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RESEARCH ARTICLE

Proposal for a Distraction Technique Using Two-Screen Projection for Stress Relief in Children With Medical Complexity

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This work involved human subjects or animals in its research. Approval of all ethical and experimental procedures and protocols was granted by the Ethical Review Board for Medical Research Involving Human Subjects of Gunma University (Application No. HS2021-112, HS2022-095).

ABSTRACT The aim of this paper is to investigate the potential of virtual reality images as a means of reducing pain and fear in children, through the use of projection technology. While body-worn immersive displays have been previously suggested for this purpose, head-mounted displays have been found to be unsuitable due to their lack of interactivity. To address this issue, we propose a simple and cost-effective two-screen projection system that can be installed in a hospital room without interfering with communication and without compromising the immersive experience. By projecting onto screens installed on the wall and floor, an immersive digital space can be created visually. Our experiments, in which we measured α-amylase activity in saliva, showed that the proposed two-screen projection significantly reduced stress levels in healthy adults when compared to one-screen projection. Additionally, we conducted an experiment using the KOKORO scale as a subjective measure, which revealed that children with medical complexity experienced a significant reduction in stress levels after viewing the two-screen projection compared to before viewing. These findings suggest that the proposed system could serve as an ideal distraction in pediatric nursing, thereby providing much-needed nursing support to children and their families.

INDEX TERMS Projection, distraction, children with medical complexity and pediatric nursing.

I. INTRODUCTION

Children with medical complexity (CMC) [1], [2] and their families often experience stress due to the numerous restrictions and interventions that are a part of their daily lives. Specifically, children who require medical devices such as ventilators and suctioning are often isolated from diverse environments, which hinders their social development [3]. According to parental reports, 96.8% of these children wish to "go out and travel with the family" in their daily lives, but only 17.2% have the opportunity to do so, highlighting the need for nursing support to enhance the availability of enjoyable activities and medical care [4].

Distraction techniques [5] have been recognized in pediatric nursing as a way to alleviate stress in children receiving medical care, and the value of promoting ingenuity in nursing practice has been emphasized [6]. Recently, virtual reality (VR) with head-mounted displays (HMDs) has emerged as a promising distraction technique that effectively reduces pain and fear in pediatric nursing [7], [8], [9], [10].

In order to effectively provide VR distraction using HMDs to CMC who undergo long-term hospitalization and have

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behavioral limitations, a comprehensive understanding of their illnesses, symptoms, treatments, and medical equipment is crucial. Considering these factors, it may be possible for CMC to wear HMDs, but the difficulty in communicating with others while experiencing VR distractions will be a major challenge. In particular, nurses emphasize the usefulness of nonverbal cues such as facial expressions and eye contact as strategies for facilitating communication with others, and the importance of observation to read from facial expressions that the other person is at ease [11]. If children with developmental disabilities are provided with sufficient communication and distractions, they can become calmer and more cooperative even in stressful situations or circumstances that introduce additional stressors [12], [13].

Immersion promotes positive factors such as empathy, extraversion, and willingness to participate [14], [15], [16]. Our group anticipated that the highly immersive experience provided by two-way communication would be an effective distraction in pediatric nursing. Therefore, we experimentally tested the hypothesis that the immersion obtained through two-screen projection, which utilizes a simple and cost-effective projection method, has a distracting effect that reduces stress.

In this paper, we present evidence that the two-screen projection distraction method is effective in reducing stress in both healthy adults and CMC. The two-screen projection method we propose is a cost-effective solution that allows CMC and their families experiencing long-term hospitalization or behavioral limitations to create a sense of being outside the hospital or facility and effortlessly share these experiences with others.

II. RELATED STUDIES

In recent years, VR has gained popularity as a technology that can simulate a realistic experience. Rheingold defines VR as an experience in which a person is surrounded by computer-generated three-dimensional representations from various angles and can move around a virtual world [17]. Bullinger et al. discuss display devices for VR, including immersive projection technology, which uses a high-definition stereoscopic projector to create a highly immersive virtual world with a wide field of view [18]. Immersion, referring to the objective level of sensory fidelity provided by a VR system, is a key component of VR according to Meehan et al. [19].

There are two main types of interfaces for visual reproduction of an immersive digital space: those that use wearable immersive displays and those that use the surrounding space as a display. One example of a wearable immersive display is an HMD, which covers the user's field of vision and allows for increased immersion in the virtual space [20]. However, Gupta et al. and Viirre have reported problems with HMDs, including functional blindness in the real world, deprivation of auditory stimuli, distraction by the virtual scene, and collision with real objects or wiring in the VR system [21], [22]. Mon-Williams et al. conducted a study investigating the effects of HMDs on users [23] and reported symptoms such as headache, eyestrain, nausea, and signs of stress in both eyes due to oblique changes and increased near point convergence. The binocular stress signs identified by Mon-Williams and Pascal suggest a fundamental discrepancy between presentation distance and focal adjustment due to convergence [24]. Golding and Gresty suggested antiemetic drugs as a generally effective measure for VR-induced nausea [25], but Koch et al. reported that the side effects of antiemetic drugs may cause severe dizziness and fatigue [26].

As a tool for experiencing VR, HMDs possess several advantages, including low cost, portability, and power-saving features. However, due to their physical burden and stress-inducing elements, HMDs are challenging to use for active interactive communication. On the other hand, projection of images onto a screen is another technique for creating an immersive digital space that employs the surrounding space as a display device. One prominent example of this is the cave automatic virtual environment (CAVE) reported by Cruz-Neira et al., which displays computer-generated images on a screen and projects them onto a cube-shaped space approximately 3 meters square to enhance immersion [27]. This technology uses an active shutter system that synchronizes binocular disparity images with LCD shutter glasses to create a virtual space and has numerous applications in fields such as education [28], medicine [29], nature [30], games [31], and vehicles [32].

Currently, the π-CAVE, a three-dimensional stereoscopic visualization device, can efficiently analyze complex CAVE simulation data in a space measuring 3 meters high $\times$ 3 meters deep $\times$ 7.8 meters wide [33]. In contrast to the standard CAVE, where multiple programs are switched from a computer outside the room, Kageyama and Tomiyama developed Multiverse [34], which enables users to interact with programs while being immersed in the space. The system comprises three wall screens and four floor screens, using six projectors for projection and ten cameras for tracking, and can provide VR for up to 20 people simultaneously.

The CAVE is an excellent facility for natural interactive communication as an interface device for experiencing VR. However, constructing a large and costly visual environment that requires a large space, multiple screens, projectors, and cameras presents various challenges. Therefore, in recent years, many systems have been proposed to enable the transformation of a surrounding space into a display device, even in ordinary homes. For example, RoomAlive, reported by Jones et al., employs projector depth camera units coupled via a scalable distributed framework to transform any room into an immersive augmented entertainment experience [35]. Razer's Ariana [36], which comes equipped with a 3D camera, recognizes the surrounding environment placed on the projection object and allows proper projection without distortion, even when furniture or sundries are placed on it, enhancing the immersive experience.

There have been various attempts to promote sensory stimulation through video projection, including the introduction of VR into snoezelen, a treatment delivery method for autism spectrum disorder (ASD) [37]. SnoezelenCAVE, proposed by Perhakaran et al., integrates a hand-motion device and a speech recognition system to provide VR that stimulates visual learning, auditory techniques, and natural free-hand interaction methods [38]. More recently, Joan et al. reported Lands of Fog and Takahashi et al. reported FUTUREGYM, both of which encourage social interaction among children with ASD through whole-body interaction systems that provide a multi-user experience [39], [40]. Additionally, Garzotto and Mirko et al. reported the Magic Room, which supports multimodal experiential interaction by providing controllable stimulation to vestibular and proprioceptive senses for neurodevelopmental disorders [41].

In another study, it was found that the implementation of projection mapping in a sterile room where patients were treated resulted in a decrease in anxiety levels before and after the intervention [42]. This study highlighted the significance of projection mapping in terms of space, presence, and usability. Additionally, GestureTek Health's immersive gesture control technology was identified as a flexible hardware solution that allows for multi-touch interactivity on any surface, regardless of size [43]. This system can be installed in a variety of locations, including entrances, halls, common areas, patient rooms, waiting rooms, treatment rooms, and hospital wards.

III. PROPOSED METHOD

While various projection methods, such as CAVE, exist, the rationale behind our proposal for a two-screen projection method is to minimize preparation time and personnel requirements while allowing projection in versatile environments, including hospital rooms. Moreover, this portable solution offers an immersive visual experience without hindering communication among multiple occupants within a hospital setting, and eliminating the need for patients to wear additional equipment or devices. Thus, the two-screen projection system presented in this study stands out as a unique approach, distinguishing itself significantly from existing implementations in other settings. This paper provides a comprehensive overview of the two-screen projection system and highlights its distinctive features and benefits.

A. PROJECTION ARRANGEMENT

The Facility Guidelines Institute in the United States has defined that a hospital room must have an area of at least 11.5 square meters per patient [44]. In Japan, Article 16 of the Enforcement Regulations of the Medical Service Act requires that hospital rooms be at least 6.4 square meters with no more than four beds in a room [45]. In order to project immersive images in such hospital rooms, it is crucial to place the equipment appropriately and set the screen size quantitatively. Specifically, to selecting the optimal screen size, the size of the room must be taken into account, and the projector must be positioned correctly.

The Field of View (FOV), which is the area that can be seen by a human without moving their viewpoint, is around 180 degrees for both eyes, and an FOV of 60-90 degrees is necessary to enhance the immersive experience [46]. It is also important to consider the field of view that will provide an effective range of information acceptance, which is generally 45-70 degrees vertically and 60-90 degrees horizontally. Therefore, we selected a setting that would provide a high degree of immersion for a 6-year-old girl [47] with a median height of 1155 mm.

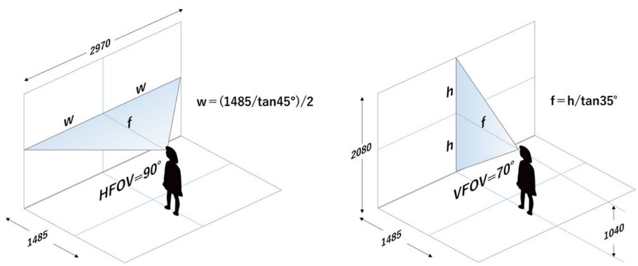


FIGURE 1. Wall and floor screen settings according to viewing angle.

As shown in Figure 1, a screen size of approximately 3000 mm × 2000 mm is required to achieve a horizontal field of view (HFOV) of 90 degrees and a vertical field of view (VFOV) of 70 degrees at a distance of approximately 1500 mm from the wall surface. It is essential to consider these factors to project immersive images in a hospital room effectively.

Assessing the level of immersion in VR experiences can be achieved through the measurement of center-of-gravity sway resulting from vection, which refers to the sensation of movement in a stationary individual caused by visual stimuli [48], [49]. Postural response is a useful method for measuring this self-motion illusion, and the magnitude of center-of-gravity sway can be used to predict the intensity of vection in individuals [50], [51], [52]. Previous research has demonstrated that the magnitude of center-of-gravity sway induced by visual stimuli increases as the viewing angle of the image presentation expands, with the lower region of the visual field being more influential than the upper region [53], [54]. Furthermore, given that the human binocular field of vision is wider downwards [55], visual information from below is crucial for maintaining an upright posture, and thus, it is necessary to include the feet in the image presentation area to enhance the immersive experience.

To enhance the sense of immersion in the VR experience, the proposed projection arrangement in this study necessitates a wall screen that considers HFOV and VFOV and a floor screen in the lower region that provides strong visual stimulation. This two-screen projection technique on both the wall and floor screens is crucial because it meets the requirements for an immersive experience in a restricted space.

Considering the constraints imposed by room size, it is crucial to allocate a designated space for projection within a hospital room. In order to tackle this issue, in the present study, we relocated two beds from a four-bed hospital room and investigated the feasibility of implementing a two-screen

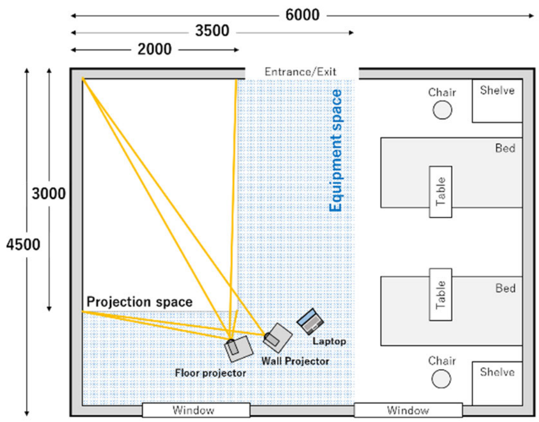


FIGURE 2. Two-screen projection arrangement in a hospital room.

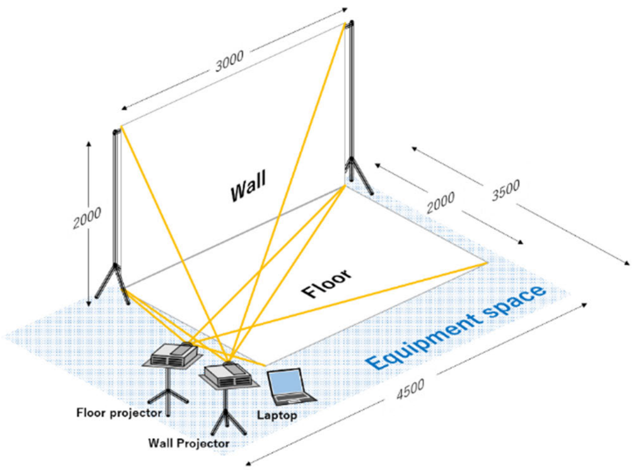


FIGURE 3. Two-screen projection limited by equipment installation space.

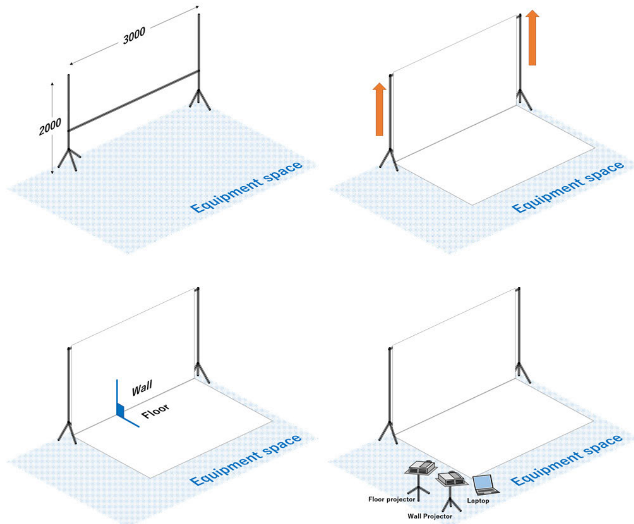


FIGURE 4. Schematic of the proposed two-screen projection process.

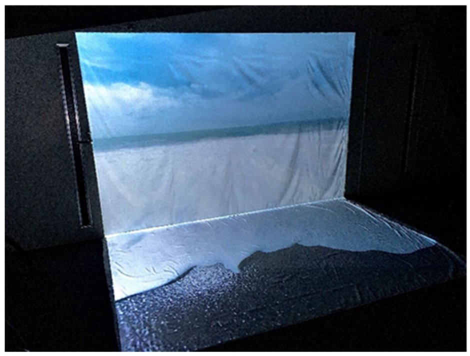


FIGURE 5. Photo of beach with two-screen projection.

projection setup within the room. Two-screen projection entails the utilization of two projectors, one projecting onto the wall and the other onto the floor, as depicted in Figure 2, thereby enabling an immersive experience within the hospital room.

We installed a laptop computer, a wall projector, and a floor projector in an equipment installation space of 4500 mm × 3500 mm, assuming a 4-person hospital room of 4500 mm × 6000 mm. The wall and floor projectors were placed within a projection space of 3000 mm × 2000 mm, positioned at an angle that minimized the reflection of the person's shadow being projected. The resulting two-screen projection system, shown in Figure 3, provided an immersive VR experience within the limited space available.

B. PROJECTION PROCEDURE

Figure 4 depicts the step-by-step process involved in performing a two-screen projection, while Figure 5 displays an actual photograph of a two-screen projection. The necessary equipment and materials required for executing a two-screen projection are commercially available, easily accessible, and appropriate for use in mobile settings. The process itself is uncomplicated, and it takes around 15 minutes from the preparation stage to the projection stage.

The first step involves installing the stand and background fabric. To accomplish this, a stand width of 3000 mm and height of 2000 mm were determined. After deciding on the stand dimensions, the background cloth was raised to a height of 2000 mm.

The next step involves adjusting the angle between the wall and floor screens and installing the necessary equipment in the specified location. It is necessary to ensure that the angle between the wall and floor screens is precisely 90 degrees to achieve the desired projection outcome.

C. PROJECTIVE TECHNIQUE

The projection method used in this study presents a challenge in that the shape of the projected image does not align with the surface of the object being projected, owing to the projector's placement at an angle to the projection surface. To address this issue, an image transformation technique known as homography transformation was applied to the projected image. Homography transformation corresponds to

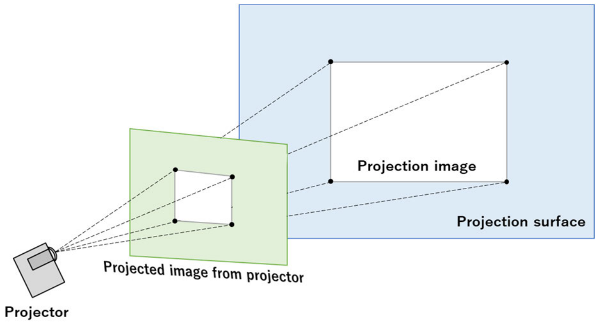


FIGURE 6. Homography transformation.

Subjective point of view

Objective perspective from the side

FIGURE 7. Image at the time of shooting.

the projection of one plane onto another plane by a projective transformation. In the context of this study, it pertains to the transformation between the projected image from the projector and the corresponding surface. Figure 6 demonstrates that the transformation matrix of the entire image can be derived from the correspondence of four points in the image through homography transformation. To achieve an image aligned with the projection plane for projection, the four corner points of the transformed image were aligned with the projection plane.

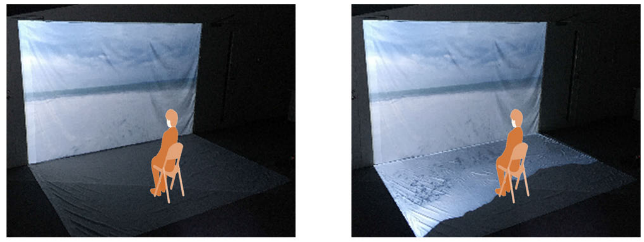
In this study, images were created using a 360-degree camera (RICOH THETA V) to capture 360-degree images, and images for the wall and floor surfaces were obtained by cropping the 360-degree images to a 90-degree angle of view. This method ensured that the boundary surfaces of the images projected on the wall and the floor were matched. To capture the images, the 360-degree camera was mounted on the end of a rod and tilted as illustrated in Figure 7. This filming method was implemented to prevent the boundary of the 360-degree camera from appearing on the wall surface and to prevent the photographer's image from appearing on the floor surface.

IV. EXPERIMENTS

The purpose of this study was to investigate the effectiveness of a simple and low-cost two-screen projection system that does not interfere with group communication, is suitable for stress reduction, and does not require the use of equipment to maintain a sense of immersion. In Experiment 1, we aimed to obtain objective evidence on whether the immersiveness of two-screen projection can reduce stress in healthy adults compared to one-screen projection. This experiment was designed to understand the effects of two-screen projection by

TABLE 1. Experimental procedure for pattern A and pattern B.

Pattern	0-3min	3-4.5min	4.5-6min	6-7.5min	7.5-10.5min	10.5-12min	12-13.5min	13.5-15min
A	Mental arithmetic	1st sAA measurement	One-screen projection	2nd sAA measurement	Mental arithmetic	3rd sAA measurement	Two-screen projection	4th sAA measurement
B			Two-screen projection				One-screen projection	



One-screen projection

Two-screen projection

FIGURE 8. Experiments underway for one-screen and two-screen projection.

restricting visual information and extracting the psychosocial stress component.

Based on the results of Experiment 1, Experiment 2 was conducted with CMC, parents, and staff as subjects. The aim was to evaluate the emotional impact of the two-screen projection and to determine whether it is effective in reducing stress based on subjective feedback. Additionally, we sought to gain insight into the suitability of two-screen projection as a platform for interactive communication.

A. *EXPERIMENT 1*

1) PARTICIPANTS

The test subjects consisted of 30 adult-aged students and faculty members who were enrolled at University A and agreed to participate in the experiment between November 2021 and April 2022.

2) MEASUREMENT METHOD

The stress reduction effect of the distraction technique using two-screen projection was evaluated through the measurement of salivary α-amylase activity (sAA). sAA is an enzyme that can predict plasma catecholamine concentrations, particularly norepinephrine, under various stress conditions, making it a more direct and simpler marker of catecholamine activity than changes in heart rate [56]. Additionally, sAA is a reliable noninvasive biomarker, as it is increased by acute psychosocial stress [57], [58]. To measure sAA, we used a salivary amylase monitor manufactured by Nipro [59]. The salivary amylase monitor detects the activity of sAA in saliva, with higher levels indicating higher levels of stress. Conversely, lower levels of sAA are indicative of lower levels of stress. Therefore, in this study, the sAA levels were used to determine the stress reduction effect of the two-screen projection technique.

3) EXPERIMENTAL PROCEDURE

The experimental procedure was composed of multiple steps, and the detailed information is provided in Table 1. Initially, the subjects performed a mental arithmetic task for 3 minutes that required them to add and subtract two to three digits. The first sAA measurement was recorded at this point. Then, the participants watched a beach video for 1 minute and 30 seconds, either in Pattern A or Pattern B. After this, the second sAA measurement was recorded. Next, the subjects were asked to perform another 3-minute mental arithmetic task that involved adding and subtracting two to three digits, and the third sAA measurement was taken. Finally, one or two screens were projected, and the fourth sAA measurement was recorded. Throughout this process, participants were seated in the position illustrated in Figure 8 and allowed to move around freely during the projection. To avoid distractions from ambient noise, they wore headphones that played white noise, and they were only provided with visual information. The participants were divided into two groups based on whether their assigned number was even or odd, and the experiment was conducted alternatively using Pattern A and Pattern B.

4) ANALYSIS METHOD

The sAA was measured four times in total: a before one-screen projection, a' after one-screen projection, b before two-screen projection, and b' after two-screen projection. The difference in sAA between after one-screen projection and before one-screen projection is denoted as $a' - a = c_1$, while the difference in sAA between after two-screen projection and before two-screen projection is denoted as $b' - b = c_2$. The difference in sAA between two-screen projection and one-screen projection is given by $c_2 - c_1 = c_3$, and the mean value of c_3 is represented as $\bar{c_3}$. The normality of the data was assessed using the Kolmogorov-Smirnov's and Shapiro-Wilk's tests, and was analyzed using the corresponding t-test and Wilcoxon's signed rank test.

5) ETHICAL CONSIDERATIONS

Experiment 1 was conducted with the approval of the Ethical Review Board for Medical Research Involving Human Subjects of Gunma University (HS2021-112).

B. EXPERIMENT 2

1) PARTICIPANTS

The study recruited a total of 24 participants, including 9 CMC, 3 parents, and 12 staff members, who were using a multifunctional day care facility from December 2022 to April 2023.

2) MEASUREMENT METHOD

The study measured the stress reduction effect of the two-screen projection distraction technique using the KOKORO scale. The KOKORO scale is a mood measurement system developed by the Institute of Physical and Chemical Research to quantify and monitor changes in human emotions and feelings. The scale consists of a four-quadrant matrix, quantified as a two-axis mood scale with Anxiety-Relief on

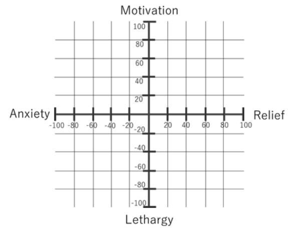


FIGURE 9. KOKORO scale for assessing subjective human emotions.

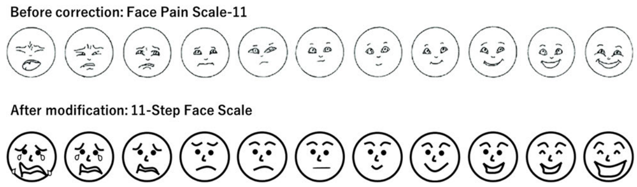


FIGURE 10. 11-step face scale modified for CMC.

the horizontal axis and Lethargy-Motivation on the vertical axis in a four-way two-dimensional space [60], [61]. Figure 9 illustrates that the center point is 0, the horizontal axis ranges from −100 (anxiety) to 100 (relief), and the vertical axis ranges from −100 (lethargy) to 100 (motivation).

This study aimed to enhance the comprehension of CMC by creating an 11-step face scale, as depicted in Figure 10, which was derived from the Faces Pain Scale-11 [62]. We then integrated this information into the KOKORO scale. Because it is challenging to quantify the emotions of CMC through this process, we needed to convert their emotions into facial expressions. Furthermore, it was crucial to allow the CMC to choose from familiar facial expressions, considering the difficulty of translating emotions into facial expressions in the existing Faces Pain Scale-11 [62].

Each participant was requested to provide answers to a set of three queries, which included: whether they experienced the feeling of having visited a particular place, whether they sensed that they had visited a place in the company of someone else, and whether they would be interested in undergoing the two-screen projection experience again. Additionally, the participants were given the opportunity to freely express their thoughts and opinions on the matter at hand.

3) EXPERIMENTAL PROCEDURE

Table 2 displays a comprehensive overview of the experimental process. Prior to the experiment, each participant was provided with an explanation of the procedure in layman's terms. Additionally, particular attention was given to ensuring that CMC had a familiar parent or staff member present to offer an explanation, if necessary. The initial KOKORO scale measurement was taken within 60 seconds before the start of the two-screen projection. Subsequently, the participants viewed the two-screen projection for a duration of 10 minutes. Lastly, the final KOKORO scale measurement was taken within a minute to conclude the experiment. The experimental setting is illustrated in Figure 11.

TABLE 2. Time schedule of KOKORO scale measurement before and after two-screen projection.

0-1min	1-11min	11-12min
1st KOKORO scale measurement	2-screen projection	2nd KOKORO scale measurement

FIGURE 11. Actual view of a subject viewing a two-screen projection.

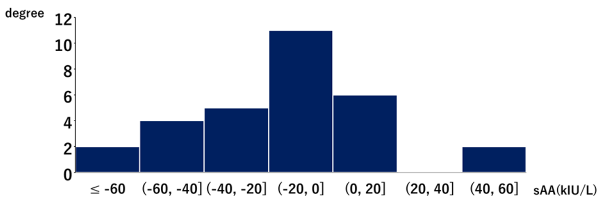


FIGURE 12. Difference in sAA between two-screen and one-screen projection.

4) ANALYSIS METHOD

In the KOKORO scale measurement, Anxiety-Relief was denoted as d before and d' after the two-screen projection, while Lethargy-Motivation was denoted as e before and e' after the two-screen projection. The differences between the after and before measurements of the two-screen projection were defined as $d' - d = f_1$ and $e' - e = f_2$, respectively. The mean values of these differences were represented as $\bar{f_1}$ and $\bar{f_2}$, and each subject was analyzed using the Wilcoxon signed-rank test.

5) ETHICAL CONSIDERATIONS

Experiment 2 was conducted with the approval of the Ethical Review Board for Medical Research Involving Human Subjects of Gunma University (HS2022-095).

V. RESULTS

A. EXPERIMENT 1

1) PARTICIPANT CHARACTERISTICS

The mean age of the 30 subjects was 27.8 ± 12.9 years, and the mean sleep duration was 6.7 ± 1.1 hours. All subjects were in good physical condition, and 90.0% of them experienced two-screen projection for the first time.

2) ANALYZE SAA BY CORRESPONDING t -TEST

The histogram of c_3 is shown in Figure 12, with $\bar{c_3}$ being -16.83 and variance 1346.28.

The Kolmogorov-Smirnov test resulted in a p-value of 0.191, and the Shapiro-Wilk test yielded a p-value of 0.053. These results indicate that the distribution of c_3 values can be considered normal, as the p-values are greater than 0.05. Therefore, assuming the normality of $\bar{c_3}$, a t-test was conducted to determine if the mean value $\bar{c_3}$ is significantly less than 0, which would imply that two-screen projection is more effective in reducing stress compared to one-screen projection. The null hypothesis (H0) states that there is no difference in sAA between one-screen and two-screen projection, suggesting that sAA was not decreased by two-screen projection. The alternative hypothesis (H1) states that two-screen projection causes a difference in sAA, indicating that sAA was decreased by two-screen projection.

Using the unbiased variance s^2, a t-statistic was calculated with μ representing the population mean of the difference between two-screen projection and one-screen projection sAA, and n representing the sample size. The significance level (α) was set at 0.05. The critical value was determined from the t-distribution with n-1 degrees of freedom, resulting in 1.699 for a one-tailed test at $\alpha = 0.05$. Calculating the t-value as -2.513, we rejected the null hypothesis (H0) as it falls outside the rejection range of -1.699. Therefore, it can be concluded that sAA was significantly reduced by two-screen projection ($p < 0.05$).

3) ANALYSIS OF sAA BY WILCOXON'S SIGNED RANK TEST

Regarding the normality of the difference in sAA between the two-screen and one-screen projections, Shapiro-Wilk's test yielded a p-value of 0.053, which was close to 0.05. To ensure the validity of the analysis, a nonparametric test was also conducted. The null hypothesis (H0) and the alternative hypothesis (H1) were set up as in the corresponding t-test. The test statistic for c_3 was 108.5, and based on the standardized test statistic of -2.551, a two-tailed test confirmed a p-value of 0.011. Consequently, the null hypothesis H0 was rejected, indicating that sAA was significantly reduced by two-screen projection ($p < 0.05$).

4) FREE TEXT RESPONSES

The responses for Pattern A, in which the one-screen projection is viewed followed by the two-screen projection, are as follows:

-The images on the lower part of the screen were more realistic and gave me a genuine feeling of being in the ocean.

-The two-screen projection induced a greater sense of relaxation.

-I felt drowsy while watching the one-screen projection, but

I became more alert when the two-screen projection began.

The responses for Pattern B, in which the two-screen projection is viewed followed by the one-screen projection, are as follows:

-After watching the video with the interlocked lower area, viewing the wall surface only felt slightly uncomfortable and left me with a sense of unease.

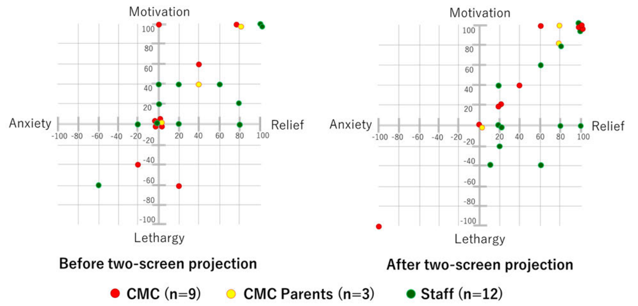


FIGURE 13. Scatter plots of the KOKORO scale measured before and after two-screen projection for each subject.

-The two-screen projection filled my entire field of view with the sea, creating a more immersive and dynamic experience compared to the one-screen projection.
-During the two-screen projection, I distinctly felt the sensation of waves on my legs.
-The one-screen projection evoked a strong feeling that I was being presented with something.

B. EXPERIMENT 2

1) PARTICIPANT CHARACTERISTICS

The mean age of the 9 CMC was 5.22 ± 2.64 years, and the mean sleep duration was 8.36 ± 1.03 hours, with 2 cases where sleep duration was unknown. The types of care provided for CMC included ventilator support, tracheostomy care, oxygen therapy, suctioning, inhalation, tube feeding, defecation management, and seizure management. All CMC reported feeling well and not tired; 77.8% of them experienced two-screen projection for the first time.

The mean age of the three parents was 37.67 ± 1.53 years, and the mean sleep duration was 7.67 ± 0.58 hours. All parents reported feeling well and not tired; 66.7% of them experienced two-screen projection for the first time.

The 12 staff members had an average age of 38.33 ± 7.44 years and slept an average of 6.79 ± 1.16 hours. All staff members reported feeling well, but 58.3% of them reported feeling tired. The staff included nurses, midwives, physical therapists, occupational therapists, caregivers, child care workers, child guidance workers, and managers, with an average length of service of 8.40 ± 5.73 years. Among the staff, 58.3% experienced two-screen projection for the first time.

2) KOKORO SCALE MEASUREMENT BEFORE AND AFTER TWO-SCREEN PROJECTION

The measurements of Anxiety-Relief and Lethargy-Motivation on the KOKORO scale before and after two-screen projection are depicted in Figure 13.

3) ANALYSIS OF THE KOKORO SCALE BY WILCOXON'S SIGNED RANK TEST

Due to the limited sample size, nonparametric tests were employed to examine the differences before and after the two-screen projection. One CMC outlier, who reported -100 for both Anxiety-Relief and Lethargy-Motivation after the two-screen projection, was excluded from the analysis.

TABLE 3. KOKORO scale measurement results before and after two-screen projection.

Participant	f_1 (Anxiety–Relief)			f_2 (Lethargy–Motivation)		
	test statistic	standardized test statistic	p	test statistic	standardized test statistic	p
CMC (n=8)	21.0	2.207	0.027	15.0	2.032	0.042
CMC Parents (n=3)	3.00	1.342	0.180	1.00	1.000	0.317
Staff (n=12)	28.0	2.388	0.017	21.5	0.503	0.615

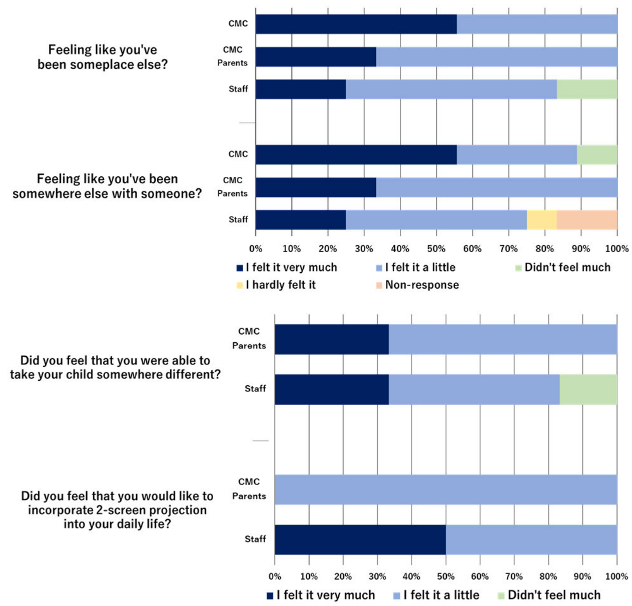


FIGURE 14. Reactions to the two-screen projection as experienced by participants, including CMC (n=9), CMC Parents (n=3), and Staff (n=12).

The null hypothesis H2 states that "Anxiety-Relief scores before and after the two-screen projection are equal = the two-screen projection did not induce feelings of relief," while the alternative hypothesis H3 suggests that "the two-screen projection caused a difference in Anxiety-Relief = the two-screen projection made me feel relieved." Similarly, the null hypothesis H4 assumes that "Lethargy-Motivation scores before and after the two-screen projection are equal = motivation was not increased by the two-screen projection," while the alternative hypothesis H5 states that "Lethargy-Motivation differed due to the two-screen projection = motivation increased due to the two-screen projection." Furthermore, if both null hypotheses H2 and H4 were rejected, it was assumed that "the two-screen projection produced stress reduction effects." The f_1 and f_2 test statistics for each subject, the standardized test statistics, and the P-values from the two-tailed test are presented in Table 3.

CMC exhibited a significant stress reduction effect with two-screen projection ($p < 0.05$), as evidenced by the rejection of null hypotheses H2 and H4. On the other hand, parents of CMC did not reject the null hypotheses H2 and

H4, indicating that they did not experience a stress reduction effect from the two-screen projection. Among the staff members, the rejection of null hypothesis H2 ($p < 0.05$) indicated that they felt reassured by the two-screen projection. However, there was no rejection of null hypothesis H2, suggesting that the two-screen projection did not significantly increase their motivation. These findings remained consistent when considering staff fatigue and whether it was their first experience or not.

4) INDIVIDUAL EXPERIENCES OF TWO-SCREEN PROJECTION

The responses to the two-screen projection experienced by each participant are depicted in Figure 14.

Approximately 90% of the CMC respondents expressed their desire to experience the two-screen projection again. Some of them mentioned, "I thoroughly enjoyed the sense of wonder when I first saw it," and "I wished I could have watched it for a longer duration." The respondents also reported a temporary increase in their pulse rate upon starting the projection, followed by a decrease, and noticed a calming effect on their voices and facial expressions while immersed in the projection. Popular destinations that CMC and their parents expressed interest in visiting included zoos, aquariums, amusement parks, and parks. CMC parents suggested that incorporating sensory elements such as wind could enhance the overall experience.

Staff members shared that witnessing the children's enjoyment helped them relax, fostering a sense of everyone playing together in the ocean. Some respondents suggested that the two-screen projection could be beneficial for children who are unable to go out, have difficulty sleeping, or experience agitation. They also highlighted its potential application in palliative care settings, creating a soothing environment for children. Additionally, some respondents requested "more vivid images," "the inclusion of theme parks for children who cannot go out," and "enhanced sensory stimulation with each projected content."

VI. DISCUSSION

Our low-cost and simple two-screen projection method was found to be more effective than one-screen projection in reducing stress levels among healthy adults. Furthermore, the two-screen projection, which does not require additional equipment and does not compromise immersion or hinder communication among multiple individuals, demonstrated its effectiveness in reducing stress among CMC after the projection compared to before. These study results highlight the innovative use of distraction techniques in pediatric nursing and suggest that the two-screen projection could serve as an ideal new tool for CMC and their families who experience long-term hospitalization and behavioral limitations. In this section, we will provide a detailed overview of the findings from Experiments 1 and 2 and discuss the significance of the two-screen projection method.

In Experiment 1, involving healthy adults, the two-screen projection demonstrated a lower likelihood of increasing sAA levels and a higher likelihood of decreasing sAA compared to the one-screen projection. These findings suggest that the two-screen projection has a more positive impact on reducing stress. This conclusion is further supported by previous studies [57], [58] that consistently reported the stress-reducing effects of two-screen projection, as evidenced by the reduction in sAA levels during psychosocial stress. Participants' subjective impressions indicated that the two-screen projection was perceived as more realistic, dynamic, and relaxing. Conversely, individuals who viewed the one-screen projection following the two-screen projection with the lower part linked reported feeling somewhat uncomfortable and uneasy.

These findings serve as evidence supporting the suitability of the projection arrangement, projection range, and projection method proposed in this study for enhancing the immersive experience in humans. Specifically, a HFOV of 70 degrees and VFOV of 90 degrees [44], which are known to contribute to high immersion, were achieved, confirming the effective utilization of the floor screen in the lower area. This lower area provides intense visual stimulation [53], [54], [55]. In other words, the two-screen projection configuration exerted a significant impact on visual stimulation, inducing vection-related center-of-gravity sway and fostering a sense of immersion [48], [49], [50], [51], [52]. These outcomes further support the results obtained in this study.

In Experiment 2, the subjective evaluation of CMC, parents, and staff was conducted using the KOKORO scale before and after the two-screen projection, which was previously found to be effective in reducing stress in Experiment 1. Following the two-screen projection, it was observed that CMC leaned more towards Relief than Anxiety and Motivation than Lethargy. This suggests that the two-screen projection was more effective in reducing stress in CMC after the projection compared to before. The findings from Experiment 2, including the free responses from CMC, indicate that the parasympathomimetic stimulating effects of the two-screen projection promoted a sense of pleasantness and heightened exhilaration. This is consistent with previous studies that have demonstrated a clear correlation between subjective effect and cardiac autonomic regulation [63], [64].

However, it is important to note that some CMC may experience surprise or discomfort due to the realism of the two-screen projection. Therefore, in addition to careful explanations, it is crucial to familiarize them with the projected images to help alleviate any discomfort.

After the two-screen projection, the staff exhibited a shift towards Relief rather than Anxiety, while Lethargy-Motivation remained unchanged before and after the projection. Parents showed no changes in Anxiety-Relief and Lethargy-Motivation before and after the two-screen projection. Given that parents and staff have more life experience than CMC, they tend to approach the projection more objectively and may find it less engaging. While this experiment had a small sample size and individual differences are expected, it is important to consider providing real-time images that can maintain interest without becoming boring.

This study proposed a two-screen projection as a solution to the challenge of achieving interactive communication, which has been problematic for HMDs used for visually reproducing immersive digital environments [14], [15], [16]. This proposal facilitates a level of interactivity that was challenging to achieve, even with the recently announced Apple Vision Pro at the Apple Worldwide Developers Conference 2023 [65]. Through the experiences of CMC, parents, and staff, many positive impressions of the two-screen projection were confirmed. In particular, CMC expressed their enjoyment while interacting with parents and staff through the two-screen projection, and the staff themselves appeared to relax when they witnessed the CMC's enjoyment. Additionally, the staff mentioned that the two-screen projection holds potential for children with chronic insomnia or agitation, as well as for palliative care, indicating its practical use as a nursing tool. Furthermore, the use of sea images in Experiments 1 and 2 may have provided a simulated experience of being in contact with the natural environment, resulting in reduced negative emotions such as stress and fear [66], [67], [68] and potentially having a healing effect.

These results are in line with a previous study that discussed a decrease in anxiety following projection mapping in a sterile room [42], and we believe that this study contributes a low-cost and straightforward two-screen projection method that is expected to effectively reduce stress. Moreover, this two-screen projection technique has the potential to offer numerous advantages in medical facilities, including enhanced mobility and reduced setup time.

VII. SUMMARY

In this study, we proposed a two-screen projection method using projectors on both a wall and the floor and demonstrated the feasibility of projecting images in a typical hospital ward through quantitative settings. The two-screen projection technique serves as an ideal tool for mitigating stress in children undergoing medical treatment, offering a highly immersive experience tailored to their specific treatment situation and hospital stay. The setup for projecting images on two surfaces is simple and cost-effective, enabling accessibility for individuals with basic knowledge of operation and layout.

Moreover, we presented how the two-screen projection can facilitate interactive communication. Children who face environments that hinder their social development can greatly benefit from the opportunity provided by the two-screen projection to experience diverse environments. This represents a crucial form of nursing support sought after by children receiving medical care and their families, and it holds significant potential for implementation as a creative approach to distraction in pediatric nursing.

Looking to the future, our goals include reducing stress even further by expanding and improving the capabilities of the two-screen projection device. Additionally, we aim to offer real-time content instead of pre-recorded material.

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REFERENCES

[1] E. Cohen, D. Z. Kuo, R. Agrawal, J. G. Berry, S. K. M. Bhagat, T. D. Simon, and R. Srivastava, "Children with medical complexity: An emerging population for clinical and research initiatives," *Pediatrics*, vol. 127, no. 3, pp. 529–538, Mar. 2011, doi: 10.1542/peds.2010-0910.

[2] C. Allshouse, M. Comeau, R. Rodgers, and N. Wells, "Families of children with medical complexity: A view from the front lines," *Pediatrics*, vol. 141, no. 3, pp. S195–S201, Mar. 2018, doi: 10.1542/peds.2017-1284D.

[3] Ministry of Health, Labour and Welfare, "For children with medical care needs and their families to live comfortably and safely," (in Japanese), *Ministry Health, Labour Welfare*, pp. 4–16, Dec. 2018. Accessed: Feb. 12, 2022. [Online]. Available: https://www.mhlw.go.jp/iken/after-service-20181219/dl/after-service-20181219_houkoku.pdf

[4] Ministry of Health, Labour and Welfare, "Report on the survey of the living conditions of children with medical care and their families," (in Japanese), *Ministry Health, Labour Welfare*, pp. 69–85, Mar. 2020. Accessed: Feb. 12, 2022. [Online]. Available: https://www.mhlw.go.jp/content/12200000/000653544.pdf

[5] J. T. Tiedge, "Clarifying the concept of distraction," *Public Opinion Quart.*, vol. 39, no. 2, pp. 178–188, 1975.

[6] H. Ogihara, "Development and validation of the distracting ingenuity promotion scale for paediatric nurses to support the psychological outcomes of paediatric patients and their families: A survey-based cross-sectional cohort study," *Nursing Open*, vol. 9, no. 3, pp. 1653–1666, May 2022, doi: 10.1002/nop2.1190.

[7] K. A. Birnie, Y. Kulandaivelu, L. Jibb, P. Hroch, K. Positano, S. Robertson, F. Campbell, O. Abla, and J. Stinson, "Usability testing of an interactive virtual reality distraction intervention to reduce procedural pain in children and adolescents with cancer," *J. Pediatric Oncol. Nursing*, vol. 35, no. 6, pp. 406–416, Nov. 2018, doi: 10.1177/1043454218782138.

[8] G. Ö. Gerçeker, M. Bektaş, Y. Aydınok, H. Ören, H. Ellidokuz, and N. Olgun, "The effect of virtual reality on pain, fear, and anxiety during access of a port with Huber needle in pediatric hematology-oncology patients: Randomized controlled trial," *Eur. J. Oncol. Nursing*, vol. 50, Feb. 2021, Art. no. 101886, doi: 10.1016/j.ejon.2020.101886.

[9] R. Eijlers, E. M. W. J. Utens, L. M. Staals, P. F. A. de Nijs, J. M. Berghmans, R. M. H. Wijnen, M. H. J. Hillegers, B. Dierckx, and J. S. Legerstee, "Systematic review and meta-analysis of virtual reality in pediatrics: Effects on pain and anxiety," *Anesthesia Analgesia*, vol. 129, no. 5, pp. 1344–1353, 2019, doi: 10.1213/ANE.0000000000004165.

[10] A. Dunn, J. Patterson, C. F. Biega, A. Grishchenko, J. Luna, J. R. Stanek, and R. Strouse, "A novel clinician-orchestrated virtual reality platform for distraction during pediatric intravenous procedures in children with hemophilia: Randomized controlled trial," *JMIR Serious Games*, vol. 7, no. 1, Jan. 2019, Art. no. e10902, doi: 10.2196/10902.

[11] B. Hemsley, J. Sigafoos, S. Balandin, R. Forbes, C. Taylor, V. A. Green, and T. Parmenter, "Nursing the patient with severe communication impairment," *J. Adv. Nursing*, vol. 35, no. 6, pp. 827–835, Sep. 2001, doi: 10.1046/j.1365-2648.2001.01920.x.

[12] M. C. Souders, D. DePaul, K. G. Freeman, and S. E. Levy, "Caring for children and adolescents with autism who require challenging procedures," *Pediatric Nursing*, vol. 28, no. 6, pp. 555–562, 2002.

[13] D. Debbaudt, "Patients with autism and other high risks: A growing challenge for healthcare security," *J. Healthcare Protection Manag., Publication Int. Assoc. Hospital Secur.*, vol. 25, no. 1, pp. 14–26, 2009.

[14] C. D. Murray, J. Fox, and S. Pettifer, "Absorption, dissociation, locus of control and presence in virtual reality," *Comput. Hum. Behav.*, vol. 23, no. 3, pp. 1347–1354, May 2007, doi: 10.1016/j.chb.2004.12.010.

[15] C. Sas and G. M. P. O'Hare, "Presence equation: An investigation into cognitive factors underlying presence," *Presence Teleoperators Virtual Environ.*, vol. 12, no. 5, pp. 523–537, Oct. 2003, doi: 10.1162/105474603322761315.

[16] D. Weibel, B. Wissmath, and F. W. Mast, "Immersion in mediated environments: The role of personality traits," *Cyberpsychol., Behav., Social Netw.*, vol. 13, no. 3, pp. 251–256, Jun. 2010, doi: 10.1089/cyber.2009.0171.

[17] H. Rheingold, "Virtual reality," in *Summit Books*. New York, NY, USA, 1991.

[18] H. Bullinger, O. Riedel, and R. Breining, "Immersive projection technology-benefits for the industry," in *Proc. Int. Immersive Projection Technol. Workshop*, 1997, pp. 13–25.

[19] M. Meehan, B. Insko, M. Whitton, and F. P. Brooks, "Physiological measures of presence in stressful virtual environments," *ACM Trans. Graph.*, vol. 21, no. 3, pp. 645–652, Jul. 2002, doi: 10.1145/566654.566630.

[20] I. E. Sutherland, "A head-mounted three dimensional display," in *Proc. Fall Joint Comput. Conf., I*, Dec. 1968, pp. 757–764, doi: 10.1145/1476589.1476686.

[21] S. C. Gupta, C. A. Wantland, and S. A. Klein, "Cyberpathology: Medical concerns of VR applications," *J. Med. Virtual Reality*, vol. 1, no. 2, pp. 8–11, 1996.

[22] E. Viirre, "A survey of medical issues and virtual reality technology," *Virtual Reality World*, vol. 2, no. 4, pp. 16–24, Aug. 1994.

[23] M. Mon-Williams, J. P. Warm, and S. Rushton, "Binocular vision in a virtual world: Visual deficits following the wearing of a head-mounted display," *Ophthalmic Physiol. Opt.*, vol. 13, no. 4, pp. 387–391, Oct. 1993, doi: 10.1111/j.1475-1313.1993.tb00496.x.

[24] M. Mon-Williams and E. Pascal, "Virtual reality displays, implications for optometrists," *Optometry Today*, vol. 2, pp. 30–33, Jan. 1995.

[25] J. F. Golding and M. A. Gresty, "Pathophysiology and treatment of motion sickness," *Current Opinion Neurol.*, vol. 28, no. 1, pp. 83–88, 2015, doi: 10.1097/WCO.0000000000000163.

[26] A. Koch, I. Cascorbi, M. Westhofen, M. Dafotakis, S. Klapa, and J. P. Kuhtz-Buschbeck, "The neurophysiology and treatment of motion sickness," *Deutsches Ärzteblatt Int.*, vol. 115, no. 41, pp. 687-696, 2018, doi: 10.3238/arztebl.2018.0687.

[27] C. Cruz-Neira, D. J. Sandin, T. A. DeFanti, "Surround-screen projection-based virtual reality: The design and implementation of the CAVE," in *Proc. 20th Annu. Conf. Comput. Graph. Interact. Techn.*, 1993, pp. 135–142, doi: 10.1145/166117.166134.

[28] T. T. de Back, A. M. Tinga, P. Nguyen, and M. M. Louwerse, "Benefits of immersive collaborative learning in CAVE-based virtual reality," *Int. J. Educ. Technol. Higher Edu.*, vol. 17, no. 1, pp. 1–18, Dec. 2020, doi: 10.1186/s41239-020-00228-9.

[29] A. Al-Khalifah, R. McCrindle, P. Sharkey, and V. Alexandrov, "Using virtual reality for medical diagnosis, training and education," *Int. J. Disability Hum. Develop.*, vol. 5, no. 2, pp. 187–194, Jan. 2006, doi: 10.1515/IJDHD.2006.5.2.187.

[30] M. Fabrika, P. Valent, and L. Scheer, "Thinning trainer based on forest-growth model, virtual reality and computer-aided virtual environment," *Environ. Model. Softw.*, vol. 100, pp. 11–23, Feb. 2018, doi: 10.1016/j.envsoft.2017.11.015.

[31] N. I. A. Rifdi, M. S. Sunar, and M. N. I. Sa'Adon, "Gamifying shooting training in cave automatic virtual environment (CAVE)," in *Proc. 2nd Int. Conf. Intell. Cybern. Technol. Appl. (ICICyTA)*, 2022, pp. 198–203, doi: 10.1109/ICICyTA57421.2022.10037856.

[32] K. K. Yuen, S. H. Choi, and X. B. Yang, "A full-immersive CAVE-based VR simulation system of forklift truck operations for safety training," *Comput.-Aided Des. Appl.*, vol. 7, no. 2, pp. 235–245, Jan. 2010, doi: 10.3722/CADAPS.2010.235-245.

[33] Education and Research Center on Computational Science and Engineering, Graduate School of System Informatics, Kobe University. (2023). *π-CAVE*. [Online]. Available: http://www.eccse.kobe-u.ac.jp/pi-cave/

[34] A. Kageyama and A. Tomiyama, "Visualization framework for CAVE virtual reality systems," *Int. J. Model., Simul., Sci. Comput.*, vol. 7, no. 4, Dec. 2016, Art. no. 1643001, doi: 10.1142/S1793962316430017.

[35] B. Jones, R. Sodhi, M. Murdock, R. Mehra, H. Benko, A. Wilson, E. Ofek, B. MacIntyre, N. Raghuvanshi, L. Shapira, "Roomalive: Magical experiences enabled by scalable, adaptive projector-camera units," in *Proc. 27th Annu. ACM Symp. User Interface Softw. Technol.*, 2014, pp. 637–644, doi: 10.1145/2642918.2647383.

[36] Razer Inc. (2023). *Project Ariana*. [Online]. Available: https://www.razer.com/concepts/project-ariana

[37] M. Lotan and M. Shapiro, "Management of young children with Rett disorder in the controlled multi-sensory (Snoezelen) environment," *Brain Develop.*, vol. 27, pp. S88–S94, Nov. 2005, doi: 10.1016/j.braindev.2005.03.021.

[38] G. Perhakaran, A. M. Yusof, M. E. Rusli, M. Z. M. Yusoff, E. M. M. Mahidin, I. Mahalil, and A. R. R. Zainuddin, "SnoezelenCAVE: Virtual reality CAVE Snoezelen framework for Autism spectrum disorders," in *Proc. 4th Int. Vis. Inform. Conf. Adv. Vis. Inform. (IVIC)*, Bangi, Malaysia, Nov. 2015, pp. 443–453, doi: 10.1007/978-3-319-25939-0_39.

[39] J. Mora-Guiard, C. Crowell, N. Pares, and P. Heaton, "Sparking social initiation behaviors in children with autism through full-body interaction," *Int. J. Child-Computer Interact.*, vol. 11, pp. 62–71, Jan. 2017, doi: 10.1016/j.ijcci.2016.10.006.

[40] I. Takahashi, M. Oki, B. Bourreau, I. Kitahara, and K. Suzuki, "FUTUREGYM: A gymnasium with interactive floor projection for children with special needs," *Int. J. Child-Comput. Interact.*, vol. 15, pp. 37–47, Mar. 2018, doi: 10.1016/j.ijcci.2017.12.002.

[41] F. Garzotto and M. Gelsomini, "Magic room: A smart space for children with neurodevelopmental disorder," *IEEE Pervasive Comput.*, vol. 17, no. 1, pp. 38–48, Jan. 2018, doi: 10.1109/MPRV.2018.011591060.

[42] S. Joko, M. Ohsuga, Y. Tada, and J. Ishikawa, "Evaluation of a mental care system for patients recuperating in a sterile room after hematopoietic cell transplantation," in *Proc. 41st Annu. Int. Conf. IEEE Eng. Med. Biol. Soc. (EMBC)*, Jul. 2019, pp. 23–27, doi: 10.1109/EMBC.2019.8857157.

[43] Gesturetek Health. (2016). *Interactive Environments and Entertainment Systems for Medical Facilities*. [Online]. Available: https://gesturetekhealth.com/solutions/interactive-environments-medical-displays

[44] *Guidelines for Design and Construction of Health Care Facilities*, Health Forum Publishing Company, USA, 2018.

[45] Ministry of Health, Labour and Welfare. (2023). *Medical Law Enforcement Regulations*. [Online]. Available: https://elaws.e-gov.go.jp/document?lawid=323M40000100050_20221209_504M60000100165

[46] C. Manetta and R. A. Blade, "Glossary of virtual reality terminology," *Int. J. Virtual Reality*, vol. 1, no. 2, pp. 35–39, Jan. 1995, doi: 10.20870/IJVR.1995.1.2.2604.

[47] Ministry of Education. (2014). *Annual Report of School Health Statistics Research*. [Online]. Available: https://www.e-stat.go.jp/stat-search/files?page=1&layout=datalist&toukei=00400002&tstat=000001011648&cycle=0&tclass1=000001064085&tclass2=000001064089&tclass3val=0

[48] M. H. Fischer and A. E. Kornmüller, "Optokinetic ausgeloste Bewegungswahrnehmungen und optokinetinetisher Nystagmus," *J. Psychol. Neurol.*, vol. 41, pp. 273–308, 1930.

[49] S. Palmisano, R. S. Allison, M. M. Schira, and R. J. Barry, "Future challenges for vection research: Definitions, functional significance, measures, and neural bases," *Frontiers Psychol.*, vol. 6, pp. 1–315, Feb. 2015, doi: 10.3389/fpsyg.2015.00193.

[50] D. Apthorp, F. Nagle, and S. Palmisano, "Chaos in balance: non-linear measures of postural control predict individual variations in visual illusions of motion," *PLoS ONE*, vol. 9, no. 12, Dec. 2014, Art. no. e113897, doi: 10.1371/journal.pone.0113897.

[51] S. Palmisano, D. Apthorp, T. Seno, and P. J. Stapley, "Spontaneous postural sway predicts the strength of smooth vection," *Exp. Brain Res.*, vol. 232, no. 4, pp. 1185–1191, Apr. 2014, doi: 10.1007/s00221-014-3835-y.

[52] S. Palmisano, B. Arcioni, and P. J. Stapley, "Predicting vection and visually induced motion sickness based on spontaneous postural activity," *Exp. Brain Res.*, vol. 236, no. 1, pp. 315–329, Jan. 2018, doi: 10.1007/s00221-017-5130-1.

[53] J. Ryu, N. Hashimoto, and M. Sato, "Evaluation of immersive virtual environments displaying various areas," *J. Inst. Image Inf. Telev. Eng.*, vol. 59, no. 7, pp. 1051–1058, 2005, doi: 10.3169/itej.59.1051.

[54] N. S. Chowdhury, W. Luu, S. Palmisano, H. Ujike, and J. Kim, "Spatial presence depends on 'coupling' between body sway and visual motion presented on head-mounted displays (HMDs)," *Appl. Ergonom.*, vol. 92, Apr. 2021, Art. no. 103355, doi: 10.1016/j.apergo.2021.103355.

[55] J. J. Gibson, "The perception of the visual world," Houghton Mifflin, Boston, MA, USA, Tech. Rep., 1950.

[56] R. T. Chatterton, K. M. Vogelsong, Y.-C. Lu, A. B. Ellman, and G. A. Hudgens, "Salivary α-amylase as a measure of endogenous adrenergic activity," *Clin. Physiol.*, vol. 16, no. 4, pp. 433–448, Jul. 1996, doi: 10.1111/j.1475-097X.1996.tb00731.x.

[57] N. Rohleder, U. M. Nater, J. M. Wolf, U. Ehlert, and C. Kirschbaum, "Psychosocial stress-induced activation of salivary alpha-amylase: An indicator of sympathetic activity?" *Ann. New York Acad. Sci.*, vol. 1032, no. 1, pp. 258–263, Dec. 2004, doi: 10.1196/annals.1314.033.

[58] U. M. Nater, N. Rohleder, J. Gaab, S. Berger, A. Jud, C. Kirschbaum, and U. Ehlert, "Human salivary alpha-amylase reactivity in a psychosocial stress paradigm," *Int. J. Psychophysiol.*, vol. 55, no. 3, pp. 333–342, Mar. 2005, doi: 10.1016/j.ijpsycho.2004.09.009.

[59] A. Nakano and M. Yamaguchi, "Evaluation of human stress using salivary amylase," *Jpn. J. Biofeedback Res.*, vol. 38, no. 1, pp. 3–9, 2011, doi: 10.20595/jjbf.38.1_3.

[60] S. Kume, Y. Nishimura, K. Mizuno, N. Sakimoto, H. Hori, Y. Tamura, M. Yamato, R. Mitsuhashi, K. Akiba, J.-I. Koizumi, Y. Watanabe, and Y. Kataoka, "Music improves subjective feelings leading to cardiac autonomic nervous modulation: A pilot study," *Frontiers Neurosci.*, vol. 11, pp. 1–11, Mar. 2017, doi: 10.3389/fnins.2017.00108.

[61] Y. Tamura, K. Takata, K. Matsubara, and Y. Kataoka, "Alpha-glycerylphosphorylcholine increases motivation in healthy volunteers: A single-blind, randomized, placebo-controlled human study," *Nutrients*, vol. 13, no. 6, p. 2091, Jun. 2021, doi: 10.3390/nu13062091.

[62] R. Fadayevatan, M. Alizadeh-Khoei, S. T. Hessami-Azar, F. Sharifi, M. Haghi, and B. Kaboudi, "Validity and reliability of 11-face faces pain scale in the Iranian elderly community with chronic pain," *Indian J. Palliative Care*, vol. 25, no. 1, pp. 46–51, 2019. [Online]. Available: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6388585/pdf/IJPC-25-46.pdf

[63] M. S. Houle and G. E. Billman, "Low-frequency component of the heart rate variability spectrum: A poor marker of sympathetic activity," *Amer. J. Physiol.-Heart Circulatory Physiol.*, vol. 276, no. 1, pp. H215–H223, Jan. 1999, doi: 10.1152/ajpheart.1999.276.1.H215.

[64] G. A. R. del Paso, W. Langewitz, L. J. M. Mulder, A. van Roon, and S. Duschek, "The utility of low frequency heart rate variability as an index of sympathetic cardiac tone: A review with emphasis on a reanalysis of previous studies," *Psychophysiology*, vol. 50, no. 5, pp. 477–487, May 2013, doi: 10.1111/psyp.12027.

[65] Apple Inc. (2023). [Online]. Available: https://www.apple.com/apple-vision-pro/

[66] P. Grahn and U. A. Stigsdotter, "Landscape planning and stress," *Urban Forestry Urban Greening*, vol. 2, no. 1, pp. 1–18, Jan. 2003, doi: 10.1078/1618-8667-00019.

[67] R. Kaplan and S. Kaplan, *The Experience of Nature: A Psychological Perspective*. New York, NY, USA: Cambridge Univ. Press, 1989.

[68] J. Barton and J. Pretty, "What is the best dose of nature and green exercise for improving mental health? A multi-study analysis," *Environ. Sci. Technol.*, vol. 44, no. 10, pp. 3947–3955, May 2010, doi: 10.1021/es903183r.

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