

Testing the Effect of Green Virtual Reality Nature with Nature Sounds on Perceived Self-Esteem Among Students

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Abstract

Low self-esteem appears to have negative effects on academic achievements and the ways in which students deal with setbacks. Hence the reason why the goal of this study was to investigate whether green nature in virtual reality, increases levels of perceived self-esteem among students. It was expected that green VR nature increases levels of perceived self-esteem. Next to that, it was hypothesized that sound would strengthen the effect of green VR nature on self-esteem. Participants (N=33) were either assigned to the sound or no-sound condition, where a pre-test was conducted to measure baseline levels. To capture possible changes in self-esteem, a post-test was implemented after participants engaged in the VR environment. To test the main effect of green VR nature on self-esteem, a simple linear regression analysis has been implemented ($P < .001$). For the comparison of means from both conditions, an independent t -test has been performed, however this outcome remained non-significant. The significant effect of green VR nature on self-esteem, suggests that the green VR nature environments increases self-esteem among students. For the sound condition, the mean appeared to be higher, however sound does not reinforces the effect of green VR nature on self-esteem. Since other research shows support in the use of audio to increase self-esteem, the outcome of this study did not align with findings of other studies. This difference in outcome could have occurred due to personal preferences in nature settings, participant's fear of heights, the time spent in the environment and personality traits.

Keywords: Virtual Reality (VR), green nature, nature sounds, self-esteem, students

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Universities and parents contribute towards pressuring students in aiming for excellence in academic achievements (Jiang et al., 2022). This may cause psychological distress and low student engagement among students (Acosta-Gonzaga, 2023). This low student engagement and distress can be an onset predictor for psychological disorders which may affect students general well-being (Nonterah et al., 2023). Well-being may be explained as a multi-dimensional concept, consisting out of several elements. One such elements is emotion, which is linked to self-esteem (Jarden & Roache, 2023). The importance of self-esteem and how it can be influenced, may be of great interest for students. Current existing health innovations target students through apps or online interventions, which results in students' need for new innovations (Hugh-Jones et al., 2023). Focus in this research is on the effect of green Virtual Reality (VR) nature on self-esteem among students, together with the potential effects of nature sounds in VR, to examine whether self-esteem can be induced through green VR nature.

Self-esteem

Self-esteem can be explained as a positive or negative attitude one holds towards him/herself (Rosenberg, 1965). In a study by Pyszczynski et al. (2004), self-esteem descends from the thought that there is a chance that a human's main purpose in this world, is to survive in a "meaningless" universe, only born to live their way towards death (Pyszczynski et al., 2004). Otherwise said, self-esteem provides a shield against the rising anxiety, through the thought of death. The ambition to thrive for any form of self-esteem is neither a beneficial nor a negative ambition. It is a way for one to cope with the confrontation of their existential crisis called life (Pyszczynski et al., 2004).

Furthermore, self-esteem can be seen as an important factor for students, due to its relationship with motivation and academic achievement (Acosta-Gonzaga, 2023). Students with higher levels of self-esteem may have clear ambitions for themselves, compared to students with lower self-esteem. In order to achieve these ambitions, students with high self-esteem, have a clear strategy in mind, to achieve set goals (Baumeister et al., 2003). Next to that, students who possess higher levels of self-esteem, show capabilities of dealing with setbacks or problems and focus on the process of succeeding. These aspects illustrate correlations between levels of self-

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esteem and academic achievements in students (Chung et al., 2014). Chung et al. (2014) state that higher levels of self-esteem are positively correlated with academic achievements. This emphasizes the influence and importance of self-esteem among students. Particularly, since high levels of self-esteem can predict academic success and influence how students deal with defeats (Chung et al., 2014).

Self-esteem and Virtual Reality

A possible way to induce self-esteem among students, is with the use of VR (Salameh et al., 2023). VR is a non-real environment in which computer based simulation duplicates the real world (Salameh et al., 2023). VR fulfills many purposes, for example, it bridges the gap between learning and theory, it is not restrained to time nor location and it duplicates environments from real-world situations (Chang & Lai, 2021). The latter, in particular, is beneficial for many, since it is difficult to repeatedly duplicate environments from the real world (Kalantari et al., 2022). Replicability, educational purposes and no time nor location restraints, allow VR to be a useful tool for students' to increase self-esteem.

Hugh-Jones et al. (2023) states that the need for new technology regarding health interventions, is desired among students. Especially, since the variety in interventions for students is limited, due to the majority of the available interventions being apps or online tools (Hugh-Jones et al., 2023). One example of how VR can be a suitable tool to induce self-esteem is by Guidolin et al. (2024). In their study, the effect of VR nature landscapes, with green scenery and water, was tested with regard to levels of self-esteem among patients. The outcome shows that patients have a reduced length of stay at the hospital and mention fewer negative comments about their symptoms during their stay. Additionally, an example of how VR can affect self-esteem is the research of Freeman et al. (2023). This research shows that self-esteem can be increased, by implementing VR nature sessions with elderly people in a nursing home. Four environments are included in their research, of which two are nature environments with green scenery. These environments include trees, a lake, a campfire, flowers and sand. All participants reported an increase in self-esteem after engaging in the environment, explaining that green VR nature induces self-esteem among its users.

The aforementioned emphasize on the effect of nature on self-esteem, specifically green nature. Barton et al. (2011) state that self-esteem is best induced using green nature (trees,

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flowers, grass and birds), compared to non-green nature. Barton et al. (2011) asked participants to take a walk in nature, the nature could either be green nature or a non-green environment. They report that changes in self-esteem are greater in the participants who are assigned to take a walk in green nature, compared to non-green settings. Green nature appears to have beneficial outcomes on one's health, due to the sense of innate survival properties humans possess (De Vries et al., 2003). De Vries et al. (2003) explains that green properties are seen as fruitful when it comes to functioning and survival, the greener the grass, trees and flowers, the higher the survival rates are. The aforesaid, explains the effect that green nature has on humans and brings attention to the underlying evolutionary reasoning behind this. Suggesting that green environments could be combined in VR, as a useful intervention when it comes to increasing self-esteem levels among students.

Natural sounds

Being outdoors not only brings attention to our visual senses, but also to our auditory senses (Jo et al., 2019). When it comes to natural sounds, it is proven to have beneficial properties for students in a sense that it can improve learning performance by promoting psychological and cognitive dimensions (Luo et al., 2022). Exposure to nature audio, such as water, birds and wind, supports students in maintaining higher levels of self-esteem by increasing positive emotions. The increase in positive emotions are linked to one's elevation in mood according to the physical reaction of the body to nature audio (Witten et al. (2022)). Due to the activation of the visual senses an increase in parasympathetic nervous activity occurs, together with a decrease in the sympathetic nervous system and decreased cortisol levels (Jo et al., 2019).

One example of the physical recovery to a stressor, is explained by Alvarsson et al. (2010), where it is described that sounds of green nature possess beneficial properties for the recovery of skin conductance levels. The sounds supported a more rapid recovery from a psychological stressor (Alvarsson et al., 2010). By describing the physical reaction to nature sounds and the positive mental effect it has on health, nature sounds may provide another way in which self-esteem could possibly be induced among students.

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Present study

Self-esteem is innate to human beings (Pyszczynski et al., 2004). Additionally, self-esteem is shown to decrease among students, due to parents and academic pressure (Nguyen et al., 2019). As aforementioned, low self-esteem negatively influences academic achievements and ways in which students deal with setbacks in their academic career (Nonterah et al., 2023). Therefore, interventions on how to enhance self-esteem are of importance to improve those academic achievements and provide growth in dealing with the aforesaid defeats.

Besides the effect of VR nature on self-esteem, it is yet to be discovered what the effect of natural sounds, such as water, wind and birds have on levels of self-esteem among students. (Frühholz et al., 2014). Therefore, the aim of this research is to investigate the effect of auditory green VR nature, on perceived self-esteem among students. Based on existing research, the following research questions and hypotheses are formulated:

RQ 1. What is the effect of green VR nature on perceived levels of self-esteem among university students?

RQ 2. What is the effect of nature sounds in green VR nature settings, compared to the no-sound condition, on perceived levels of self-esteem among university students?

Hypothesis 1. Students will report higher levels of self-esteem after engaging in a VR session in green scenery.

Hypothesis 2. Students with nature sounds in VR will report higher levels of self-esteem, compared to the students without nature sounds.

Methods

Design

The design of the study consisted out of a pre- and post-measure, implementing the Self-Esteem Scale (SES) by Rosenberg (2006). To test for the statistical effect of VR nature (with/without sound) on self-esteem, two conditions were created, one condition with sound and one condition without sound. Both the conditions were exposed to the same questions from the SES and the same green VR environment. Subsequently, the study was approved by the ethics committee.

Participants

In this study, the number of participants was 33, of which 21 (64%) of them identified as female and 12 (36%) as male. The age of the participants ranged from 19 to 25 years, with an average age of 22 ($SD = 1.75$) and were either Dutch (58%), German (24%) or other nationalities (19%). A total of 16 participants were recruited implementing a convenience and voluntary response sampling strategy. The remaining 17 participants were collected from a parallel study, of which the research design was similar to this research design. The participants were divided into either the sound condition or no-sound condition. A total of 16 participants belonged to the sound condition and 17 participants to the no-sound condition. The sound condition consisted out of seven male and nine female participants. The no-sound condition consisted out of 7 male and 10 female participants. All participants involved in this research agreed to the informed consent.

Materials

Equipment

The questionnaire was conducted using a laptop on which it was presented to the participants. The VR environment was displayed using a Oculus Quest 2 headset, which was retrieved from the faculty of Behavioural, Management and Social sciences from the University of Twente. For the sound condition, a WH-1000XM4 Sony headset was used for the audio that was selected. All participants answered the questions to the SES, sitting down on a chair, with the laptop on a table in front of them.

Questionnaire

To measure levels of self-esteem among students the SES questionnaire by Rosenberg (2006) was selected and implemented, using Qualtrics (Qualtrics XM - Experience Management Software, 2024). The SES consists of 10 items. The SES provides a test-retest reliability between .82 and .88 and the Cronbach's alpha may range from .77 to .88 (Rosenberg, 2006). The SES measures perceived levels of self-esteem among individuals. Examples of these questions are positive items such as; "*On the whole, I am satisfied with myself*" and negative stated items such as; "*I feel I do not have much to be proud of*". Answers were given on a scale from 1 – 4, strongly agree to strongly disagree. Items 2, 5, 6, 8 and 9 are negatively formed questions, hence they

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need to be reversed. Items 1, 3, 4 and 7 are positively formulated to measure high levels of self-esteem, these do not need to be reversed. In total, a 40 score indicates the highest level of self-esteem (Rosenberg, 2006). The questions from the SES can be viewed in Appendix A1.

VR-environment

The VR environment was shown using a VR headset. The headset provides opportunities to watch immersive YouTube videos (Poppy Field Armenia - Google Search, n.d.). The video displayed trees, mountains, the sun, and a poppy field (see Figures 1 and 2). Both the conditions were exposed to the same VR environment for 4 minutes and 34 seconds.

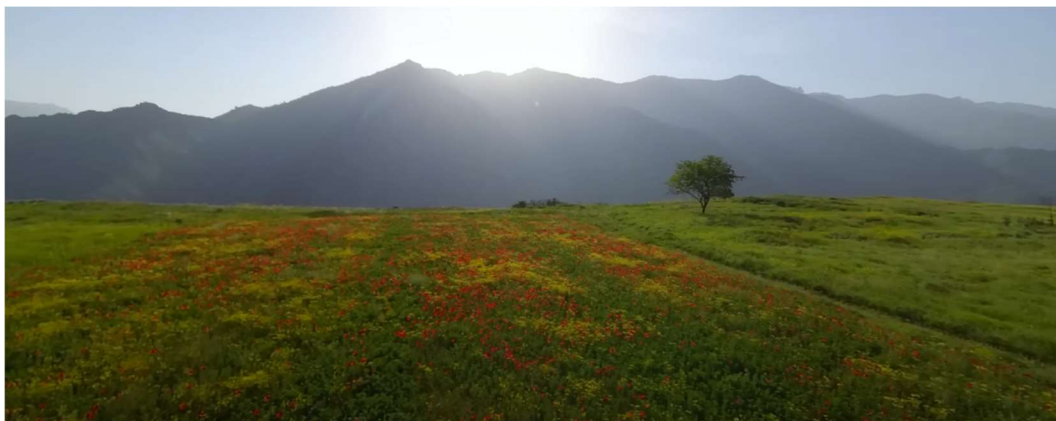
Figure 1

Green Grass and Trees Shown in VR Environment



Figure 2

Poppy Field, Mountains and Sun Shown in the VR Environment



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Nature sound

The audio used for the sound condition was retrieved from YouTube (Calmed By Nature, 2020). The natural sounds included sounds which were synchronized with what the participants viewed. Examples of these sounds include bees, wind and birds. Subsequently, the no-sound condition watched the same green immersive environment without the sound (Calmed By Nature, 2020).

Procedure

For the study's execution, the researcher was always present. Part of the participants took part in the experiment at the assigned Flexperiment rooms on the campus of the University of Twente. However, few participants engaged in the experiment while being at home in an enclosed room. For the latter, the researcher visited the participants in their home setting. Before the study started, participants were obligated to either give consent to the experiment or not. If consent was not given, continuation of the research could not take place. Each participant experienced the VR nature setting individually, sitting in a silent room to prevent further distractions. The sound condition was exposed to natural sounds through a headset, whereas the no-sound condition was not.

First, the participants were asked to answer demographic questions, such as gender, age, type of study and nationality. Then the participants were asked to continue by filling in the questionnaire, which lasted for approximately ten minutes. The SES questionnaire was used for both conditions, the sound condition and the no-sound condition. After completing the first questionnaire, participants were instructed to continue with the VR part of the experiment. During this part, the participants stayed seated for the entire procedure. It was explained that the researcher was nearby when participants needed assistance in a situation such as dizziness. After providing a short explanation of the headset, the participants started their VR session.

After 4.34 minutes in the VR environment, the researcher assisted in taking off the headset. Next, participants were asked to fill in the SES questionnaire for the second time. This time participants did not have to fill in the demographic questions again, since those were already obtained from the pre-test part. The second questionnaire lasted 5 to 10 minutes. The researcher was only present to help adjust and remove the VR headset. The remaining time the

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researcher was not present in the same room as the participant to ensure privacy. After completing the post-test questionnaire, the participant finished the study.

On the contrary to the no-sound condition, the sound condition followed the same procedure. However, the only exception being that the sound condition was exposed to audio from a YouTube which is called Calm By Nature (Calmed By Nature, 2020). For this condition, the WH-1000XM4 Sony headset was used to be able to listen to the audio. While watching the immersive video, the participants from this condition also listened to the audio. The headset was adjusted on participants after the VR headset was put on, by the researcher.

Data analysis

Questionnaire

In order for the hypotheses to be tested, the outcomes from the questionnaire needed to be transformed into usable data for the software program Rstudio. The pre- and post-data were exported into a CSV document, in order to transfer these into the statistical program. After both the conditions were uploaded into Rstudio, the categorical answers were transformed into numerical answers. For example, Strongly agree became 4, Agree became 3, Disagree became 2 and Strongly disagree became 1. As aforementioned, the items 2, 5, 6, 8 and 9 were reversed, since those were negatively formulated. After the scores per participant were summed for the pre and post-test, a maximum of 40 points could be obtained. As shown in Figure 3, 4 and 5, the assumptions of normality, linearity and equal variance were met, which allowed the linear regression to be the right parametric model for this research.

Figure 3

Visualization of Normality of the Residuals

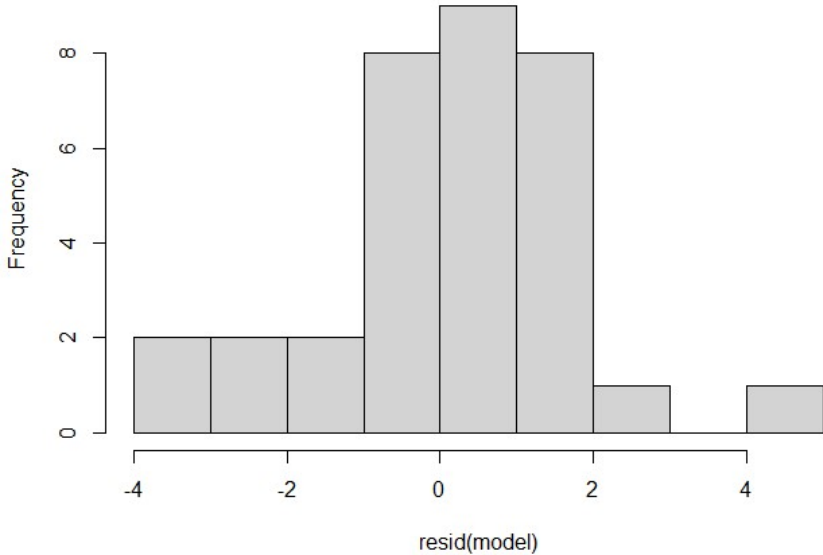


Figure 4

Visualization of the Linearity

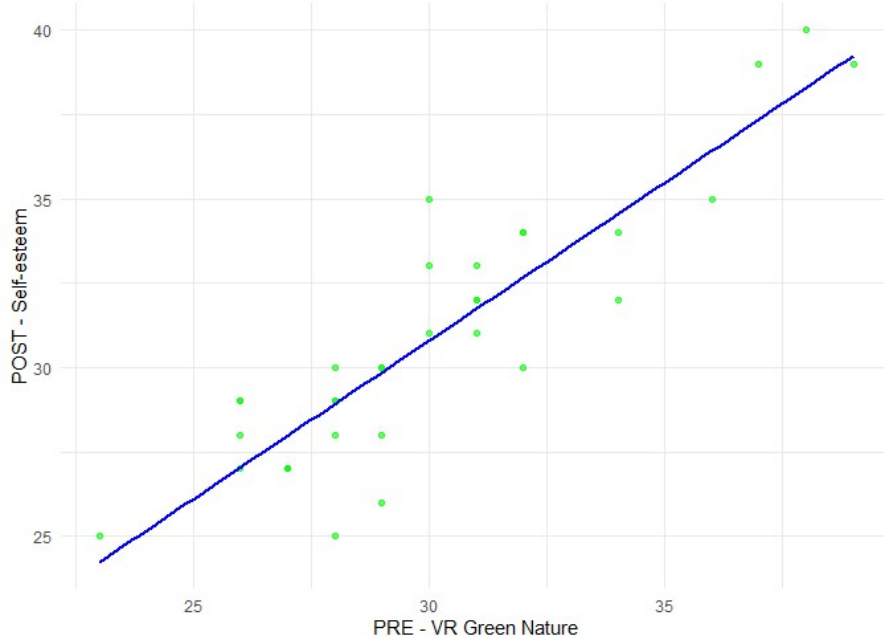
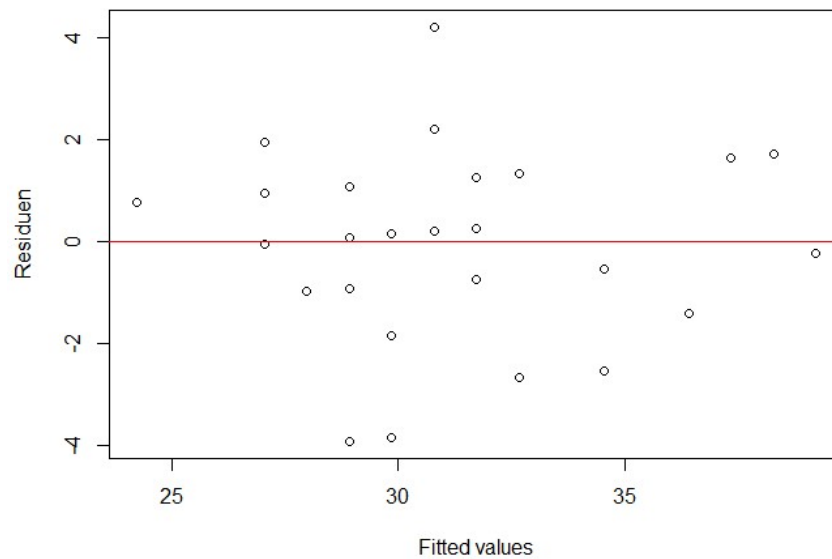


Figure 5

Visualization of the Equal Variance of the Residuals



Hypothesis 1. Effect of VR on self-esteem

Since the main goal was to measure the relationship of the independent variable VR nature, on the dependent variable self-esteem, a simple linear regression analysis was selected. Multiple packages have been used for different statistical means. ‘‘Ggplot2’’ has been implemented for the data visualization. ‘‘dplyr’’ has been used for the data manipulation, ‘‘tidyr’’ has been used for data tidying, ‘‘readr’’ for the import of the data sets, ‘‘psych’’ for reliability/validity testing and ‘‘lmtest’’ has been used for the linear regression analysis. The reliability and validity from the RSES were calculated, then the total score on the pre- and posttest were calculated and renamed.

Hypothesis 2. The sound-condition presents higher means than the no-sound condition

To compare means of the post-test between the sound and no-sound condition, an independent *t*-test has been conducted. The package ‘‘psych’’ has been selected, in order for the results in Rstudio to be obtained. The independent *t*-test compares means between two groups, which said something about the statistically significant difference between the two groups (Kim, 2015). For this the means from the posttest for both conditions were used from the sound condition, after which the independent *t*-test could be computed.

Results

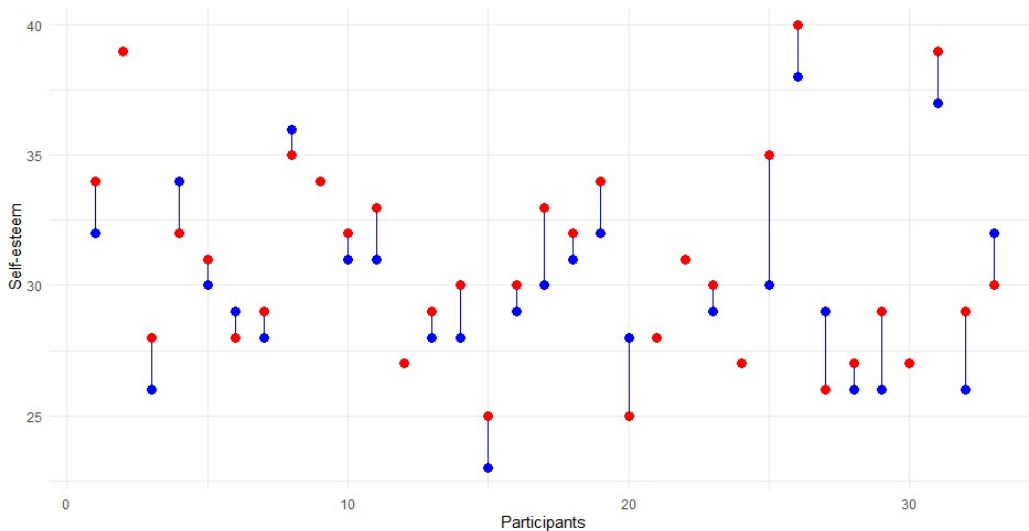
Hypothesis 1. Effect of VR on self-esteem

For the first hypothesis a simple linear regression was implemented to test what the effect was of VR nature on perceived levels of self-esteem among students. Reliability of the questionnaire measuring self-esteem was assessed, using split-half reliability methods. The Guttman's Lambda 6 for the pre- test (.84) and post- test (.89) coefficients and Cronbach's Alpha of the pre- test ($\alpha = .80$) and post-test ($\alpha = .85$). The questionnaire’s fit was assessed through the Root Mean Square of the Residuals (RMSR), which was .1, and the fit based on off-diagonal values, which was .95.

The regression analysis showed a statistically significant positive relationship between VR green nature and self-esteem $R^2 = .80$, ($F(1, 31) = 123,10$, $p < 0.001$). With the pre-condition ($M = 30.10$, $SD = 3.72$) and the post-condition ($M = 30.90$, $SD = 3.90$). The difference between the pre and post measure can be obtained from Figure 6. One participant decreased in self-esteem by 3 points, while another participant increased by 5 points in self-esteem.

Figure 6

Difference in Levels of Self-Esteem From all Participants



Note. The blue-colored scatters represent the pre measure and the red-colored scatters represent the post measure.

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Hypothesis 2. The sound-condition presents higher means than the no-sound condition

For the second hypothesis the independent *t*-test was used to compare means of the post-test from the sound and no-sound condition. This analysis aims to check whether there was a statistical difference between the post-test between the sound ($M = 31.12$, $SD = 3.50$) and no-sound condition ($M = 30.50$, $SD = 4.48$). The independent *t*-test revealed no significant difference between the mean scores of the two groups ($t(25.74) = .45$, $p = .66$). The difference in scoring per condition is visualized in Figure 7. Looking at the total scoring from the sound condition, a score of 0 - 40 could be obtained where the highest score was 39 and the lowest was 25. For the no-sound condition the highest score was 40 and the lowest score was 25. For the pre scores the lowest score captured was 26 points, whereas the highest pre score 39 was. The change in scoring between the pre and post measure was calculated and compared. The biggest change was observed in the no-sound condition, which increased by five points after engaging in the VR environment. Additionally, the lowest change in score was captured from the no-sound condition as well, showing a decrease of 3 points in self-esteem after engaging in the VR environment. The total change in score per condition can be obtained from Table 1.

Figure 7

Results on the Post-test From the Sound and No-sound Conditions

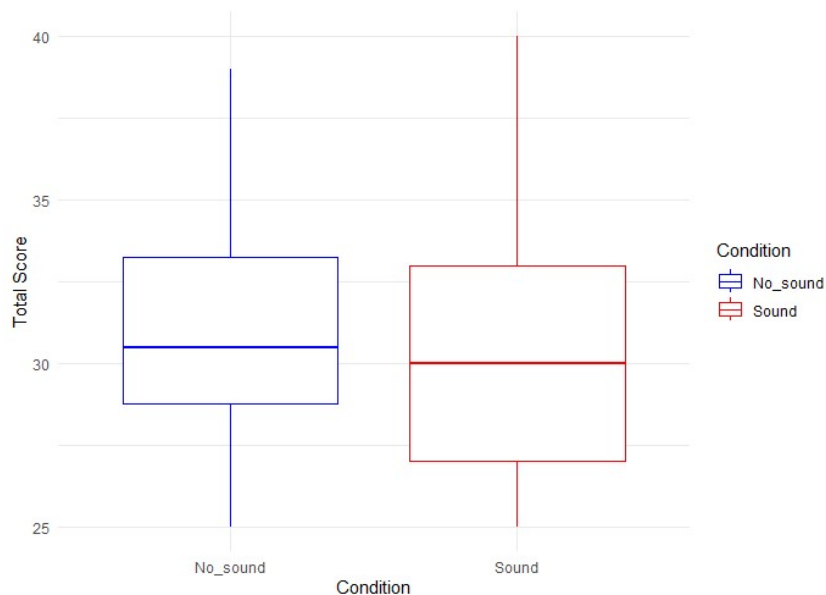


Table 1

Change in Score Between Pre and Post Measure

No-sound condition	Sound condition
3	2
1	0
2	2
-3	-2
0	4
0	-1
1	1
0	-1
5	0
2	1
3	2
1	0
3	1
0	2
2	2
3	1
Total	19
	14

Discussion

Key findings

The aim of this study was to find out to what the effect is of green VR nature is on perceived levels of self-esteem and what the effect of natural sounds in green VR nature is on levels of self-esteem among. The first research question is answered due to the findings of the present study: *What is the effect of green VR nature on perceived levels of self-esteem among university students?* The answer shows that there is a positive relationship between green VR nature and self-esteem, due to the discovered effect of VR on self-esteem. However, findings to

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answer the second research question were non-significant: *What is the effect of nature sounds in green VR nature settings, compared to no sound condition, on perceived levels of self-esteem among university students?* The analysis showed that sound in green VR nature has no effect on self-esteem among students. Therefore, hypothesis 1 related to the effect of green VR nature of self-esteem is accepted. Whereas, the second hypothesis on the comparison between the means of the sound and no-sound condition, is rejected.

Hypothesis 1. The effect of VR on self-esteem

The analysis for the first hypothesis suggests a significant effect of VR nature on levels of self-esteem among students. Explaining a positive effect between green VR nature and self-esteem among students. Self-esteem increased after students engaged in the VR environment. Similar outcomes arose from a study by Yu et al. (2018), where they state that nature settings increase self-esteem after engaging in the environment. Another study which aims to increase levels of self-esteem by implementing VR environments, was conducted by Fan et al. (2022). Participants engaged in different activities within the outdoor environments, such as walking in nature, arranging flowers and treasure hunting in a garden. Outcomes of this study showed a significant effect of VR on self-esteem, which is in line with findings of the current research.

Namely, self-esteem can be induced by engaging in green outdoor VR. Note that Fan et al. (2022) created interactive activities with nature where its users could move freely, whereas this study did not provide those functions. Which shows that not being able to move within the environment, proposes similar outcomes to those that do provide this function (Fan et al., 2022; Freeman et al., 2023; Holopainen et al., 2023; Koek & Chen, 2024). Therefore, outcomes of this research are in line with the aforementioned research, stating that green VR nature induces levels of self-esteem among students (Yu et al., 2018; Fan et al., 2022).

Hypothesis 2: The sound-condition presents higher means than the no-sound condition

As aforementioned, the results did not show significant differences between the post measure from the sound and no-sound condition. Since the mean for the sound condition is higher compared to the no-sound condition, it suggests this difference occurred due to chance instead of a statistical effect. As mentioned in the introduction, research on the effect of natural audio versus natural visualization, lacks attention. Studies who aim to measure the effect of sounds within VR, showed dissimilar results compared to this study. Kern and Ellermeier (2020)

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conducted a walk in nature research, which shows significant differences between the sound and no-sound condition, this is not in line with the outcomes of the current study.

Moreover, Luo et al. (2022) researched the effect of nature sounds in a mobile device, which also showed a significant difference compared to the no-sound condition, which is not in line with the outcomes of the present study. Luo et al. (2022) implemented a four-week intervention, where the participants engaged in the application for 30 minutes per day, whereas this research only allowed participants to engage in the environment for nearly five minutes. Suggesting that the time window of interaction, might have influenced the non-significant outcomes of this study.

Subsequently, another example of what might have influenced the non-significant differences, is the audio of choice. A study by D'Acci (2021) researched why some people could prefer urban sounds. They state that sounds from the city, may be linked to feelings of social mobility, money, culture and overall happiness, which explains why some participants might have the personal preference of urban sounds, instead of nature sounds which led to the non-significant outcome. These personal preferences can occur due to different personality traits of the users (Atherton et al., 2023). Atherton et al. (2023) explain that environmental preferences can be linked to personality traits. In their study they found that lower levels of openness, conscientiousness and psychological well-being are linked to rural preferences. Suggesting that the audio of choice that was used for this research, could have influenced the outcomes of the sound condition.

Furthermore, Alexanian et al. (2022) show that the combination of visual and audio stimulus, provide better outcomes than visuals by themselves. Supporting this, is the research by Tang (2023) who states that our senses will be linked and connected to each other, when audio and visual representations are used to create a real-life setting. Suggesting that audio enhances the VR experience which otherwise would not have occurred (Brinkman et al., 2015). Due to this VR enhancement, several participants from the current research mentioned that their fear of heights interfered with the experience. Proposing that the immersion with the environment triggered fear of heights among participants in this study, which possibly intervened with the outcomes from the sound condition.

Strengths and Limitations

Strengths

This research provides clear insights into the relationship between green VR nature on levels of self-esteem among students. One noteworthy strength, is that research on the effect of VR on self-esteem among students, lacks scientific attention. The present research has explored these variables, which have not been explored to this extent before. Outcomes of this research provide valuable insights for potential future research, due to the finding that self-esteem can be induced using green VR nature. As aforementioned, not much research has been conducted on the implementation of VR on levels of self-esteem among students. Therefore this study provides great insight into new variables, such as personal preferences, fear of heights and duration within the VR environment, which can become a possible stepping stone for future research.

Limitations

This research encountered several limitations. First, after entering the VR environment, several participants mentioned their fear of heights. This fear might have influenced outcomes of the study, since they were ‘‘flying’’ in the green scenery of the VR environment (Peterson et al., 2018). Suggesting that only including participants without fear of heights, might have resulted in different outcomes. Second, while participants were able to look around freely in the VR environment, they were not able to move freely since an immersive video was being played. This might have influenced the experienced embodiment of participants, since they could not explore the environment themselves by using the controller to move (Murray, 2004). Third, not all participants participated the experiments in the same setting. Several participants were appointed to experimental rooms, whereas others were able to engage in the study from their home. This might have influenced the outcomes due to the comfortableness of the familiar space at their home, instead of an experimental room (Ozono & Nakama, 2022).

Implications

Theoretical implications

As for theoretical implications, the relationship between green VR nature and self-esteem, indicate a positive relationship. Suggesting that this model can be seen as a fitted measurement tool to provide growth in self-esteem among students. Therefore, student achievements and well-being could possibly be improved by implementing these VR sessions.

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Previous research showed improvement in self-esteem when VR when sessions were scheduled for a course of several weeks, with sessions longer than 5 minutes (Freeman et al., 2023; Holopainen et al., 2023; Koek & Chen). This study shows that less with five minutes within the VR environment, increased self-esteem levels among students are observed. Additionally, to increase the effect of sound in VR, different variables are of importance. These variables can be personality traits, preferences for urban or natural environments and whether someone already has low self-esteem or not (Atherton et al., 2023; D'Acci, 2021).

Practical implications

According to the effect that green VR nature has levels of perceived self-esteem among students, application of the VR environment can be proposed for educational settings within universities, to help students increasing their self-esteem. This increase in self-esteem can benefit academic outcomes, together with student engagement (Nonterah et al., 2023; Acosta-Gonzaga, 202). Not only academic achievements could benefit from this, self-esteem could also be improved for students to gain personal insights on how to deal with difficult situations as well as personal growth (Baumeister et al., 2003). Suggesting that the green VR nature environments can be implemented in the educational setting among universities, to increase self-esteem among their students.

Future research

Based on the key findings of this research, several recommendations are formulated in order to maximize effectiveness for the outcome of the study. First, based on previous research, one should take into account that embodiment of the VR experience can be maximized when users are able to move freely and are on the ground (Ellermeier, 2020; Luo et al. 2022; Freeman et al. 2022). Next to that, creating self-awareness of the users can be increased by including the option of creating an avatar, which potentially influences levels of self-esteem as is shown in already existing research (Freeman et al. 2023; Koek & Chen, 2024). These recommendations stress the importance of feelings of embodiment and immersion within the VR environment, to improve the overall experience and effect it could have on self-esteem (Peck et al., 2013).

Secondly, comparable studies have implemented a longitudinal study design, which lasted for several weeks. Offering repeated interactions with the environment, which creates more opportunity for improvement of the results from the sound condition (Freeman et al. 2023;

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Koek & Chen, 2024). Current study implemented exposure to the environment for less than five minutes, which could have been why the difference between sound and no-sound remained non-significant. To further research the effect of sound in VR on self-esteem, it is suggested that engagement within the green environment exceeds 4.34 minutes and provides more than only one interaction moment for the students with the green VR nature.

Third, to maximize the difference between sound and no-sound in VR on self-esteem, other variables should be considered. For example, targeting people who already possess low levels of self-esteem (Karch, 2019). By targeting participants with lower self-esteem, the results might show greater effects from the VR environment. Next, to take the fear of heights into account, people with fear of heights could be excluded from the research or a VR environment where users are on the ground is advised. Suggesting an inclusion criteria of participants possessing lower levels of self-esteem and an exclusion criteria of participants with a fear of heights.

Conclusion

Based on the outcomes of this research, the effect of green VR nature on levels of self-esteem among students has been explored. It is discovered that green VR nature has an effect on self-esteem among students, showing that self-esteem can be induced using green VR nature among students within five minutes. When sound was added to the environment, the sound condition did not show significant differences compared to the no-sound condition. This explains that sound in green VR nature did not add any effect on the perceived levels of self-esteem among students from the sound condition, compared to the no-sound condition.

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Appendix A

Rosenberg's Self-esteem Scale items

Number	Question
Q1	On the whole, I am satisfied with myself
Q2	At times I think I am no good at all.
Q3	I feel that I have a number of good qualities.
Q4	I am able to do things as well as most other people.
Q5	I feel I do not have much to be proud of.
Q6	I certainly feel useless at times
Q7	I feel that I'm a person of worth.
Q8	I wish I could have more respect for myself.

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Q9 All in all, I am inclined to think that I am a failure.

Q10 I take a positive attitude toward myself.

Appendix B

Informed consent

I have read and understood the study information, or it has been read to me. I have been able to ask questions about the study and my questions have been answered to my satisfaction.

I consent voluntarily to be a participant in this study and understand that I can refuse to answer questions and I can withdraw from the study at any time, without having to give a reason.

I understand that taking part in the study involves looking at VR environments and filling out questionnaires.

I understand that taking part in the study involves the following risks: motion sickness

I understand that information I provide will be used for educational purposes.

I understand that personal information collected about me that can identify me, such as [e.g. age, nationality, study field], will not be shared beyond the study team.

I give permission for the collected data that I provide to be archived on the UT drive so it can be used for future research and learning.

I agree that my information may be shared with other researchers for future research studies that may be similar to this study. The information shared with other researchers will not include any information that can directly identify me. Researchers will not contact me for additional permission to use this information.

Appendix C

Artificial Intelligence (AI) statement

During the preparation of this work the author(s) used ChatGPT, Scopus, RStudio, Web of Science, Google Scholar, Science Direct, SAGE Journals Online, SpringerLink, Wiley Online Library, YouTube and Scribbr, in order to provide examples on how to apply different analyses, how these analyses could benefit current research outcomes, analyze the actual data in a software program, collect information which contributes to the literature review and help understanding correct forms citations. After using this tool/service, the author(s) reviewed and edited the content as needed and take(s) full responsibility for the content of the work.