other-directed intelligence robot-aided learning	Distance	No
Self-intelligence robot-aided learning	Robot	Yes
Blended intelligence robot-aided learning	Robot & distance	Yes

2.2 Contents of r-learning

Contents for education can be available in the environments of offline, online and mobile through reproducing contents into digital forms for the purpose of education or education supports [11]. And contents for education are sometimes thought as courseware. The courseware as a compound, course or software, is a kind of computer software that includes contents, instructions and methods of education. The courseware contains a series of learning instruction on learning methods and strategies, and its contents contain course contents primarily in curriculum, and sometimes in extra curriculum or integrated courses.

Robot contents consist of action, order-job process and multimedia contents of robot. With gestures and movability in robot contents, human−robot interactions are possible and given tasks are processed on the basis of situation cognition and artificial intelligence according to scenario. And multimedia contents such as flash, movies and music, can be given to users.

Comparison of robot contents and computer contents by service forms is described in Table 2 [10]. Computer contents serve multimedia information and a function of artificial intelligence, while robot contents serve not only whatever computer contents serve, but also kinetics and emotional expressions. That is, the robot contents serve scenario-based intelligence that can make a decision after perceiving the outside environment and situation, and can serve emotional expressions and service actions. Based on the above mentioned, the characters of robot contents for education are as follows. First, they can do the emotional or educational interaction via nonverbal expressions such as facial appearance, and gesture of robot. Most robots for education can serve human emotions because they have appearances of human beings or animals. And they can recognize learner's face and voice, and it is possible to serve educational interaction, meeting with learning contents and learner's ability through kinetics and emotion expression. Second, robot contents are equipped with artificial intelligence. Robots are equipped with artificial intelligence itself and then they do not serve contents depending on learning situation and learner's ability, but provide services embedded artificial intelligence in contents.

Table 2 Comparison of computer contents and robot contents

Type	Knowledge information service forms	Physical service forms
Computer contents	Multimedia information; Artificial intelligence	—
Robot contents	Multimedia information; Artificial intelligence; Kinetics and emotional expressions	Scenario-based intelligence that can make a decision after perceiving outside environment and situation, and can serve emotion expression and service actions

2.3 Effects of r-learning

TOSHIKI [12] suggested the utilization of robot for education. In order to find out what kinds of emotion a person has for robot, with emotional adjectives that a person uses, "intimacy" or "fear" for things, it was studied by University of Ochamomizu and NEC together. In result, it is discovered that the human-robot-machine groups are divided into human-animal group, robot (AIBO, Asimo, and Papero) group, and machine-inanimate object group, as shown in Fig. 2. That is, human robot interaction (HRI) means more effective for emotional interaction than human machine interaction (HMI) or human computer interaction (HCI), because the shape and appearance of robot contribute to reduce the fear of machine. It is suggested that learning with robot is more familiar to a learner without reluctance than that with CAI.

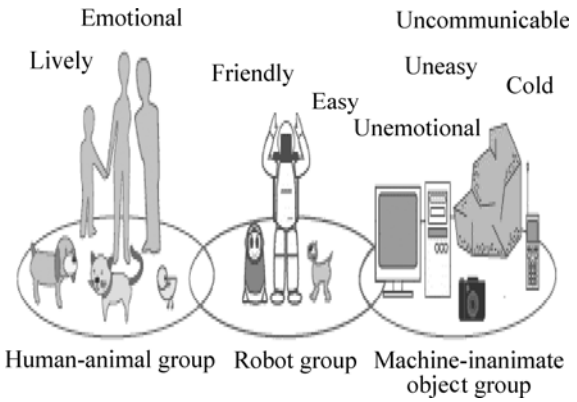

Fig. 2 Intimacy of human-robot-machine group

HAN et al [4] studied whether there is a significant difference among learning concentration, learning interest and academic achievement, for children as subject, with different media. In result, home robot gained a significant result in concentration, interest and achievement, resulting from self-learning with home

robot, serving printing and recording source and web-based source. It is showed the utilization of robot for education. KIM and HAN [5] discovered that robot reduces fear of a child, and is more efficient in learning concentration, learning interest and learning achievement than machine. It suggested that robot induces much more active and positive interactions with a learner than other medium. LEE and HAN [7] also studied an experimental class during 16 weeks by English exclusive teacher in English room after school in the elementary school. In result, it is discovered that there is a significant effect in interest, participation and self-confidence for English learning. JEONG et al [6] investigated the difference of learner's interest, achievement and concentration for English learning by manufacturing and using English learning contents with teacher-aided robot. The result is that learners tend to have more interests in playing robot than in serious robot, and in terms of learning concentration, playing group participates in more freely than serious group, while in terms of the duration of learning concentration, the case by playing group is shorter than the one by serious group. It is suggested that, on manufacturing robot contents for education, it is effective for learning interest that voice tone and expression are brighter and more playful, while it is recommended for duration of learning that voice tone and expression are more serious.

KIESLER and GOETZ [2], under the presumption appearance, character and language of robot influence the interaction with human being, investigated achievement time and participation time of old men exercise programs with playful robot and serious robot. In result, old men exercising with playful robot are more positive and more interested in the human aspects of robot than those with serious robot, while old men exercising with serious robot achieve the given exercise task even faster than those with playful robot [2]. It is suggested that both children and old men are affected by nonverbal message of robot. KANDA et al [3] investigated the class with robot, called ROBIE, which can memorize 800 words, shake hands, greet, and play the game, through CCTV for 2 weeks in the whole classes from the first grade to the sixth grade. The result is that, as time goes by, interest in robot becomes less, while motivation for English learning is active. BAN et al [9] investigated students who participated in the after school program in three elementary schools, in order to study the effect of learning with English teacher aided robot. The result is that student's speaking ability is improved prominently, and interest, self-confidence and learning motivation are also significantly high. It is suggested that robot-aided learning is effective in learning improvement.

3 Methods: Assessment criteria for nonverbal interaction

3.1 Nonverbal interaction

Communication among people has a system of verbal and nonverbal languages [13]. American sociologist, Albert Meharabian, says that message communication consists of speech 7%, voice (tone, intonation, loudness) 38%, and nonverbal attitude 55%. LIM [14] insisted on the importance of nonverbal communication, depending on nonverbal message whenever verbal and nonverbal messages are conflicted with each other. BIRDSHISTELL [15] insisted that communication is achieved with 30% of verbal expression and 70% of nonverbal expression. As above, a nonverbal message must be an essential part in the successful communication as well as verbal message.

Because personal interactions are communicated with verbal and nonverbal expressions, the concept of nonverbal interaction can be defined with the concept of nonverbal communication. LIM et al [14−16] defined nonverbal communication means literally all the significant communication except verbal message by spoken language, and a report which defines semi-verbal expression refers to pronunciation, articulation, pitch, tone, speed and loudness, which are involved in linguistic expression directly, while nonverbal expression includes posture, hand motion, body gesture, facial expression and eye contact, which are independent of linguistic expression [17].

STWART and LOGAN [18] specified the features of nonverbal interaction as follows. The first features are action and gesture. The greek term, Kinesecs, means motion and is a technical term covering a study of action and gesture. The action of motion is interpreted similarly in the whole world. For example, it is common in general anywhere that nodding the head means acceptance, clenching the fist upset, and clapping acceptance. On the other hand, LEE et al [16] insisted that gestures are a product of culture and the meaning of the same action may be different in the different cultural backgrounds. The second is facial expression. It is sometimes thought as the most feature among the components of nonverbal interaction. The messages from pleasure, happiness, sadness, frightening, fear, upset and reluctance, can be conventionally read from facial expression. The third is eye contact. Eye contact is the first action after birth, and it plays a key role in cultivating personality of an infant. Noticing increases intimacy of personal relation and diverse motions of eye express a variety of emotions. The fourth is space. Space is essential in the human relation, is classified into intimacy distance, personal

distance, social distance and public distance, and explains the relation of distance and intimacy. The fifth is physical contact. The physical contact is the direct action that initiates intimacy and the essential element that makes children happy. The sixth is semi-verbal language. Speech speed, loudness, voice quantity and voice quality are involved in the verbal communication. The seventh is silence. Silence induces emotion, thinking, wish, and so on. The last is about nonverbal expressions such as appearance, dress, smell, time and color.

3.2 Development guide of assessment criteria for nonverbal interaction

In this work, the nonverbal interaction will be defined into all the significant communications but spoken and written languages. We propose the development guide of assessment criteria for nonverbal interaction in r-learning contents, in order to be widely used as helpful and necessary developing the r-learning contents for education as follows. First, the consistency of learning contents and nonverbal messages should be involved in assessment criteria. For example, assessment criteria should estimate whether gesture or facial expression is consistent with learning contents. Second, the learning efficiency should be involved. One of the most important aims of contents development is learning efficiency. For example, assessment criteria should estimate how efficient r-learning contents are in learning and teaching. Third, safety should be involved. Robot for education should not be mis-manipulated against learners, because it is not fixed hardware, but a movable machine on learning and teaching. Fourth, the function efficiency of robot for education should be involved. Robots for education are developed in various forms, for example, animal robots, human robots, depending on the functions of education. Robot A may have a function of diverse gestures, while Robot B has a function of diverse facial expressions. Therefore, it should be estimated whether function efficiency of robot for education is maximized. Fifth, learning ability of learners should be involved. Active or diverse gestures might be interesting to the lower classes, but not to the higher, sometimes interrupting. Therefore, appropriateness for the grades of learners should be estimated. Sixth, the accuracy of nonverbal messages should be involved. For example, it should be estimated whether nonverbal messages distort verbal messages in the aspects of pronunciation, stress, tone and speech speed.

3.3 Ranges of development

The range of nonverbal interaction in r-learning contents is proposed in Table 3 and the assessment criteria of nonverbal interaction are also proposed within the range, considering the character of robot contents. Assessment criteria in Table 3 are proposed, considering the technical limits of robot for education, based on the previous studies [18−20] on nonverbal communication in r-learning and on nonverbal communication with the human relation. The specified contents of the range are as follows. The first is gesture. Because the human behaviors such as gesture, nodding head, posture, walking, attitude and body motion, can be acted by the education robots for nonverbal communication with a learner, their parts can be specified into gesture. The second is facial expression. Because robots for education can express laughing, upsetting and sadness by eye contact, eyebrow, and eyelid of robots, facial expression should be specified. The third is semi-verbal message for pronunciation, tone, speech speed, intonation, loudness, stress, silence, etc. which are also in verbal message. The

Table 3 Ranges of nonverbal interaction in r-learning contents

Type	Ref. [18]	Ref. [19]	Ref. [20]	This work
Gesture	Action and gesture	Gesture/motion of head/posture/walking style	Gesture/ attitude	Gesture
Facial expression	Facial expression/eyes	Facial expression/eye contact	Face and eyes	Facial expression
Semi-verbal message	Speed/variation of pitch/voice quantity/voice quality/silence	Variants of voice/height of voice/loudness speed/voice quality/intonation	Voice	Semiverbal expression (pronunciation/tone/speed/ intonation/loudness/stress/ silence)
Distance	Space	—	Proxemics	Distance
Physical contact	Physical contact	Contact	Contact	Physical contact
Time	Time	—	Time	Time
Interface	—	—	—	Interface
Appearance	Smell/appearance/ dress/color	Breath/dress	Situation/dress	—

fourth is distance. Because robots for education can move to a learner or a place where they are expected to go, on two feet or with wheels, distance comes to be specified. The fifth is physical contact. Robots for education can contact physically with a learner by embracing, shaking hands, stroking head or patting shoulder. The six is time. It might be efficient if positive feedback is given immediately for the learner's response, while negative feedback after an interval or less. The seventh is interface. R-learning communicates with a learner via interface in terms of HRI (human robot interaction).

3.3.1 Gesture

Gesture is a kind of nonverbal communication expressed by neck, shoulder, hands, arms, and so on. Nodding head up and down expresses the positive meaning, while nodding head right and left the negative. Folding arms and eye contacting the other express the unpleasant and defensive attitudes, and nodding head and moving unnecessarily express degrading and sometimes come to interrupt communication. Gesture may be differently expressed under different culture backgrounds. For example, making roundness with thumb and index finger can be interpreted into "perfect" or "nice" to American, while 'meaningless' to the French [18]. Also, clapping to encourage and compliment a learner results in increasing intimacy with a learner and in inducing motivation. Referring to a thing or a learner by indexing with a finger is effective both in making a learner pay attention and in emphasizing learning contents. In order to transfer the meaning of message exactly, both verbal and nonverbal messages should be used, and the expression with nonverbal messages is more effective in communication. Any action of robot should not be harmful to a learner, and transfer nonverbal messages by gesture without error in the aspect of culture. The great advantage of r-learning that e-learning and u-learning don't have is that robot for education gives a learner to demonstrate. For example, it might be helpful in learning conducting in music class, exercises in physical education, etiquettes in moral education, etc. Therefore, the functions of demonstration in the education robot should be an assessment criterion in the domain of gesture.

3.3.2 Facial expression

Facial expression is a kind of nonverbal communication expressed by face, eyes and lip. The image of a teacher has a strong influence on the rate of audience attention. A teacher under attention rate of audience 15% can be regarded as "heartless" or "poor", while one over attention rate of audience 80% as confident or friendly.

Eyes communicate a diverse emotion. Natural eyes deliver a warm and positive emotion, while avoiding eyes an indifferent and negative emotion. In addition, a face with mild smile can induce learning motivation and convey a warm emotion. Eyes contact with a learner as a sign of communication positively influences memory facilitation, learning concentration and learning participation and has an effect on making a learner stop a distracted behavior, too. Widely open eyes give a romantic and attractive image, but narrowly open eyes a confrontation and negative image [21]. Because of thinking of eyes as a window of soul, we tend to be careful of eye shape and eye contact in communication. A speaker with good eye contact is much more likely to succeed in communication [22].

3.3.3 Semi-verbal message

Semi-verbal message as phonetic elements such as pronunciation, tone, speed, intonation, loudness, stress and silence, independent of verbal contents, is a kind of nonverbal communication. A tone should be appropriately expressed, considering the degree of concentration, intimacy, feedback of learning motivation, and learner's ability. Soft voice might lead a communication smoothly, convey a warm feeling, and succeed in inducing intimacy and motivation [23]. JEONG et al [6] investigated learning interest, learning concentration, and academic learning time through robot with serious tone and robot with playful tone, and discovered the fact that robot with serious tone is effective in learning interest, while robot with playful tone in learning concentration and academic learning time. Putting a strong stress on the key words to emphasize learning contents and to facilitate memory is, in particular, effective, while silence may be used when giving a negative meaning, giving time to consider, and providing an integrated task and an active learning participation [21].

3.3.4 Distance

Distance is a kind of nonverbal communication, transferring teacher's intention by the distance that occurs when approaching to a learner or moving to the intended place. Moving to a learner has influence on paying attention, emphasizing learning contents, and enhancing interaction. The movement of robot can convey intimacy to a learner, and be focused on learning contents. Dr. Hall divided the distance where one interacts with the other subconsciously into four kinds; intimate distance 15−46 cm, personal distance 0.46−1.2 m, social distance 1.2−3.6 cm, and public distance over 3.6 m [18]. Intimate distance is what interlocutors feel familiar emotionally, personal distance what interlocutors talk to each other at ease, social distance

what ordinary voice can be heard, and public distance what a voice with high pitch and loudness is required. In general, one tends to be closer to the other to feel more familiar. Though most people don't think about personal distance, being closer is itself a sign of friendship or interest.

The further the distance between a teacher and a learner is, the more the unidirectional teaching and the teaching-based class are likely to be. But teacher's nonverbal behaviors enhance learner's participation. In the study on nonverbal behavior of a teacher in the fields of teaching and class management, it is discovered that learners closer to a teacher tend to take parts in learning and class activities more actively. That is, they follow a teacher's instruction without hesitation. They pay attention to a teacher's instruction, take more notes, and give a positive attitude to a teacher. When a teacher is closer to a learner, a learner is likely to be active and communicate freely. In result, even if robot cannot move, more educational effect might be expected if having a learner come to robot nearer.

3.3.5 Physical contact

Physical contact is a kind of nonverbal communication by embracing or shaking hands. Physical contact is divided into the positive and the negative. The positive physical contact is for expressing love or intimacy, while the negative for punishing or scolding, sometimes giving a physical sickness. Physical contact can convey what a teacher wants to give to a learner effectively, and result in having a great educational effect. And physical contact helps child to enhance, to feel at easy emotionally, and is one of the major nonverbal elements, in particular, in expressing intimacy [21].

The most precaution when leading physical contact in r-learning contents must be safety for protecting a learner. In addition, the diverse and active physical contact for intimacy and familiarity is more effective to the lower grade learners than to the higher.

3.3.6 Time

Time is a kind of nonverbal communication, synchronizing with verbal messages to a learner and giving feedback. That is, the duration while a teacher is waiting for a learner's response might influence the interaction between a teacher and a learner. If a teacher doesn't wait for a learner's response for a long time, only learners who are good at speech can give a response. Therefore, enough time should be given, in particular, to the low-level learners or to the young learners.

A good teacher gives both a verbal instruction and a physical activity. Messages will be conveyed effectively whenever the verbal and nonverbal behaviors are given at the same time. Therefore, verbal expression and nonverbal expression should be conveyed after motivation.

3.3.7 Interface

Interface is a kind of nonverbal communication about the interaction with a learner, in terms of human computer interaction (HCI), and should be estimated by the following aspects.

The first is user's convenience. Contents should be convenient in order to enhance effect, utility and satisfaction. Whenever a learner needs anything, contents should be so convenient that a learner can see what he wants to see, and he can get what he want to get. To do it, the interfaces with buttons, which is accustomed to a learner, should be included, and finding a road for learning should be also provided with ease. And site maps might be provided to give convenience to users and learning contents should be provided with the proper quantity and size within a screen. The second is esthetic. A beautiful screen should be designed to inspire a learner to work much harder. The third is accuracy. Learning contents should be accurate to be understood with ease, and hyperlinks supporting learning activities should be also connected correctly. The fourth is autonomy. Interface providing a learner with self-determined study can increase the effect and satisfaction of learning. It should be designed for self-determined learning so that a learner can manipulate and control everything on a screen anytime with his intention, and choose and search for learning contents that he wants freely. The fifth is support. It should support to increase the effect and satisfaction of learning. In order to reduce a cognitive burden besides learning performance itself, guide and voyage information should be provided. It should be supported to keep from missing a lesson direction, linking a preview lesson and a review, and the clear instruction on what should be carried at a given time should be provided. And search function should be included for resolving questions from learning contents, and feedback and error message for the results of learning. The sixth is accuracy of circumstance understanding. To serve an appropriate service to learner's circumstances, the learning history and level of a learner should be understood exactly, by linking the position of a learner and robot, accuracy of screen recognition, and databases.

3.4 Discussion

The results of comparison of the assessment criteria for nonverbal interaction contents in r-learning with those of the previous studies are as follows. First, it is distinct in terms of the objects of interaction. The interaction between robot and a learner, that is, between robot and human, is constructed in r-learning, while in

the previous studies on nonverbal interaction, as well as on verbal interaction, interaction was constructed between a teacher and a learner, that is, between human and human. Second, though the previous studies have no limit of expressions due to the human nonverbal message, r-learning has some limits on expressing messages because the object is robot. The first limit is on gesture. Unlimited and diverse gestures come from individual habits and situations, because human gestures have not been standardized. But robot's gestures come from the standardized movement. The second is on facial expression. Human face can make 7 000 kinds of facial expressions with lots of sophisticated muscles in the face. Meanwhile, robot's face can produce only a few of standardized expressions such as pleasure, sadness, upset and fright. Therefore, whether nonverbal messages like standardized facial expression and gesture, as well as verbal message, can be appropriately expressed in learning situation should be one of important criteria to assessment criteria of nonverbal interaction contents in r-learning. Third, though they are crucial in the human interaction, the parts that are not in the r-learning contents, or not related with robot were excluded in this work. For example, smell and breath are excluded because of no relation with robot, and appearance and circumstance of robot are also excluded because of no relation with contents, though appearance, dress and color of robot play a great role in the communication through nonverbal interaction between a learner and robot for education. Fourth, the domain of interface is added. Robot for education provides learning contents through touch panel, and is required to assess the domain of information collection to understand the circumstances of learning and a learner. In result, the domain of interface is added.

4 Results

To verify the validity and reliability of our assessment criteria proposed in Section 3, data have been analyzed as follows. SPSS 18.0 program and Amos 18.0 have been used for data process. First, contents validity has been verified through an individual interview with 6 experts on assessment criteria of r-learning contents. The questions that opinion agreement of experts is over 3.0 are accepted because of over "normal", while those under 3.0 are excluded because of under "normal". Second, construct validity has been verified through confirmatory factor analysis. With the results of interviews with 180 elementary and middle school teachers who have experienced teaching with both r-learning contents and e-learning, confirmatory factor analysis of assessment criteria of r-learning contents has been done for assessment criteria of learning contents, assessment criteria of verbal interaction and assessment criteria of nonverbal interaction, respectively. With average of assessment factors, model fit index has been calculated, using maximum likelihood estimate. Criteria for the goodness of fit test used to verify the validity of the assessment criteria are as Table 4. Absolute fit measures are an index of verifying the goodness of fit test for the whole model, including χ^2, GFI (goodness of fit), AGFI (adjusted GFI), and RMR (root mean-square residual). Incremental fit measures are indexes of verifying the goodness of fit test for the proposed model against the basic model, to verify the fit measures of the developed model through NFI (normed fit index) and NNFI (non-normed fit index). On verifying the goodness of fit test for the model, it would be better to apply some kinds of fit indices simultaneously, rather than to apply only one kind of fit index. Because the value of χ^2 is very sensitive, both the first fallacy (the fallacy that ignores the null hypothesis which is true) and the second fallacy (the fallacy that adapts the null hypothesis which is false) could be violated. Thus, the values of both absolute fit measures and incremental fit measures should be verified at the same time, and the goodness of fit for the model can be explained through the experimental criteria of fit measures, even if the null hypothesis is ignored by less than 0.05, p value from χ^2. In addition, the goodness of fit for the path model is discovered to analyze the cause and result relations among assessment criteria, evaluation territory and evaluation elements. The judgment of significance refers to CR (critical ratio, t) of RW (regression weights). If $t>|1.96|$, it is significant from 5%, If $t>|\pm 2.58|$, it is significant from 1%. Third, reliability of assessment criteria has been verified. The factor, Cronbach-α has been used to inspect the internal consistency and the same quality of the questions.

Table 4 Criteria for goodness of fit

Model	Absolute fit measure				Incremental fit measure	
	χ^2	GFI	AGFI	RMR	NFI	NNFI
Worst model	$p\leq 0.05$	0	0	<0.05	0	0
Normal model	$p\geq 0.05$	<0.9	<0.85	>0.05	<0.9	<0.9
Optimal model	$p\geq 0.05$	1	1	>0.05	1	1

4.1 Contents validity

The result of content validity of assessment criteria for nonverbal interaction is shown in Table 5.

Table 5 Result of content validity

χ^2	p	GFI	AGFI	RMR	NFI	NNFI
120.318	0	0.831	0.662	0.034	0.830	0.767

Because opinion agreement of experts is over 3.0, we determined that the content validity of our assessment criteria for nonverbal interaction is regarded as good.

4.2 Construct validity

With the theoretical basis, the range of nonverbal interaction has been specified into such seven domains as gesture, facial expression, semi-verbal message, distance, physical contact, time and interface. The fit index of assessment model for nonverbal interaction is listed in Table 6.

Because the significant value of nonverbal interaction is $p<0.05$, AGFI (0.662)≤0.85, NNFI (0.767)≥0.9, but GFI (0.831)<0.9, RMR (0.034)≤0.05, NFI (0.830)<0.9, our assessment criteria for nonverbal interaction can be accepted.

Path diagram of assessment criteria for nonverbal interaction is shown in Fig. 3, and the result of path analysis is listed in Table 7.

After the coefficient of determination for gesture is regarded as 1, the relative coefficients of determination for the others have been analyzed. The assessment criterion for facial expression is significant, because coefficient of determination is 0.535, and standard error is 0.071, $t=7.514>|\pm2.58|$. The assessment criterion for semi-verbal message is significant, because coefficient of determination is 0.957, and standard error is 0.089, $t=10.756>|\pm2.58|$. The assessment criterion for distance is significant, because coefficient of determination is 0.418, and standard error is 0.106, $t=3.935>|\pm2.58|$. The assessment criterion for physical contact is significant, because coefficient of determination is 1.127, and standard error is 0.081, $t=13.950>|\pm2.58|$. The assessment criterion for time is significant, because coefficient of determination is 1.136, and standard error is 0.093, $t=12.195>|\pm2.58|$. The assessment criterion for interface is significant, because coefficient of determination is 0.566, and standard error is 0.053, $t=10.719>|\pm2.58|$. In result, it has been proved that the path model of assessment criteria for nonverbal interaction is significant.

4.3 Reliability

In order to identify inter-item consistency and homogeneity of assessment items, reliability of assessment criteria for r-learning contents has been verified by using Cronbach-α factor in Table 8. The value of reliability factor, Cronbach-α, is 1-0, and the

Table 6 Fit index of assessment model of for nonverbal interaction

Range	Assessment factors	Average
Gesture	Accuracy of showing an example	4.67
	Concentration	4.17
	Intimacy	4.50
	Content consistence	4.67
	Expression consistence	4.67
	Effect	4.00
	Motivation reinforcing feedback	4.67
	Appropriateness of learner's level	3.33
	Safety	5.00
Facial expression	Concentration	4.83
	Intimacy	4.33
	Effect	3.67
	Consistence	4.17
	Motivation reinforcing feedback	4.67
	Appropriateness of learner's level	4.17
Semi-verbal	Concentration	4.67
	Intimacy	4.50
	Consistence	4.83
	Effect	4.33
	Motivation reinforcing feedback	4.67
	Appropriateness of learner's level	4.83
Distance	Concentration	3.83
	Intimacy	3.67
	Effect	3.67
	Motivation reinforcing feedback	3.50
	Appropriateness of learner's level	3.50
Physical contact	Intimacy	4.33
	Motivation reinforcing feedback	4.00
	Appropriateness of learner's level	4.00
	Safety	5.00
Time	Motivation	4.33
	Motivation reinforcing feedback	4.50
Interface	Convenience	4.67
	Esthetic	4.50
	Accuracy	5.00
	Self-determined study	4.17
	Support	3.67
	Accuracy of circumstance understanding	4.17

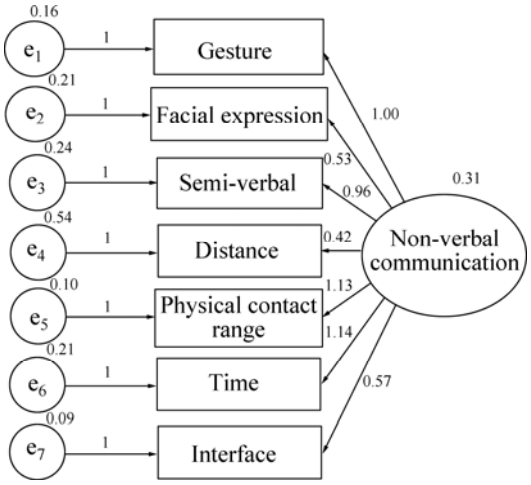

Fig. 3 Path diagram

Table 7 Path analysis of assessment criteria for nonverbal interaction

Range	RW	SE	CR	*p*
Gesture	1			
Facial expression	0.535	0.071	7.514	***
Semi-verbal message	0.957	0.089	10.756	***
Distance	0.418	0.106	3.935	***
Physical contact	1.127	0.081	13.950	***
Time	1.136	0.093	12.195	***
Interface	0.566	0.053	10.719	***

closer to 1, the more reliable. In general, the values between 0.8−0.9 are regarded as highly significant.

Table 8 Reliability of non-verbal interaction

Range	Cronbach-α
Non-verbal interaction	0.945

As Cronbach-α factor for assessment criteria for nonverbal interaction is 0.945, the reliability of them is verified as very high. In conclusion, 38 sub-assessment factors as very valid in this work can be regarded as assessment criteria for nonverbal interaction.

4.4 Discussion

Efforts to enhance the quality of teaching and learning by applying multimedia into education have been made since the advents of CAI. Owing to e-learning, learning and teaching without limits of time and place can be available through bidirectional communication between a teacher and a learner, or between learners. The development of ubiquitous computing has overcome limits of the traditional media for education, and can give intelligence service to a learner, based on understanding of circumstances. With the development of intelligence robot techniques and their outstanding effects, nowadays, r-learning is appearing as a new paradigm of multimedia use in school education. The great advantage of r-learning can provide an educational service by robot contents and nonverbal interaction of a learner. So far, however, assessment criteria for nonverbal interaction, which can verify the validity and reliability of r-learning contents, have not been studied. In this respect, we aimed to develop reliable and valid assessment criteria for nonverbal interaction contents in r-learning, exclusively considering the characteristics of robot for education. The result of study is summarized as follows. 1) In order to develop assessment criteria for nonverbal interaction contents in r-learning, the effect and contents of r-learning, nonverbal interaction, and the development guide of assessment criteria in r-learning contents have been investigated from the previous studies. 2) The range of assessment criteria for nonverbal interaction in r-learning contents has been specified into gesture, facial expression, semi-verbal message, distance, physical contact and time. Gesture has been specified into 9 kinds such as accuracy of showing an example, concentration, intimacy, content consistence, expression consistence, effect, motivation reinforcing feedback, appropriateness of learner's level and safety. Facial expression and semi-verbal message have been specified into 6 kinds such as concentration, intimacy, effect, consistence, motivation reinforcing feedback and appropriateness of learner's level. Distance has been specified into 5 kinds such as concentration, intimacy, effect, motivation reinforcing feedback and appropriateness of learner's level. Physical contact has been specified into 4 kinds such as intimacy, motivation reinforcing feedback, appropriateness of learner's level and safety. And time physical contact has been specified into motivation and motivation reinforcing feedback. 3) The validity of the developed assessment criteria has been verified by statistics. As opinion agreement of content validity is over 3.0, it has been verified that assessment criteria for nonverbal interaction are valid. In addition, as the significant value χ^2 of nonverbal interaction is $p<0.05$, AGFI (0.662)≤0.85, NNFI (0.767)≥0.9, but GFI (0.831)<0.9, RMR (0.034)≤0.05, NFI (0.830)<0.9, it has been verified that assessment criteria for nonverbal interaction are also valid statically.

In order to identify inter-item consistency and homogeneity of assessment items, it has been verified that reliability of them is 'very high', resulting from inspecting reliability of them.

5 Conclusions

The assessment criteria for nonverbal interaction contents in r-learning, developed in this work, look

forward to the development of r-learning in the following respects. First, they can be used when choosing the better r-learning content. They are expected to be used as a guide in choosing contents that include lots of advantages of robot, not served by e-learning and u-learning. Second, they can be used when producing r-learning contents. They are expected to be a guide in making a high quality of r-learning contents with the functions of nonverbal interaction. Third, they can contribute to enhancing the functions of robot for education. They are expected to be a guide in developing robot with the enhanced functions of nonverbal interaction such as gesture and facial expression. Fourth, they are expected to improve reliability of school education ultimately, due to increasing learner's satisfaction of r-learning.

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