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Virtual reality prototype for measurement of expression characteristics in emotional situations

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ABSTRACT

Expressions are a basic necessity for daily living, as they are required for managing relationships with other people. Conventional expression training has difficulty achieving an objective measurement, because their assessment depends on the therapist's ability to assess a patient's state or training effectiveness. In addition, it is difficult to provide emotional and social situations in the same manner for each training or assessment session. Virtual reality techniques can overcome shortcomings occurring in conventional studies by providing exact and objective measurements and emotional and social situations. In this study, we developed a virtual reality prototype that could present emotional situation and measure expression characteristics. Although this is a preliminary study, it could be considered that this study shows the potential of virtual reality as an assessment tool.

1. Introduction

Expression conveys one person's behavior and feelings towards another person, and is necessary for managing relationships between people. Expressions (including nonverbal behavior and speech characteristics) are the most important component of assertive behavior [1]. According to Wolpe [2] and Wolpe and Lazarus [3], assertiveness is defined not only as "one's suitable emotion expression without anxiety from another person", and assertiveness is not only "one's right demand", but also "another person's right protection" [2,3]. According to Fensterheim and Baer [4], assertiveness is defined as "action what informing one's sort of man", "action what saying as one's feeling or thinking", and "action what positive approaching in one's life than passive approaching" [4]. That is to say, expression is direct and frank behavior of one's feelings, rights, desires, and thinking towards another person in an interpersonal relationship with due respect to the other person's opinion or thinking without impinging upon the other person's authority. Effective expression is necessary so that people can make positive personal relationships, and to decrease or avoid tension. Expression is an ability needed for daily life, and is necessary for making and managing relationships with other people. Therefore, these social skills are among the most important abilities for maintaining a self-supported life.

Expression training is one of the cognitive behavioral therapies used for patients with schizophrenia, autism, and other mental disease. Some psychopathic patients have a deficit in expressions that needs to be improved before they can return to normal life. In general, expression training is used to help psychopathic patients attain their goals in interpersonal relationships. According to Libeman's (1982) definition, expression (i.e., sending skill) is one stage of social skill, along with social perception (receiving skill) and social problem solving (processing skill) [5,6]. The sending skill, called expression, is needed to communicate one's response effectively to another person [6].

In expression skill training, measurement or assessment is important to ascertain the effect of such training. According to a study on the components of assertive behavior by Eisler, two components can be used to measure these characteristics: nonverbal behavior (duration of looking and smiling) and speech characteristics (duration of reply, latency of response, loudness of speech, and fluency of speech) [1]. In this study, the duration of reply, latency of response, and loudness of speech were considered to be parameters that formed significant components of expression. However, duration of looking is also considered one of the most important components of expression [7].

There have been some investigations that have explored expression characteristics by measuring timed "eye contact" (defined as the percentage of time the assertive model spent looking directly at the face of the stimulus model) and the "duration of reply" (defined

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as the percentage of time the assertive model spent in replying to the stimulus model) using stimulus videotapes [7]. However, there are some shortcomings in this approach regarding the difficulty in obtaining reliable parameters, because these techniques used stopwatches and subjective judgments to measure the response time. The "beginning of reply", which is also an important factor of expression, was not considered in these previous studies. In addition, there was some difficulty in presenting emotional and social situations using videotapes.

Expression skill training is vital for patients with schizophrenia and other mental conditions as these conditions are governed by negative symptoms, leading to incongruent behavior and emotions, along with unreasonable thinking. However, there are also some problems with regard to nonobjective assessment in conventional expression skill training due to the dependence on the therapist's ability to assess a patient's state or in conducting expression skill training effectively [8]. In addition, conventional methods are limited to a time and space for conducting social skill training. Moreover, emotions are a very important factor in expression skill training because most situations are emotional, and expression characteristics can be easily changed depending on the emotion. However, it is difficult to assess a patient's skills in an emotional situation, because it is difficult for a therapist to provide emotional situations in the same way in every training or assessment session.

Virtual reality techniques can overcome the shortcomings of conventional studies by providing a method that can provide exact and objective measurements. They can provide emotional and social situations in interpersonal relationships using dynamic interactions with avatars. Virtual reality is the latest technique that can provide an immersive environment, a presence using three-dimensional (3D) rendering, and interpersonal parameters. Moreover, virtual reality can provide a standard method that is based on computerized parameters to perform an assessment objectively. Virtual reality can also provide a safe experimental environment, and can overcome time and space limitations in conducting training or assessing tasks. Virtual reality techniques have the advantage of providing emotional and social stimuli, and have recently been applied to mental diseases, such as the treatment of substance intoxication or phobias, using exposure therapy [9–11]. In addition, virtual reality techniques have also been used in the treatment and rehabilitation of psychopathic patients [12]. Recently, some studies have reported on the treatment of autism using virtual reality [13].

In this study, we constructed an emotional situation and developed an expression skill measurement prototype using virtual reality techniques for the objective measurement of expression characteristics that provided a constant emotional and social situation. Emotional scenarios based on general emotional situations that occurred frequently in daily life were composed. The emotional intensity was controlled in each scenario, which is important for objective measurements, and a consistent stimulus was presented in a preliminary study. As the participant expressed to an avatar in a virtual environment, our virtual reality prototype measured various parameters, such as "beginning of reply" (after conversation with an avatar in virtual reality), "duration of reply", and "watching avatar" (during emotion expression). We ascertained which participant could accept an emotional stimulus and respond suitably, and our virtual reality parameters were objective. In addition, we investigated the differences in expression characteristics in positive and negative situations by comparing these parameters.

2. Method

2.1. System

The system designed in this study was composed of a PC with a Pentium IV 2.8 GHz CPU, 1 GB RAM, and DirectX 3D acceleration graphics card for rendering and providing the virtual environment, an HMD (Eye Trek FMD 250W, OLYMPUS) for displaying the virtual environment in a more immersive manner, and a position tracker (InterTrax2, InterSense) having three degrees of freedom for the acquisition of head direction in real time. As shown in Fig. 1, the virtual environment rendered depended on the orientation data obtained from the participant's head direction using the fixed tracker attached to the HMD. The participant could look around in a natural manner. A camcorder (Sony DCR HC42, NTSC) was used to record the participant's response, to assess their expression ability by two social skill training therapists.

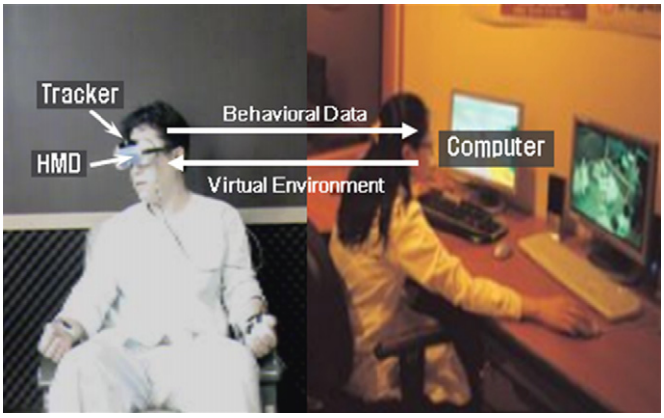

Fig. 1. Composition of the virtual reality hardware system. The experimental setting was composed of two rooms: one for the participant, and the other for the therapist controlling the scenarios. The therapist could monitor the participant using a one-way mirror or a video screen image captured by a video camera.

2.2. Virtual reality environment and tasks

Social skill training therapists and psychiatrists created six scenarios based on general emotional situations in normal life that covered a range of emotional situations (see Appendix A). The scenarios developed were composed of three positive and three negative situations that contained various situations involving family, friends, and coworkers in various environments, such as at home, at a café, at a bakery, at a restaurant, and in the street. There are more details on the six scenarios in Table 1, and Fig. 2 shows each virtual reality task. In addition, we performed a practice scenario for participants to familiarize them with the virtual reality devices so that the participants could look around without any problems when using the HMD and tracker during the main experiments.

All practice and main tasks were composed of 3D environments and objects (including avatars). They operated via a 3D virtual-reality rendering engine. In addition, objects were controlled using programming-language function calls. The virtual reality task procedure introduced a situation using a text panel that contained information about the task and a recorded narration that provided information. After the introduction, the participants experienced various emotional situations. After experiencing the virtual tasks, the participants were asked to assert their opinion or think within a given time after conversation with an avatar on each situation in the virtual environment. If a participant could not express their opinion or think in the given time, then a reinforcement which encouraged expression was offered by the virtual avatar. The reinforcement, using an avatar's short question, evoked a response from the participant. Questions such as "How about you?", "What do you think about that?", or "Why don't you do anything?" were posed.

Table 1
Scenarios for three positive and three negative situations.

Positive situations	Street Participant is awaiting an old friend of his on the street, the friend having made an appointment to see the participant after a long separation. After a short time, the friend appears and suggests a meal and conversation. Café Participant has a conversation at a café with a friend who has come to meet the participant for the first time in a long time. Then the friend gives a surprise present, even though it is not a special day. Café Participant works at a café in a part-time job and it is a very busy day. The owner of the store praises the participant for clever work after business hours
Negative situations	Street Participant is awaiting a friend of his on the street, the friend having made an appointment. The friend is extremely late (over an hour) and is not sorry about the lateness as well as being impolite. Bakery Participant works at a bakery in a part-time job. The owner of the bakery reprimands the participant over an incident, even though it was the fault of a coworker. Restaurant Participant works at a restaurant in a part-time job. A coworker overbearingly requests extra work by the participant to cover the coworker's absence, without remuneration or agreement.

Fig. 2. Screen shots of examples of virtual reality tasks: (a) an initial panel, (b) a situation involving a meal treat from a friend who has an appointment to see the participant, (c) a situation involving a surprise present from a friend who has come to meet the participant for the first time in a long time, (d) a situation involving praise from the owner of a store where the participant works, (e) a tasks selection panel, (f) a situation involving a friend who is extremely late for an appointment with the participant, (g) a situation involving a reprimand from the owner of store where the participant works that is the fault of a coworker, and (h) a situation involving an unfair request from a coworker about working as their substitute.

2.3. Experimental

2.3.1. Participants

Twenty-six paid normal participants were recruited for our experiments. The participants comprised 11 males aged from 24–47 years and 15 females aged from 22–50 years, with a mean age of 29.9 years, who had no history of mental illness. They had no experience of virtual reality and no problems using the human computer interaction devices (HMD tracker and joystick). They had no problems with social ability and emotional expression. Moreover, they had sufficient mental faculties for insight into their circumstances (their mean intelligence quotient was 105.65 (SD = 11.78) and their mean education duration was 14.92 (SD = 1.96) years.

2.3.2. Procedure

When a participant entered the experiment room, they were instructed on how to perform the experiment and the virtual reality device (HMD and tracker) was explained by the social skill training therapist. The participant answered questions on their name, gender, age, and educational background. Then, the participant put on the HMD and tracker and performed a practice task to familiarize themselves with the HMD and tracker. After performing the practice task, the participant performed six main tasks concerning emotional situations, in random order. After finishing each task, the participant was asked to assess their valence and arousal. Moreover, subjective feelings about cyber-sickness were queried, with nobody reporting cyber-sickness. We recorded all responses from the participants performing all the virtual tasks using a camcorder. The recorded response data were used to monitor the emotionality of each reply, the loudness of each reply, and other expression characteristics that are difficult to ascertain using virtual reality parameters ("beginning of reply", "duration of reply", and "watching avatar").

2.3.3. Measurements

In our experiments, we measured various parameters: "beginning of reply", determined by the time after the avatar speaks; "duration of reply"; and "watching avatar", determined by the amount of time the participant took to look at the avatar during an expression. All of these parameters were measured in both the positive and negative situations as the participant progressed through the tasks using our virtual reality prototype. In the "beginning of reply", cases were excluded where the expression started with any reinforcement

where the participant's expression was influenced by the virtual reality avatars.

We measured a self assessment manikin (SAM) to ascertain the intensity of emotion in each task. The SAM was used to assess a participant's change in emotion during their experience in virtual reality [14], and was composed of figures representing different magnitudes of valence and arousal scores. In this study, the valence ranged from –4 (extremely unpleasant) to 4 (extremely pleasant) and arousal ranged from –2 (extremely relaxed) to 6 (extremely excited). In arousal, it was expected that relaxed feelings would be unusual in these tasks, and we tried to focus on excited feelings, depending on the emotions in each task. Valence had the same scale of dependency on emotion because it was expected that unpleasant and pleasant could have equal intensity potential, depending on the emotion. A value of zero in arousal was set as a base line, which denoted a state where the participant did not feel any excitement and was not relaxed.

The emotionality of reply and the loudness of reply were assessed by two social skill training therapists who were trained to assess expression ability using videotape recordings that contained all the responses from the participants performing the virtual tasks. They were instructed not to communicate with each other. The emotionality of reply and the loudness of reply were assessed to confirm that a participant's response was an expression. This means that "beginning of reply", "duration of reply", and "watching avatar" are significant parameters that reflect the behavioral characteristics of an expression. The emotionality of reply and the loudness of reply values ranged from 1 (low level or bad response) to 5 (high level or good response).

2.4. Data analysis

The beginning of reply and the duration of reply were measured automatically by the VR prototype, but watching avatar (the percentage of watching avatar time during the whole reply in each task) was used after a conversion process. This was because each task and participant had a different duration of reply. Therefore, we used the percentage of time spent watching the avatar during the duration of the reply as an expression of watching avatar.

We used paired samples t tests to ascertain the difference in parameters between positive and negative situations. The SPSSWIN 12.0 software package was used to analyze these parameters.

3. Results

In this study, the developed virtual reality prototype presented an emotional situation that was common in normal life, and the participants responded after a conversation with an avatar in a virtual environment.

In the results of paired samples of t tests on the valence and arousal between positive and negative situations to test the emotional equality between the negative and positive situations, there was no significant difference in the absolute values of the valence ($p = 0.086$). With arousal, there was also no significant difference between the positive and negative situations ($p = 0.774$). Fig. 3 shows valence and arousal in positive and negative situations.

In the results of paired sample t tests between the positive and negative situations, there was a significant difference in the virtual reality parameters. There was a faster "beginning of reply" ($p = 0.020$), a longer "duration of reply" ($p = 0.001$), and more "watching avatar" ($p = 0.001$) in the negative situations compared with the positive situations. Fig. 4 shows "beginning of reply", "duration of reply", and "watching avatar" in positive and negative situations.

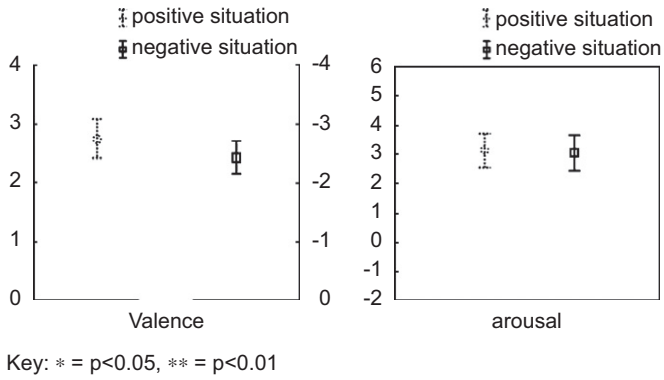

Fig. 3. A comparison of valence and arousal between positive and negative situations.

In the results of paired sample t tests for the positive and negative situations, there was a significant difference in the use of reinforcement ($p = 0.203$). Moreover, "beginning of reply", "duration of reply", and "watching avatar" did not differ between positive and negative situations ($p = 0.353$, 0.827, 0.111). It was considered that use of reinforcement was not dependent on emotion. Table 2 shows the use of reinforcement and the VR parameters ("beginning of reply", "duration of reply", and "watching avatar"), when reinforcement was used in positive and negative situations.

In the results of paired sample t tests between the positive and negative situations, there was no significant difference in the emotionality of reply and the loudness of reply. The participants showed a high value of emotionality of reply and loudness of reply in both the positive and negative situations. Table 3 shows emotionality of reply and loudness of reply in positive and negative situations.

4. Discussion

We developed a virtual reality prototype for presenting controlled emotional situations and investigating expression characteristics in emotional situations. The virtual reality tasks were composed of positive and negative situations. These contained various situations involving family, friends, and coworkers in various environments, such as at home, at a café, at a bakery, at a restaurant, and in the street. Our virtual reality prototype used three parameters as objective measurements that could characterize human expressions in emotional situations. There was no cyber-sickness subjectively reported after the experience of virtual reality tasks. Moreover, the performance time was not long enough, and motion was not large enough, to involve cyber-sickness.

In a previous study, we controlled the emotional intensity in scenarios (see Appendix A) using valence and arousal with 20 normal control subjects, measuring valence and arousal again in virtual reality contexts. There were no differences in valence ($p = 0.764$ in positive situations and $p = 0.091$ in negative situations) and arousal ($p = 0.612$ in positive situations and $p = 0.397$ in negative situations) between the scripted version of the scenario and the virtual reality contexts. It could be considered that the scripted version of a scenario converts well into a virtual reality context. Moreover, there were no differences in valence and arousal between positive and negative situations.

The idea that differences between positive and negative situations can be thought of as the result of the intensity of emotion provided by the virtual situations was not true, because there were no significant differences between positive and negative situations in a comparison of the absolute values of the valence and arousal. The results of our comparison of emotional intensity provide evidence that positive and negative situations involve a similar level of emotion. Therefore,

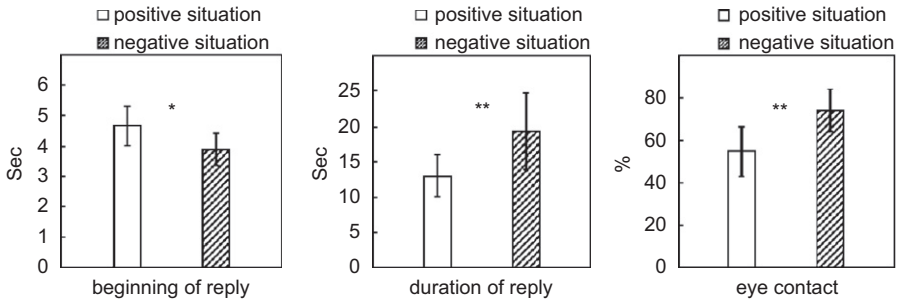

Fig. 4. A comparison of the "beginning of reply", "duration of reply", and "watching avatar" between positive and negative situations.

Table 2
Comparison of use of reinforcement and VR parameters when reinforcement was used in positive and negative situations.

	Positive situation	Negative situation	Significance
Use of reinforcement	0.26 time	0.13 time	0.203
Beginning of reply with reinforcement	2.43 s	3.85 s	0.353
Duration of reply with reinforcement	10.96 s	10.14 s	0.827
Watching avatar with reinforcement	1.57%	6.38%	0.111

Table 3
Emotionality of reply and loudness of reply in positive and negative situations.

	Positive situation	Negative situation	Significance
Emotionality of reply	3.29/5	3.23/5	0.526
Loudness of reply	3.51/5	3.56/5	0.574

the differences in the virtual reality parameters ("beginning of reply", "duration of reply", and "watching avatar") are based on the type of emotion, and not on the intensity of the emotion. As a result of our comparison of emotional intensity, we developed a virtual reality prototype that could provide emotional situations.

We measured virtual reality parameters ("beginning of reply", "duration of reply", and "watching avatar"), and we considered that these virtual reality parameters reflected the behavioral characteristics of an expression in emotional situations. However, we had to be able to guarantee that a participant's response was an expression in an emotional situation before we could derive any conclusions. The result of a comparison of the emotionality of reply and the loudness of reply provides evidence that the participants showed emotional expression while performing the virtual reality tasks and that there was no difference between the positive and negative situations. Therefore, it is considered that our virtual reality prototype leads to a participant's expression in emotional situations.

In the analysis of the "beginning of reply", the participants showed a faster reply in negative situations than in positive situations ($p = 0.020$). This result is consistent with established reports that people feel a higher level of stress in negative situations than in positive situations [15,16]. Individuals with high levels of anxiety (stress) pay more attention in negative situations because of the stress [17]. Therefore, individuals with high anxiety (stress) levels are quicker at responding to probes in negative (angry) situations than in positive (neutral or happy) situations compared with low anxiety (stress) level individuals [17–19].

In the analysis comparing "watching avatar", the participants showed more watching avatar in negative situations than in positive situations ($p = 0.011$). This result suggests that participants made more watching avatar to reduce stress during their social interactions in negative and stressful situations.

From the results of the "duration of reply" study, we observed that the participants spent much more time in negative situations than in positive situations ($p = 0.001$). This result concurs with the usual observation that humans take much more time when they argue with, or try to persuade, someone else, particularly in negative situations. The participants showed a significantly longer duration of reply in negative situations than in positive situations, because they felt a higher level of stress in negative situations than in positive situations [15,16,20] and they used more expression to reduce their stress; i.e., humans usually have longer conversations under negative or stressful situations so that they can reduce their stress in such situations.

For the "beginning of reply", "duration of reply" and "watching avatar", cases where the expression started with reinforcement were excluded. Reinforcement could influence the "beginning of reply", "duration of reply", and "watching avatar". There would not be pure expression characteristics with reinforcement even though using reinforcement can be a symptom characteristic of psychopathic patients. Moreover, it was considered that use of reinforcement was not dependent on emotion ($p = 0.203$) and there were no differences in VR parameters between positive and negative situations when reinforcement was used (beginning of reply: $p = 0.353$, duration of reply: $p = 0.827$, and watching avatar: $p = 0.111$). For application to patients with schizophrenia, it would need to be considered that the VR parameters depend on use of reinforcement. Moreover, reinforcement would be needed in social skill training for patients.

In this study, we constructed emotional situations and developed an expression characteristics measurement prototype using virtual reality. We verified that the tasks (i.e., six situations) had an emotional content, and that there was no difference in the emotional intensity between positive and negative situations by comparing the absolute values of the valence and arousal. We also verified whether a participant's response was an emotional expression from a comparison of the emotionality of reply and the loudness of reply. After measuring the virtual reality parameters ("beginning of reply", "duration of reply", and "watching avatar") we considered that these virtual reality parameters could reflect the behavioral characteristics of expression in emotional situations.

The prototype designed in this study can overcome the difficulties experienced using conventional methods by providing enough emotional situations for expression training and obtaining objective measurements. Appling virtual reality can be more effective than using pictures or videos in expression training or assessment, because virtual reality can provide social and emotional situations that will be a more realistic stimulus, and virtual reality can be used to computerize various parameters so that objective measurements are possible. This can improve on the limitations of existing methods, such as objective measurements, time and space limitations, and provision of sufficient emotional situations. The virtual reality prototype developed in this study provided immersive reality, dynamic

Table A1
Comparison of the valence and arousal between each positive situation and negative situation.

Positive tasks			Negative tasks		
Situation	Valence	Arousal	Situation	Valence	Arousal
Surprise present from friend	3.05	3.25	Unfair request from coworker	−3.15	3.40
Meal treat from friend	2.90	2.85	Friend who was extremely late	−2.85	3.70
Praise from the owner of store	2.50	2.75	Reprimand from the owner of store	−2.45	2.90
Mean of positive tasks	2.82	2.95	Mean of negative tasks	−2.82	3.33

interaction, social and emotional situations, and interpersonal parameters. In addition, we identified parameters indicating the expression characteristics of humans in emotional situations, particularly those that are stressful.

A future study could be undertaken on reliability verification using our virtual reality prototype for patients with schizophrenia who have a deficit in expression skill, which is one of the social skills required for their return to normal life. Social skill training is the most important part of cognitive behavioral therapy for patients with schizophrenia, and expression is one stage of social skill training, along with social perception and social problem solving. The virtual reality prototype developed here could provide emotional and social situations that allow for effective expression training. Moreover, the virtual reality prototype could give feedback with objective parameters that will be immersed in the training.

Considering the results discussed in this work, our virtual reality prototype can offer controllable social and emotional situations. Therefore, we conclude that our virtual reality prototype can be used as an expression training tool by measuring behavioral and expression characteristics in social situations in a natural manner.

5. Summary

Expressions are a basic necessity for daily living, as they are required for managing relationships with other people. Expression skills training is one stage of a social skill training program for psychopathic patients needed to return them to a normal social life. Conventional expression training and assessment methods have difficulty achieving an objective measurement, because their assessment depends on the therapist's ability to assess a patient's state or their social skill training effectiveness. In addition, it is difficult to provide emotional situations or social situations in the same manner for each training and assessment session. Virtual reality techniques can overcome shortcomings occurring in conventional studies by providing a method that is able to obtain exact and objective measurements. Virtual reality techniques can provide emotional and social situations in interpersonal relationships using dynamic interactions with avatars. In this study, we developed a virtual reality prototype that could measure expression characteristics. The virtual reality tasks were composed of three positive and three negative situations in various places with various avatars. The participants expressed their opinion or thinking within a given time after conversation with an avatar in a given situation in a virtual environment. Our virtual reality prototype measured the "beginning of reply", "duration of reply", and "watching avatar", which are important parameters for ascertaining the effect of expression skill training. At the "beginning of reply", participants showed a faster reply time in negative situations than in positive situations. In "duration of reply" and "watching avatar", participants provided a longer reply and more watching avatar in negative situations than in positive situations. This can be explained in that people become more stressed in negative situations than in positive situations, and the participants replied more and made more watching avatar to reduce their stress in the more stressful negative situations. Considering the results, the parameters of our virtual reality prototype indicate the expression characteristics of humans in emotional situations, particularly under stressful conditions. Although this is a preliminary study, it could be considered that this study indicates the potential of virtual reality as an assessment tool. Therefore, we conclude that our virtual reality prototype can be used as a training tool for psychopathic patients by measuring their behavioral and expression characteristics in a social situation in a natural manner.

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Appendix A. Control of emotional intensity in scenarios

Method: Our preliminary study was concerned with the composition of general emotional scenarios. Psychiatrists rich in clinical experience composed a set of emotional contexts based on general situations in normal life. Then social skill training therapists created six scenarios based on the emotional contexts. To measure expression characteristics in emotional situations, we had to make sure the contexts used have emotional situations, and that there was the same emotional intensity in both positive and negative contexts. First, we controlled the emotional intensity in scripted versions of scenarios. Twenty normal participants were assessed for their valence and arousal in each of the emotional situations using scripted versions of scenarios. Six scenarios based on general emotional situations in normal life were generated by this preliminary study.

Results: In the results of this preliminary study (valence and arousal), the positive and negative emotional situations had similar valence ($p = 1.000$) and arousal ($p = 0.187$) values, which meant that the mean emotional intensity differed little between the positive and negative situations. Table A1 shows the valence and arousal in each task for positive and negative situations.

It is shown that there were no differences between the emotional intensity of the scripted scenarios in this preliminary study, with respect to the valence and arousal values. Therefore, it can be considered that we composed similar levels of emotional and general situations in this preliminary study.

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