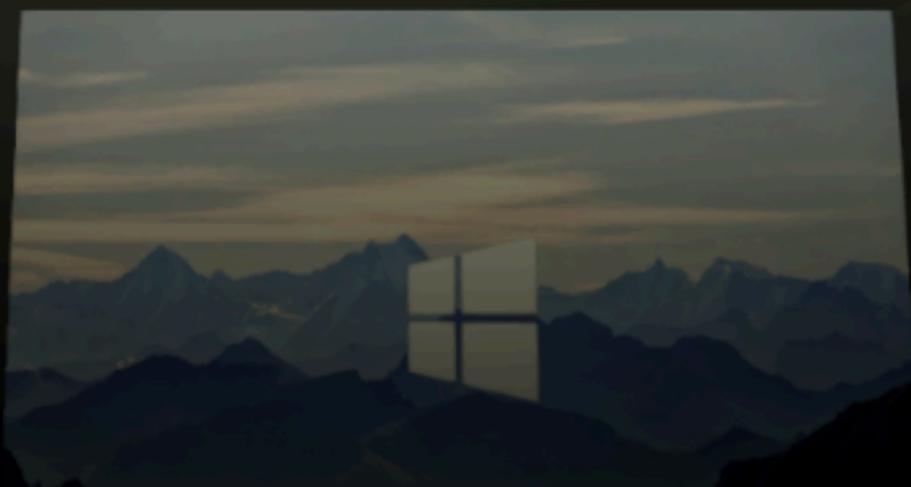


OVERSTIMULATION

A VR SIMULATION

CREATING EMPATHY FOR THE ASD YOUTH...





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Abstract:

This paper investigates whether a virtual reality (VR) simulation of sensory overstimulation in a classroom can increase empathy towards individuals with Autism Spectrum Disorder (ASD) among students in 7th-8th grade. The evaluation methods conducted included using an empathy questionnaire, the IPQ questionnaire, and semi-structured interviews (N=12). The results indicate a modest but non-significant increase in overall cognitive empathy, likely due to the small sample size. However, associative empathy showed a statistically significant improvement, suggesting that the VR experience effectively helped participants relate the VR simulation to real-world scenarios described in the accompanying vignettes. Affective empathy remained high but unchanged.

The IPQ scores showed moderate presence, with stronger general and spatial presence than involvement or realism. The interview data showed that participants still experience irritation, stress, and distraction, mainly due to auditory overstimulations, suggesting the simulation effectively conveyed sensory overstimulation despite limited interactivity and narrative. The findings suggest that VR-based overstimulation simulations can contribute to empathy-building, especially within cognitive and associative empathy for students in 7th-8th grade, while also highlighting the need for improved interactivity, clearer objectives and larger sample size for future work.

1 INTRODUCTION

Autism Spectrum Disorder (ASD) is a neurodevelopmental disorder which poses a variety of challenges and impairments in communicative skills, social interactions, and patterns of behavior [1]. These deficits fluctuate in their severity depending on where the autistic individual lies on the Autistic Spectrum. According to the Fifth edition of the Diagnostic and Statistical Manual of Mental Disorders (DSM-5), ASD is categorized into three levels of severity, fluctuating between high-functioning, and low-functioning. Among these impairments, one of the most common aspects of ASD is Sensory Over-Responsivity (SOR), in which many autistic individuals exhibit atypical negative reactions to sensory input across one or more domains, including auditory, visual, tactile, and olfactory stimuli [2, 3]. SOR was recently added to the Diagnostic and Statistical Manual of Mental Disorders 5th Edition (DSM-5) diagnostic criteria for ASD. SOR is also known as hyperreactivity or hypersensitivity [2, 4, 5]. SOR is an exaggerated and aversive reaction to sensory stimuli. These sensitivities to stimuli have a substantial impact on day-to-day functioning, where ordinary situations can become overwhelming or distressing. To some individuals, beyond the heightened stress and lowered concentration, sensorial stimuli can even feel painful [2, 6].

SOR is also associated with social communication challenges, suggesting a link between sensory and social information processing in ASD. Functional Magnetic Resonance Imaging (fMRI) studies have shown that individuals with SOR display stronger responses in the parts of the brain that handle both sensory input and emotional responses. It also showed reduced habituation to repeated stimuli, and increased salience attribution to irrelevant input, especially when many different sensory inputs happen simultaneously [7, 8]. Research also suggests that social information may be less salient than nonsocial stimuli for youth with ASD, who show enhanced processing of nonspeech sounds, preferential attention to nonsocial objects, and difficulty focusing on a single sound source in complex environments. These differences are linked to altered connectivity and activity in the brain's salience network, which helps determine the importance of incoming information. For these reasons, busy social environments with loud, unpredictable, and often human-generated sounds are often challenging environments for individuals with ASD and SOR [8].

When sensory input becomes excessive or persistent, autistic people frequently go through a stage known as Overstimulation. This stage is characterized by heightened sensitivity, increasing stress and difficulty in filtering environments with different competing stimuli. Overstimulation in itself does not result in a complete breakdown, however it can place significant cognitive and emotional burden on the individual [9]. If the level of input continues to escalate without relief, then overstimulation progresses further into further acute mental and physical distress, delving into the state of Sensory Overload. At this stage, the nervous system no longer processes incoming information, thus leading to an overwhelming or panic-like state, leaving the autistic individual unable to function in their environment [3, 6, 9]. The consequences of such can lead to outward responses such as withdrawal, meltdowns and difficulty in focusing, which to other people can lead to misinterpretations of defiance, disengagement or lack of interest [1, 9], despite these behaviours being a result of high distress in an attempt to regain control over an overwhelming situation [6].

To cope with the risk of overstimulation and sensory overload, many individuals with ASD may actively avoid environments which are unpredictable, noisy or crowded. While this strategy can protect the individual's well-being, it may also limit their participation in everyday activities, isolating themselves in favor of becoming distressed, or be perceived as difficult. Moreover, when an autistic individual experiences a sensory-related outburst, these reactions are often misunderstood by others, reinforcing social barriers and negative perceptions about ASD. Research by MacLennan et al. (2022) and Elwin et al. (2012) has shown a correlation between ASD and an increased risk of developing mental health issues such as anxiety and depression [1, 6, 10].

According to a recent Danish survey on welfare and well-being among students in 4th-9th grade, children and youth with psychological disorders such as ASD are reported to have significantly lower levels of school well-being, self-efficacy, social competence, and sense of belonging compared to their peers without such diagnoses [11]. Similarly, a report from Autismeforening 2024 [12] reported that around one-third of children and youth with ASD have concerning absenteeism from school. The number of people diagnosed with ASD has also increased since 1994 with the introduction of ICD-10, a classification of diseases and other health-related conditions developed by the WHO [13], and today, more than half of individuals diagnosed with ASD are under the age of 22. Parents of children with ASD report that their children often face various types of rejection including being regarded as weird, struggling to make friends, being excluded from activities or being avoided [14]. In addition, young people with autism are significantly more likely to experience repeated bullying, with some studies indicating that nearly one in two pupils up to one in two students might be affected by physical, verbal, or relational bullying at school [15]. These experiences can have serious consequences such as emotional trauma, academic difficulties, and lower self-perceptions [14, 15]. Increasing awareness of ASD and SOR has been found to reduce stigma, foster empathy, and create more inclusive school environments [16, 17]. Gaffney et al (2021) found that school-based anti-bullying interventions can reduce both bullying perpetration and victimization and that peers understanding of ASD significantly influences the social experiences of students with autism [18]. A recent systematic review of eleven studies on autism awareness programs found evidence that these interventions can increase understanding of ASD, foster positive attitudes, and promote intentional behaviors toward students with ASD [16]. Similarly, the organization Anti-Bullying Alliance emphasizes that to combat stigma and bullying, schools need to teach and youth about ASD and its challenges [15]. Together, these findings highlight the importance of spreading awareness and knowledge about ASD and SOR.

Virtual Reality (VR) has proven to be an effective tool for spreading awareness and fostering empathy towards individuals with disabilities [19, 20, 21, 22]. Studies have shown that, compared to non-VR interventions, VR interventions foster greater empathy toward people with disabilities when users previously had embodied an avatar with a disability [20]. Similarly, VR simulations can be used to spread awareness and understanding of ASD by giving participants the opportunity to experience SOR from the perspective of an individual with ASD, as VR enables the controlled simulation of real-world environments through head-mounted displays [23]. VR as perspective-taking approaches can foster empathy and positive attitudes by giving peers a broader understanding of the perceptual, cognitive,

and emotional challenges associated with ASD and SOR [14].

This study proposes a VR simulation set in a classroom, allowing participants to experience what it is like to have ASD and SOR by simulating overstimulation. The simulation aims to increase empathy towards individuals with ASD. We describe the simulated environment and a qualitative and quantitative study with 16 neurotypical participants aged 13-15.

2 BACKGROUND & RELATED WORK

2.1 SOR in ASD

Individuals with ASD and SOR are particularly vulnerable to settings like school environments, which are typically designed primarily for neurotypical students, and therefore often lack accommodations for sensory differences and support needs. School classrooms are even being described as overstimulating and disabling for children and youth with ASD, with multisensory inputs that can be triggering such as noise and social interaction, bright fluorescent lights, visual stimuli and certain textures [24, 25]. Price and Romualdez (2025) conducted a qualitative study exploring how the school environment affects autistic pupils. Seven pupils with ASD, aged 12–16, were interviewed about their daily school experiences and sensory challenges. The findings highlight several aspects of the school environment that were problematic. Noise was mentioned as the most significant trigger, with all participants describing themselves as noise-sensitive. Cafeterias, break times, and other communal areas were mentioned as particularly overwhelming. Additional triggers included cluttered, disorganized, and overcrowded classrooms, limited space, and the use of fluorescent lighting, which many associated with fatigue and discomfort. Participants also emphasized classroom environments as a trigger for their sensory sensitivities and emotional state. Group discussions and class activities often led to confusion and overwhelm, especially when processing visual and verbal stimuli. Social interactions were also affected, with some students struggling to process spoken communication in noisy settings. Peer disruptions were also described as especially triggering, one participant reporting that the sound of a peer rolling their pen was annoying and physically painful [25].

Another study by Jones et al. (2024) explored sensory experiences at school as reported by parents and teachers of children and youth with ASD. 57 parents and 70 UK teachers completed an online questionnaire focusing on the types of sensory experiences pupils encountered and how these affected their learning and school life. The findings indicated that sensory differences among children and youth with ASD had a significant impact with 49% of parents and 36% of teachers reporting that these differences affected school life all of the time. 47% of parents and 30% of teachers also reported that the sensory differences affected learning consistently. Auditory stimuli were reported as the most disruptive, with 78% of teachers and 70% of parents identifying them as frequently or constantly affecting learning. Common auditory triggers included loud or unpredictable noises, such as fire alarms or hand-dryers, as well as lower-intensity sounds like pencil writing and whiteboard markers. The tactile experiences elicited different responses. Some pupils sought physical contact, while others strongly disliked touch, especially during group activities or crowded spaces. Visual stimuli, such as fluorescent lighting and classrooms with extensive displays, were often overwhelming, whereas taste

and olfactory experiences mainly disrupted learning because of stress during lunchtime or incidental smells like cleaning products and perfumes [26].

These findings are supported by a study of adults with ASD by MacLennan et al. (2022), which highlights the wide range of sensory inputs that individuals with ASD struggle with. Participants reported heightened sensitivity to bright (e.g. artificial or sunlight) or flashing lights, cluttered environments, loud or high-pitched noises, multiple conversations, tactile stimuli such as certain fabrics or unexpected touch, extreme temperatures, strong food textures, and odors and scents including perfumes and environmental smells. Similarly to the children and youth with ASD described by Price and Romualdez (2025), auditory stimuli were the most commonly reported trigger among autistic adults in the study by MacLennan et al. (2022), with 85.7% reporting high sensitivity to loud noises, 82.5% to multiple conversations, 77.5% to high-pitched sounds, 75% to music, and 70% to public transport sounds [6]. These findings highlight how school environments can be particularly challenging for individuals with ASD due to the many sensory inputs. School is a central part of childrens and youth's lives, where they spend a large portion of their time, making these challenges especially impactful in their daily lives. Given the impact on learning, social interactions, emotional well-being and that a significant number of children and youth have ASD, this study will focus on simulating overstimulation in a VR classroom environment to allow participants to experience these challenges.

2.2 Empathy Simulations

VR has emerged as a powerful tool for fostering empathy by giving users the opportunity to embody an avatar and experience the world from the perspective of another individual. Perspective-taking interventions have been one of the main techniques to increase empathy toward specific groups of people, helping to reduce the gap between oneself and others, such as stigmatized or disabled individuals, by providing a more holistic understanding of their perceptual, cognitive, affective, and behavioral experiences [14, 20, 27]. VR simulations can help immerse individuals in sensory-rich and realistic virtual worlds to create a strong feeling of presence. They also allow for a higher degree of ecological validity than other simulations, meaning a strong similarity between the designed intervention and the real world [20]. Presence is commonly understood as comprising place illusion, the sensation of being there, and plausibility illusion, the perception that events in the environment are actually occurring, both of which are necessary for users to respond to virtual events as if they were real (Slater & Sanchez-Vives, 2016). Achieving such presence depends on a high level of immersion, which is defined as the extent to which the VR system delivers convincing and coherent sensory input in relation to perception. This requires sufficient fidelity, such as realistic and detailed visuals, sounds, and interactions as well as low latency, which is having a minimal delay between the actions of the user and the systems response to make the environment feel responsive and believable [28]. Studies show that environmental presence and immersion help to promote a greater feeling of empathy when embodying an avatar with characteristics and experiences that oneself does not have. This is enforced by the individual's concept of Theory of Mind, the ability to understand that other people have thoughts, beliefs, desires, intentions, and perspectives that are different from one's own [29] and the ecological validity of the environment [20].

Several studies have explored the use of VR to foster empathy. Ahn et al., (2013) conducted a study on empathy using a virtual color blindness simulation. The participants were divided into two groups, a group which experienced an embodied VR simulation of red-green color blindness and a group which engaged in a perspective-taking task, where they viewed normal colors but were instructed to imagine being colorblind. The first experiment showed that the embodied VR simulation was especially effective for participants with initially lower levels of empathy and had effects lasting up to 24 hours after the treatment. The second experiment found that the embodied VR created a stronger sense of realism, which enhanced selfother merging compared to the perspective-taking task. The third experiment showed that the effects carried over to real-world behavior. Participants who had experienced the embodied VR simulation put in about twice as much effort to help individuals with color blindness compared to those who experienced the perspective-taking task [19].

Embøl et al. (2021) designed HearMeVR, a VR simulation to help parents of children with cochlear implants understand the auditory challenges of their children. Fifteen parents of children with bilateral CIs participated, exploring different virtual environments, either a quiet classroom and a noisy playground or both. Here they switched between normal hearing, unilateral CI, and bilateral CI hearing conditions. The findings showed that the experience made them more aware of and understanding of the challenges that their children with hearing impairments experience in noisy environments. During the evaluation, some of the participants suggested that the simulation could also be adapted for teachers or peers, which in turn might help them better understand the challenges and adjust the physical environment and social behavior to support children with CIs. The study suggests that VR simulations can effectively promote empathy and awareness of hearing impairments [20].

Sri Kalyanaraman et al. (2010) studied the use of VR to foster empathy toward individuals with schizophrenia. Participants were divided into four groups: a VR simulation that allowed them to experience schizophrenia-related symptoms, a written empathy-induction exercise, a combination of both interventions and a control condition. Their findings revealed that the combined VR and written empathy condition produced the strongest results with participants reporting greater empathy and more positive attitudes toward people with schizophrenia. However, participants in the VR-only condition showed the greatest desire for social distance, despite no significant differences in empathy and attitudes compared to the written and combined conditions [22].

Herrera et al. (2018) studied the effects of VR perspective-taking on empathy and prosocial behaviors toward the homeless. Participants either experienced homelessness in VR perspective-taking tasks (VRPT), a traditional narrative-based perspective-taking task (NPT), or received fact-driven information. Their findings showed that participants in the VRPT condition showed more positive and longer-lasting attitudes toward the homeless. They were also significantly more likely to sign petitions that support initiatives like affordable housing, compared to participants in the other conditions. While the participants' self-reported empathy and connectedness were similar across the conditions, behavioral measures indicated that the VRPT was especially effective in motivating real-world helping behaviors. These findings suggest that VR can enhance perspective-taking interventions by creating an embodied experience that promotes empathy and prosocial actions [21]. As previous studies have demonstrated VR's potential in promoting empathy, the same principles can be applied to understanding the sensory challenges individuals with ASD face.

2.3 ASD Simulations

Many easily accessible video simulations exist which focus on the visual and auditory aspects of experiencing enhanced stimuli such as Carly's Café by Fleischmann (2013), which focuses on the social discomfort experienced by autistic individuals [30], or "What it's like to walk down a street when you have autism or an ASD" by Thomson (2010), which additionally illustrates how many things can alter one's focus when you have ASD [31]. Although many of these videos are developed by or in collaboration with individuals with ASD, and met with positive feedback from other individuals with ASD (e.g., in the comment sections), there is a lack of peer reviewed studies surrounding the accuracy and effect of these types of videos. Video games and Extended Reality (XR) have also been used to simulate ASD and SOR to foster empathy and understanding.

This field of study has been examined in peer-reviewed studies, such as the paper "An Anti-Sim Intervention: The Role of Perspective Taking in Combating Public Stigma with Virtual Simulations" by Sarge et al. (2020). This paper focuses on whether a first person virtual simulation could be more effective in reducing the stigma of autistic individuals, than other interventions. Sarge et al. specifically wished to utilize the VR simulation's ability to encourage perspective taking. In the study, participants either experienced the simulator, watched someone using the simulator or read about overstimulation. They also had each participant take a test before and after the experience which included perspective taking, emotional concern, helping intentions, willingness to volunteer, and general positive attitudes toward people with ASD. The findings showed that participants who engaged with the virtual simulation had significantly higher scores across the test except for general positive attitudes toward people with ASD, which was the same across all groups. Sarge et al. concluded that a virtual simulation may contribute more to combating stigma, but the effect may only be short term. It was also noted that the simulation only portrayed a small part of the autistic experience, sensory overload, and that there are many stigma-inducing parts of being an individual with ASD, that were not included [14].

In another study, Mikropoulos et al. created an Augmented Reality (AR) application to simulate sensory overload experienced by children with ASD. The simulation administered six visual and two auditory stimuli individually and consecutively to simulate the sensory overload under controlled conditions. Acceptance, usability, and user experience were tested using questionnaires and feedback. Overall the study showed positive results with the participants finding the experience informative, indicating that this type of application has potential in fostering empathy [32]. A noteworthy observation is that no individuals with ASD were involved in the creation of the applications developed in either of these studies.

In the study "Brief Report: Virtual Reality to Raise Awareness About Autism", Koniou et al. (2025) created a VR application to simulate a wide variety of struggles that autistic individuals experience addressing overstimulation, social struggles etc., while having everyday tasks to complete within the simulation. To develop this application Koniou et al. consulted a focus group of four individuals with ASD. To test their application they had a control group and an experimental group where both answered a questionnaire, but only the experimental group tried the VR application. The results showed that the participants who engaged with the virtual reality simulation reported better attitudes, more knowledge, and higher openness toward ASD than the participants in the control group. Although the study was successful within its goal, the application still only portrayed a more simplified version of

the autistic experience and has not been tested for long-term effect [33]. VR has been extensively studied in interventions for individuals with ASD, particularly focusing on training and skill development [1, 34, 35, 36, 37]. However, there is a notable gap in research exploring the potential of VR to foster empathy and awareness of ASD. While VR has proven effective in training individuals with ASD, its application as a tool for promoting understanding and empathy in neurotypical populations remains underexplored. Therefore, this study aims to investigate the research question: “*To what degree can a VR simulation of overstimulation increase empathy towards individuals with ASD among students in 7th to 9th grade?*”

3 METHODS

3.1 VR Simulation

To address the research question “*To what degree can a VR simulation of overstimulation increase empathy towards individuals with ASD among students in 7th to 9th grade?*”, a VR simulation was developed as a 3D representation of a classroom in elementary school. The project was developed in Unity 6, and the Meta Quest 2 was chosen to run the VR experience. The 3D environment of the classroom for the project was based on reference images from two real classrooms at Buddinge elementary school. Using the reference images of the two classrooms, a single 3D environment of a classroom was created, which closely mirrors the physical layout and interior of the two classrooms. A comparison between pictures taken from the real classroom and the virtual version can be viewed in **Figure 1** and **Figure 2**.

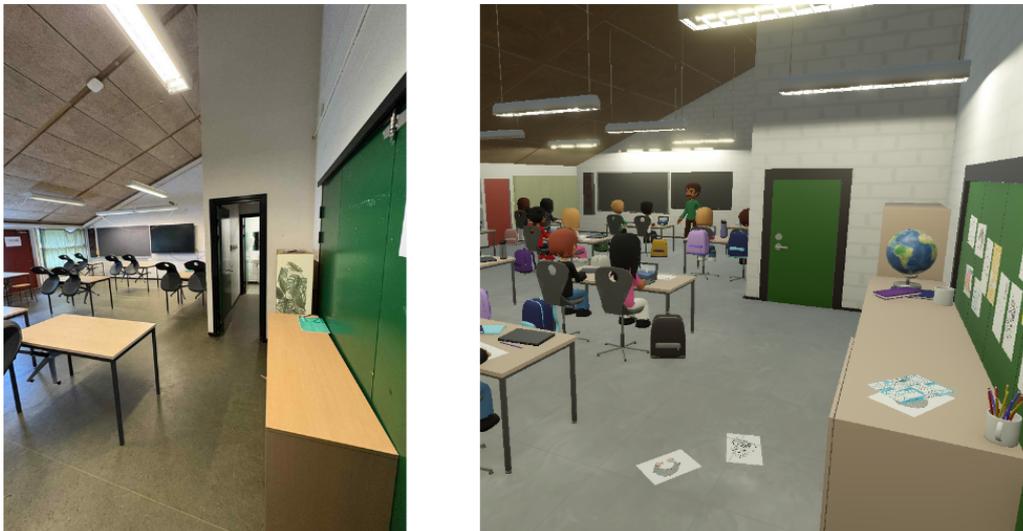


Figure 1: Comparison of the real and virtual classrooms. The left image shows the physical classroom, and the right image shows the virtual environment.

Replication of a real classroom was done to enhance the ecological validity and make the environment feel familiar and realistic to the participants, to support immersion and presence [20]. While the environment is not high poly due to frame-rate restrictions in VR, all 3D models made for the environment are realistic and as close to the real world as possible. All 3D models were created using Blender. While accuracy was chosen for creating the setting and replicating the classroom, some liberties were taken to better support the theme and message of overstimulation. Firstly, more tables have

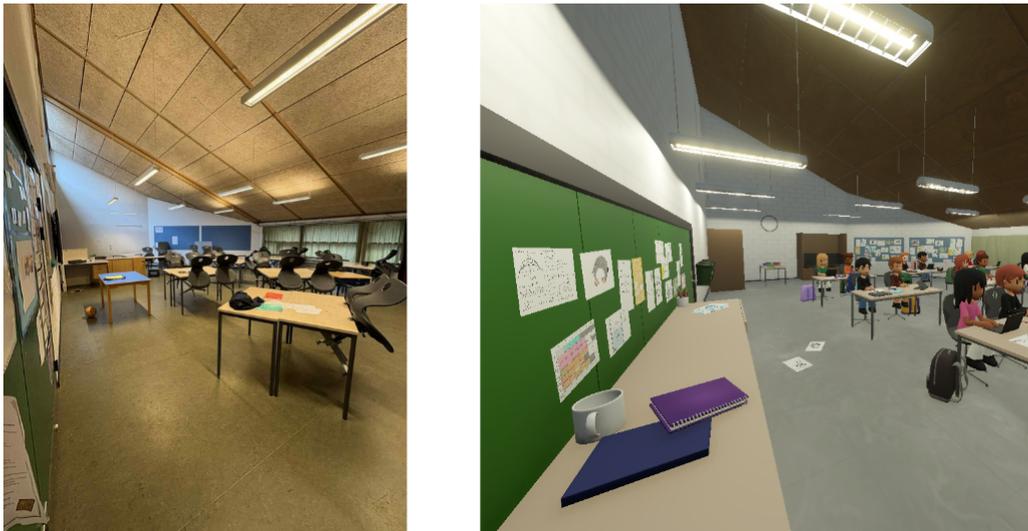


Figure 2: Comparison of the real and virtual classrooms. The left image shows the physical classroom, and the right image shows the virtual environment.

been placed in the classroom to make the room more crowded. The ceiling lights have been placed horizontally instead of vertically, as the lights were more blinding this way. More clutter and mess have also been placed on the tables.

The classroom also includes Non Playable Characters (NPC's) as students and teachers. The NPC's are intentionally less detailed than our environments, including their clothes, hair and their faces. Having less detail reduced the development time, and having them less realistic and more stylized in a more cartoony style avoided the uncanny valley [38]. While they may not be highly realistic in terms of anatomy or style, they still fit within the environments simple low-poly aesthetic. The most important aspect while the designing NPCs was the inclusion of diversity, both to support realism and to ensure that all participants trying the experience felt represented. The design aimed to make the characters outfits appear diverse and natural by having different shirts and bottoms in different colors and a variety of skin tones to represent different races, as well as hairstyles such as afro-styled hair to reflect cultural diversity. Skin tones and hairstyles can be viewed in figure **Figure 3**.

The simulation takes place inside a classroom during a class and lasts a total of 4 minutes. The experience allows the participant to embody a student with ASD in a 7th–9th grade class, experiencing overstimulation during a class. The student the participant is embodying is sitting on a chair in front of a table, which is positioned in the center of the classroom. Based on research and interviews, the center of the classroom is the most uncomfortable spot to be placed for someone with ASD and SOR, as that exposes them to stimuli from all directions. For practical reasons related to the headset and the target group, the experience is designed to be seated, and users cannot physically walk through the environment. Being seated and not being able to walk impairs the sense of immersion. Locomotion could have been implemented, but that would conflict with the principle of body-centered interaction, which emphasizes that participants should ideally walk in the virtual world by walking in the real world and could induce cybersickness [39].



Figure 3: Skin tones, hair colors and hairstyles featured in the game

3.1.1 Auditory and Visual Stimuli Design

The simulation aims to illustrate sensory overstimulation by using visual and auditory stimuli. Therefore, throughout the experience, visual and auditory stimuli gradually increases in number and intensity and becomes progressively more disruptive. The specific stimuli and scenarios included in the simulation were selected and designed based on related research and interviews conducted with 2 individuals with ASD. The auditory stimuli included an array of different sounds, such as a pen-clicking, students whispering, a clock ticking and similar classroom-related sounds. Some of the sounds were sourced from the online sound libraries Pixabay and ProSoundEffects. The rest of the sound, the teachers voice, student whispering and talking, were recorded using professional audio equipment. All sounds were processed in DaVinci Resolve. The processing primarily included adding reverb to simulate the acoustic properties of the classroom, applying equalization with a low-pass filter to gradually create a muffled effect, for example on the teacher speaking, using key-frame modulation to change volume levels, applying crossfades to transition smoothly between clarity and distortion and changing the pitch to make voices sound deeper or higher.

All the sounds in the experience are external diegetic, and there are no non-diegetic sounds such as background music or narration. This choice was intentional, as non-diegetic elements could have broken the realism and therefore immersion [40, 41]. The goal of the experience is to simulate overstimulation as realistically as possible, so all sounds come from within the scene itself. Internal sounds such as heartbeats, breathing, or inner thoughts were not included. While they can communicate stress or inner thoughts, they can also create distance, where participants hear something from another persons body or mind, which can break presence. The Point of Audition is subjective, meaning the audience hears the environment from the perspective of the character experiencing sensory overstimulation. Sounds are filtered, muffled, layered, and distorted to simulate how the environment is perceived by someone with ASD and SOR, placing the audience directly inside the characters head and therefore their perception.

Steam Audio was added to the project to provide more physically accurate spatial sound than what

Unity's built-in audio system offers. While Unity supports basic 3D audio, it does not simulate how sound interacts with the environment. Steam Audio, which uses HRTF-based spatialization, enables the generation of room geometry and the assignment of materials such as wood and glass to static elements in the environment, including walls, floors, and objects. This allows for simulation of realistic acoustic properties, including reflections, reverberation, and absorption, based on the materials characteristics. The use of Steam Audio significantly enhances the overall acoustic realism of the experience (Steam Audio, u.å.). **Figure 4** is a diagram of all sounds included in the experience and how they progress throughout the 4 minutes in relation to their volume.

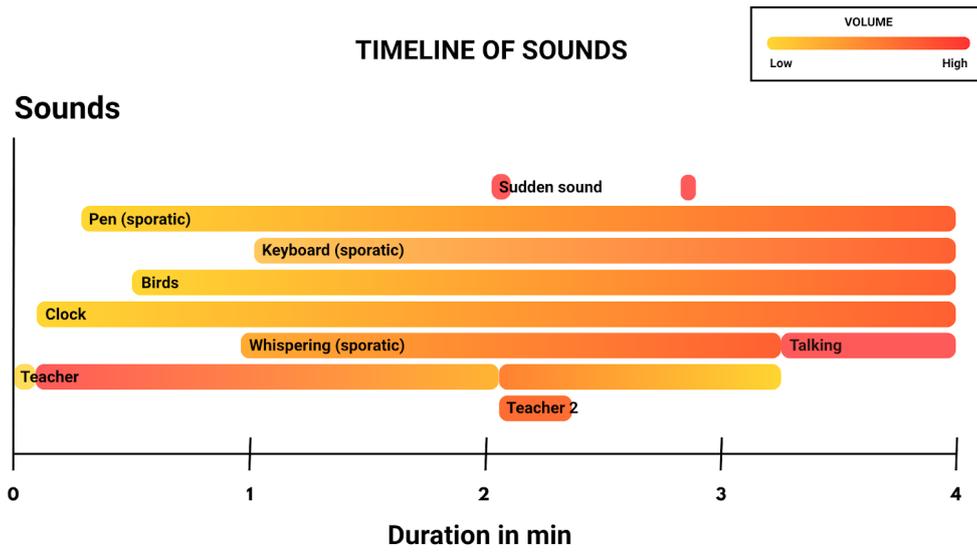


Figure 4: *Timeline of Sounds in the VR Experience. Time in minutes on the x-axis. Different sounds on y-axis*

The visual stimuli includes the lighting, the changing of colors on objects such as the curtains, posters and folders and a vignette/blur effect. Another aspect is the tables filled with objects such as pens and note-books to simulate clutter, which is also a trigger of SOR. The bright ceiling lights gradually increase in intensity over time, eventually reaching a maximum point where they begin to pulse slightly. The colors turning brightly neon intends to simulate the struggle of focusing on irrelevant stimuli instead of relevant stimuli (the teacher talking). A comparison between the start and the end of the experience of the posters' colors and the lights' brightness can be viewed in **Figure 5**. The vignette/blur effect at around 2 minutes simulates having difficulty maintaining visual focus while overstimulated. The vignette/blur effect can be seen in **Figure 6**. **Figure 7** is a diagram of all visuals included in the experience and how they progress throughout the 4 minutes in relation to their intensity.



Figure 5: Comparison of poster colors and light brightness at the start and end of the experience. The left image is taken at the start of the experience. The right image is taken at the end of the experience.



Figure 6: Vignette and Blur effect at the end of the experience

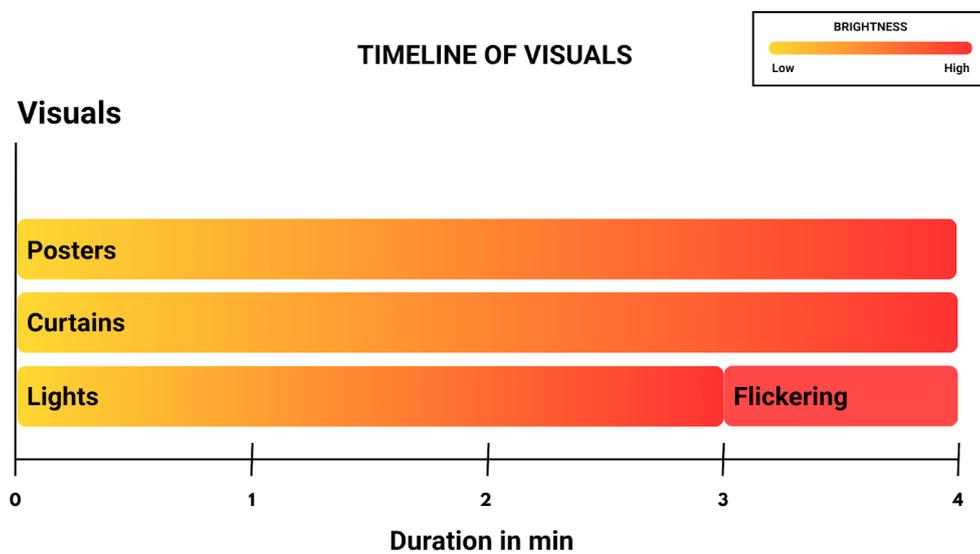


Figure 7: Timeline of Visuals in the VR Experience. Time in minutes on the x-axis. Visual stimuli on the y-axis

3.2 Participants and Ethics

The evaluation was conducted at Buddinge Skole, a Danish elementary school where all participants were enrolled. Participants were recruited using a combination of convenience and purposive sampling, which are both non-probability sampling. The evaluation included a total of 16 participants. However, questionnaire data from 4 participants were lost, resulting in a final dataset of 12 completed questionnaires. Of the participants whose questionnaires were lost, two were still included in the interview sample. The participants were aged 13-15, all in 7th to 8th grade and included male = 8, and female = 4. The target group did not include people with ASD or other disorders, that could make them vulnerable individuals regarding this project and its theme. Before conducting our evaluation and sampling our participants, a consent form was sent to the school and teachers, which distributed them to the students. The consent form had to be signed by their parents and checked by the teachers. This served to both get parental consent, as all participants are under 18, as well as their own consent and to ensure that the parents confirmed that their child did not have ASD or other disorders. Participants were anonymized with assigned IDs and their data was labeled accordingly. Preliminary information regarding the participants can be viewed in **Figure 8**

ID	Age	Gender	Familiar with ASD
1	NA	NA	NA
2	13	Female	Yes
3	15	Male	Yes
4	13	Female	Yes
5	NA	NA	NA
6	13	Male	Yes
7	13	Male	Yes
8	13	Male	Yes
9	NA	NA	NA
10	13	Female	Yes
11	13	Male	No
12	13	Male	No
13	NA	NA	NA
14	13	Male	Yes
15	13	Male	Yes
16	13	Female	Yes

Figure 8: Overview of participants ID, Age, Gender and Familiarity with ASD

3.3 Pilot Testing

The pilot test was conducted at Aalborg University. The pilot testing included three students from Aalborg University aged 23-25, (female = 2, male = 1). The test was conducted in November 2025. The pilot testing took place after the prototype test and before the final evaluation. The prototype test included two individuals with ASD to ensure that our game accurately reflected experiences of overstimulation. A description of the prototype test can be viewed in Appendix A.

The pilot testing was conducted to validate the evaluation procedure on a smaller scale, making sure interview questions and questionnaire questions were clear, especially after being translated from

danish to english, to prevent any misinterpretations before doing the evaluation on a bigger scale in the final evaluation. Furthermore, pilot testing was conducted to obtain feedback on the overall experience, make sure no usability issues were present and to confirm that the aim of the project was communicated effectively. After the pilot testing, several minor adjustments were made. One question in the IPQ and one interview question were revised, a line was added to the briefing, and a talking animation in the game was adjusted to better reflect the classmate looking at the player.

3.4 Procedure

For the final evaluation both quantitative and qualitative methods were employed to gather comprehensive feedback. The procedure for the final evaluation is outlined below.

1. Equipment is checked (disinfect VR-headset and questionnaire ready in computer).
2. The participant is welcomed and given a verbal briefing on the evaluation.
3. The participant is asked about medical conditions (e.g., epilepsy, heart problems).
4. The ID number of the participants is assigned and noted.
5. The participant answers the pre-test empathy questionnaire.
6. The participant is given the headset and headphones and the simulation is started.
7. When the simulation is finished, the participant is asked how they feel and if they need a short break.
8. The participant answers the post-test empathy questionnaire.

For the participants who were interviewed, the following steps were included:

9. A voice recorder is started and the participant gave verbal confirmation.
10. The participant is interviewed.

For all participants, the evaluation is concluded with the following steps:

11. The participant is thanked for their participation and time.
12. The participant is reminded that their data is anonymous and confidential.

3.5 Data Measures

3.4.1 Semi-structured Interviews

The interview was conducted with 10 out of 16 participants. The interview consisted of 6 questions, which can be viewed in Appendix B. The purpose of the interview was to gain a deeper understanding of the personal experience of the participants. This includes how they felt during the experience, how they perceived the experience, how it might have influenced their perspective and understanding of autism, and what aspects of the experience made an impression on them.

The interviews follows a semi-structured guide. This gives structure, ensuring that every participant answers the same question while at the same time, allowing for flexible wording and follow-up questions.

3.4.2 iGroup Presence Questionnaire

The IPQ was developed by Schubert et al. [42] and has been widely used to measure presence in virtual environments [20, 43, 44]. The Igroup Presence Questionnaire (IPQ) is a scale for measuring the sense of presence experienced in a virtual environment. It consists of 14 items across 3 subscales and one item for general presence:

1. Spatial Presence: the sense of being physically present in the VE.
2. Involvement: measuring the attention devoted to the VE and the involvement experienced.
3. Realism: measuring the subjective experience of realism in the VE.
4. General Presence: measuring the general sense of "being there".

All items are rated on a Likert scale from -3 to +3 and it is recommended to use the questionnaire in its entirety, rather than only including some subscales. Subscale and general presence scores are calculated by averaging the items within the scales. The IPQ was used to quantify participants' sense of presence in the virtual environment. It provides a standardized measure of presence, which has been validated for over 20 years and allows for classifying participants' presence scores, indicating the strength of their experienced presence [44, 45].

3.4.3 Vignette Empathy Questionnaire

The Empathy questionnaire was made using the Experimental Vignette Methodology (EVM). When using EVM, short and systematically constructed scenarios, called vignettes, are presented to participants, where they are asked to make explicit decisions, judgments, and choices or express behavioral preferences. Vignettes make it possible to manipulate and control specific independent variables and examine how these influence participants' responses. Because the scenarios are systematically controlled, they offer strong internal validity, while still remaining realistic enough to support external validity [46]. Vignettes have been used in previous research to measure empathy [47, 48, 49, 50], including a study using VR-based ASD simulation [14], and have also been applied in prepost study-designs to assess changes following an intervention [48, 49].

This study used the vignette-based empathy questionnaire both before and after the VR experience to evaluate potential changes in participants' empathic responses to an individual with autism. The questions following the vignettes were based on Shen's [51] 12-item State Empathy Scale. This scale describes state empathy as a multidimensional process consisting of affective, cognitive, and associative empathy. State empathy refers to a temporary and situation-specific empathic reaction that happens in the moment when a person is exposed to a specific scenario. The vignettes are based on the related research and the interviews. Two different vignettes were created: One vignette describes a person, Luca, sitting in the school cafeteria and the other in the hallway of the school. Both vignettes describes Luca getting overstimulated. During the evaluation, participants were presented with both

vignettes, one pre-intervention, one post-intervention. Half of the participants received the cafeteria vignette first and the hallway vignette second, while the other half received them in the opposite order. Each vignette was followed by the same set of 12 questions. The vignettes and the following questions can be viewed in Appendix C.

3.6 Data Analysis

The Empathy questionnaire consisted of 12 items across 3 subscales. For each participant, a mean score was calculated for each subscale and for the overall score, both before and after the intervention. A difference score between pre- and post-intervention was then computed for each participant, for each subscale and for the overall score. This resulted in a dataset for each subscale and for the overall score consisting of one difference score per participant. The normality of the datasets was assessed using the Shapiro-Wilk test, which indicated that all the datasets were normally distributed. Therefore, paired samples t-test was used to assess whether there were any significant difference between pre and post intervention for the subscales and overall score. The p-values, Cohens d, means and standard deviations were calculated and reported. The pre- and post intervention mean scores and standard deviation are visualized in a bar chart with error bars (**Figure 9**).

The IPQ consists of 14 items across 4 subscales. General Presence (GP), Spatial Presence (SP), Involvement (INV), and Realism (REAL). For each subscale, mean scores, standard deviations, 95% confidence intervals, and Cronbachs alpha were calculated. Cronbachs alphas values ranges between 0 and 1, where values closer to 1 indicates greater consistency. Value above 0.7 is generally considered acceptable for research purposes [52]. The meanscores and standard deviation are visualized in a barchart with error bars.

The interviews were analyzed using thematic analysis as described by Braun and Clarke [53], with support from a traditional coding method following Bjørner [54]. The traditional coding approach offered a structured way to organize the data, extract key concepts, and establish an initial codebook. Two coders independently went through all the transcripts to identify and note potential codes and emerging themes. They then met to discuss their observations and to develop a shared codebook. Subsequently, each coder examined the transcripts independently to select units of interest for coding. The coders compared their selected units, resolved any discrepancies, and agreed on a final set of units to be included in the coding. The first interview was then coded independently by both coders using the shared codebook, and intercoder reliability was measured using Krippendorffs Alpha on this initial coding. The codebook can be viewed in Appendix D. Any disagreements were discussed and resolved to finalize the coding for that interview. This iterative procedure was repeated for each interview, with the codebook being updated and previously coded transcripts revisited and re-coded as necessary. After completing the coding, the coders grouped related codes together to identify broader themes. These themes were reviewed and refined to ensure they accurately represented the data, and each theme was clearly defined and named. Based on the codings and themes, two thematic maps were created: one showing the total number of mentions for each code across all participants (**Figure 13**) and showing showing the number of participants who mentioned each code at least once (**Figure 14**). The transcribed interviews can be viewed in Appendix E.

4 RESULTS

In the following chapter, the results from the data analysis will be presented.

4.1 Empathy

Figure 9 presents the means and standard deviations for overall empathy and each subscale before and after the VR intervention. The corresponding p-values and Cohens d values are also included. The standard deviations may have been influenced by the small sample size ($N = 12$) as well as individual differences in how participants interpreted the questionnaire items.

For overall empathy, the mean increased from $M = 3.34$, $SD = 0.41$ before the VR intervention to $M = 3.63$ ($SD = 0.44$) after the intervention, representing a mean increase of 0.30 and an increase of 0.03 in variability. A paired samples t-test showed that this difference was not statistically significant, $p = 0.07$, although the effect size was moderate, $d = 0.59$.

Affective empathy remained unchanged from before $M = 3.90$, $SD = 0.51$ to after the VR experience $M = 3.90$, $SD = 0.45$, reflecting no change in the mean and a small decrease in standard deviation (0.06). This was supported by the statistical results, $p = 1.00$, with an effect size of $d = 0.00$.

Associative empathy increased from $M = 2.52$, $SD = 0.67$ to $M = 3.04$, $SD = 0.71$, representing a mean increase of 0.52 and an increase of 0.04 in variability. A paired samples t-test showed that this increase was statistically significant, $p = 0.04$, and the effect size was medium-to-large, $d = 0.68$.

Cognitive empathy increased from $M = 3.60$, $SD = 0.55$ before the VR intervention to $M = 3.96$, $SD = 0.65$ after, corresponding to a mean increase of 0.36 and an increase of 0.10 in standard deviation. However, this change was not statistically significant, $p = 0.08$, though the effect size was moderate, $d = 0.56$.

Empathy Subscale	Mean Before	SD Before	Mean After	SD After	Cohen's D
Total	3.34	0.41	3.63	0.44	0.59
Affective	3.90	0.51	3.90	0.45	0.00
Associative	2.52	0.67	3.04	0.71	0.68
Cognitive	3.60	0.55	3.96	0.65	0.56

Figure 9: Results of the empathy questionnaire. Means, standard deviations, p-values, and Cohens d for overall empathy and each subscale before and after the VR intervention.

Figure 10 displays a bar plot summarizing the before- and after mean scores for total empathy and each subscale, including their associated standard deviations.

4.2 Sense of Presence

For each subscale, their mean scores, standard deviations, Cronbach's alpha and confidence intervals are presented. The results subscales for the IPQ (GP, SP, INV and REAL) are reported individually down below.

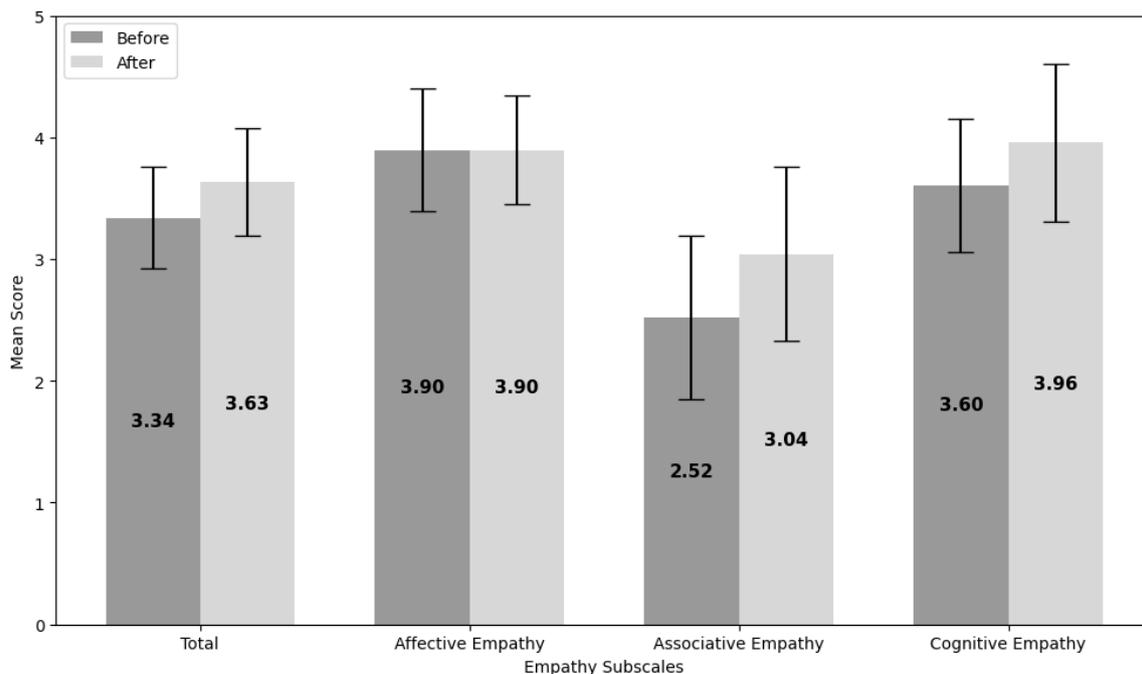


Figure 10: Bar chart and error bars of mean scores and standard deviations for the empathy subscales and total. Subscales on X-axis, Mean scores on y-axis.

General Presence (GP) indicates the general sense of being there. The mean score for GP was $M = 1.50$, $SD = 1.17$, with a 95% confidence interval of $[0.76, 2.24]$. Because GP consists of only one item, Cronbachs alpha could not be calculated.

Spatial Presence (SP) indicates the participant feeling physically present within the VE. SP consists of 5 items. The mean score for SP was $M = 0.88$, $SD = 1.50$, and the 95% confidence interval was $[0.50, 1.27]$. Cronbachs alpha for this subscale was 0.83, indicating good internal consistency above the acceptable threshold (> 0.70).

Involvement (INV) indicates the participants' attention to the VE and if they were distracted by the real world around them. INV consists of 4 items. The mean INV score was $M = 0.31$, $SD = 1.70$, with a 95% confidence interval of $[-0.18, 0.81]$. Cronbachs alpha for this subscale was 0.41, which is below the acceptable threshold.

Realism (REAL) indicates the participants' subjective experience of realism in the VE. REAL consists of 4 items. The mean score for REAL was $M = 0.08$, $SD = 1.72$, with a 95% confidence interval of $[-0.42, 0.58]$. Cronbachs alpha was 0.27, which is also below the acceptable threshold.

Figure 11 presents a bar chart with error bars over the mean scores and standard deviations for each IPQ subscale, (GP, SP, INV and REAL).

Figure 12 presents the means, standard deviations, Cronbach's alpha and 95% confidence intervals for each subscale.

4.3 Interviews

The interview data was analyzed using thematic coding, resulting in several themes and codes. To provide a visual overview, two thematic maps were created. The first thematic map, **Figure 13** shows the total number of mentions for each code across all interviews. The second thematic map, **Figure**

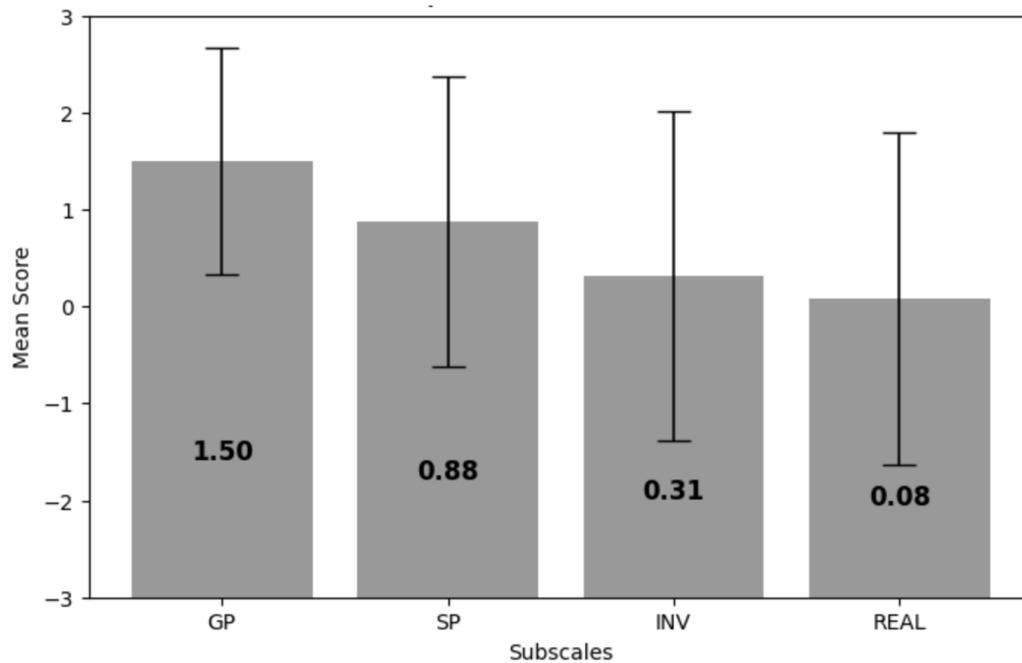


Figure 11: Bar chart and error bars of mean scores and standard deviations for the IPQ subscales. Subscales on X-axis, Mean scores on y-axis.

Presence Subscale	Mean	SD	Cronbach's α	95% Confidence Interval
GP	1.50	1.17	none	[0.76, 2.24]
SP	0.88	1.50	0.83	[0.50, 1.27]
INV	0.31	1.70	0.41	[-0.18, 0.81]
REAL	0.08	1.72	0.27	[-0.42, 0.58]

Figure 12: Mean, SD, Cronbach's Alpha and 95% Confidence Interval for each IPQ subscale

14, shows the number of participants who mentioned each code at least once.

The theme "Emotions and Effects," included codes for participants describing various feelings during experiences during the VR simulation. The most frequently coded response based on total mentions within this theme was "Irritation" (6 total mentions across 3 participants). Participants described feeling irritated by certain aspects of the simulation, for example, participant 5 stated: "There were many things that were annoying. The pen also.". The second most frequently coded response based on total mentions within this theme was "Loss of Focus" (5 total mentions across 4 participants). Participants described struggling to keep focus during the experience, such as participant 7, who stated: "It was a lot. you couldn't focus on one thing. I heard sounds coming from everywhere.". The less frequently responses included the codes "Discomfort" (3 total mentions across 2 participants), "Confusion" (2 total mentions across 2 participants) and "Stress" (2 total mentions across 2 participants). Participant 4 described being uncomfortable: "It was not very comfortable to be in the classroom.". Participant 6 described feeling confused because of all the sounds: "Yes, it was confusing because you could hear sounds from all around, with the children talking to each other." and Participant 3 described feeling stressed: "Well, it was quite stressful being in there, but I'm feeling fine now."

The theme "Understanding" included codes for participants showing either affective or cognitive em-

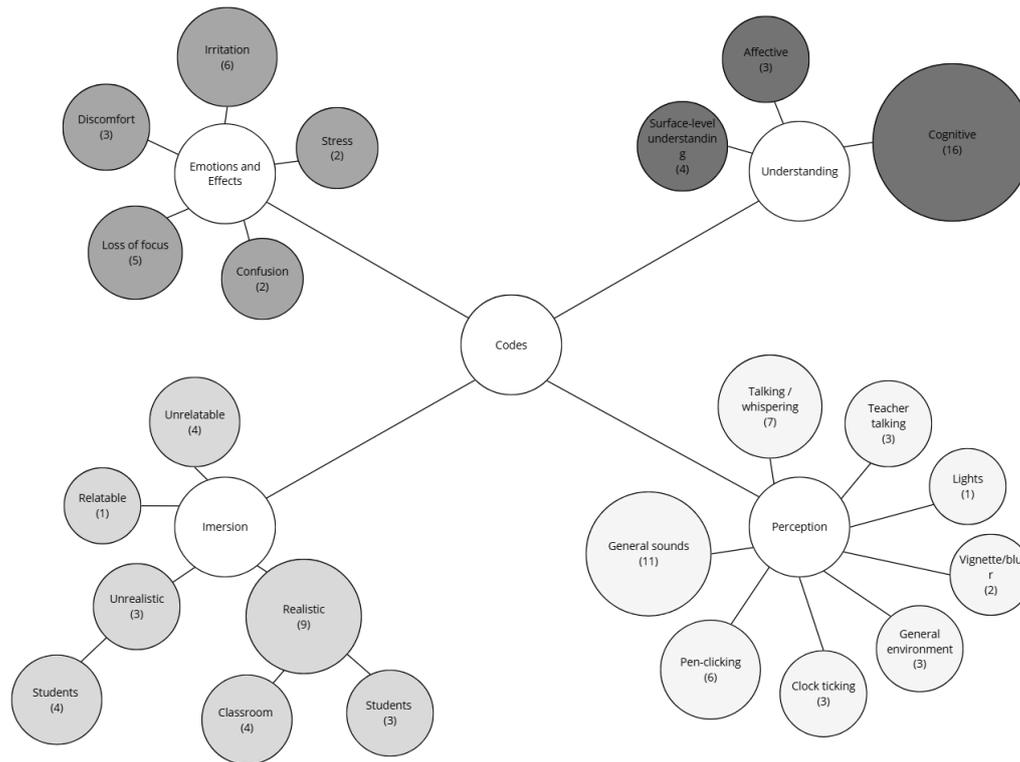


Figure 13: Thematic map of coded interview responses, showing the total number of mentions for each code across all participants.

pathy, or any surface-level understanding of the experience. The code “Cognitive Empathy” (16 total mentions across 8 participants) was the most frequently code in this category, with participant 1, who stated: “Yes. I feel now that I can better understand how difficult it actually is for them to learn like a typical student.” The code “Affective Empathy” (3 total mentions across 2 participants) was less frequently coded compared to “Cognitive Empathy”, with participant 5, who stated: “I could really feel what it would be like for a person with autism”. Lastly in this theme is the code “Surface level understanding” (4 total mentions across 4 participants), with participant 2, who stated: “I think it was trying to show me I mean, it was trying to show me what people with was it autism? Experienced it. Yes, Im not quite sure, yeah.”.

The theme “Immersion” included codes capturing participants responses of either realistic or unrealistic and relatable or unrelatable aspects of the simulation. The code “Realistic” was the most frequent code (9 total mentions across 7 participants). An example of this is participant 2, who stated: “I definitely felt it seemed very real because the classroom looked like real classrooms, the chairs were the same.”. The code “Unrealistic” (3 total mentions across 3 participants) was mentioned less frequently. An example of this is participant 3, who stated: “Like, really, we humans dont talk like that. The children wouldnt talk like that, no.”. The code “Relatable” (1 total mentions across 1 participants) was mentioned the least with only 1 mention by Participant 4, who stated: “Like, when people were talking. Its just how it is in the classroom.”. The code “Unrelatable” (4 total mentions across 4 participants) was more frequently than “Relatable”. An example of this i participant 1, who stated: “Thats not really how I feel in reality? So its probably just something I dont relate to.”.

The theme “Perception” included mentions of the auditory and visual stimuli within the experi-

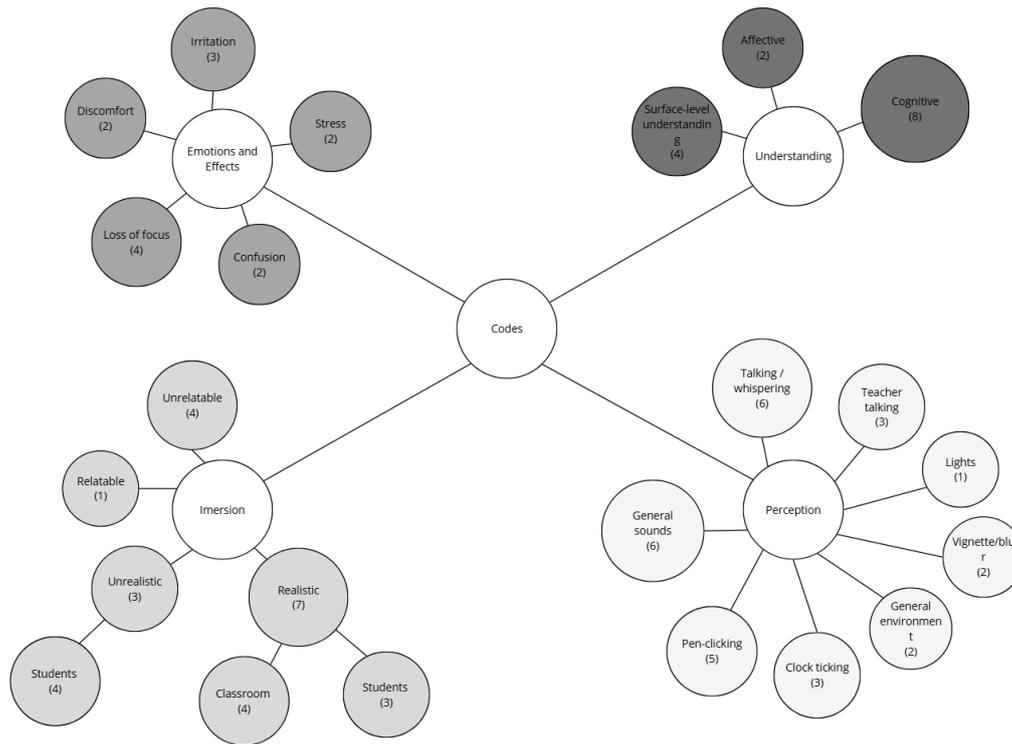


Figure 14: Thematic map of coded interview responses, showing the number of participants who mentioned each code at least once.

ence. The most frequently mentioned code was “General Sound” (11 total mentions across 6 participants), “Talking/whispering” (7 total mentions across 6 participants) and “Pen-clicking” (6 total mentions across 5 participants), such as Participant X, who stated: “*And everyone was talking around me, and there was someone who had a pen and so on, yeah, looking at it. It was quite annoying.*”. The codes “Clock ticking” (3 total mentions across 3 participants), “General environment” (3 total mentions across 2 participants), “Vignette/blur” (2 total mentions across 2 participants), “Lights” (1 total mentions across 1 participants) and “Teacher talking” (3 total mentions across 3 participants) were less frequently mentioned.

5 DISCUSSION

The aim of this study was to investigate whether a VR-based overstimulation simulation could increase empathy toward individuals with Autism Spectrum Disorder (ASD) among student in 7th to 8th grade. The results of the Empathy questionnaire, the IPQ and the interviews will be discussed below.

Overall empathy increased slightly with 0.29 after the VR experience, although the change was not statistically significant ($p = 0.07$). Despite this, the effect size was moderate ($d = 0.59$). A similar pattern was observed for cognitive empathy, which slightly increased with 0.36, and also had a moderate effect size ($d = 0.56$), but did not have a statistical significance ($p = 0.08$). This aligns with the interview data, where several participants described gaining a better understanding of how sensory overload affects individuals with ASD. Participants often articulated this in terms of perspective-taking

(e.g., I thought, it must be really stressful to see the world like this), indicating a cognitive engagement with the experience. This is also reflected in the interview, where cognitive empathy was the most frequently occurring code. Participants often expressed understanding of the struggles experienced by individuals with ASD and SOR, such as one participant stating: *“I thought, it must be really stressful to see the world like this.”*. No significant differences, but moderate effect sizes indicate that the intervention might have had a meaningful effect that the small sample size could not detect ($N = 12$).

Associative empathy was the only sub-scale that showed a statistically significant increase ($p = 0.04$). Despite having the lowest score both pre and post intervention, and the highest SD ($SD = 0.71$) among all sub-scales, the increase suggests that the VR experience may have helped participants connect aspects of the simulation to situations described in the vignette. Interestingly, associative empathy was not reflected in the interviews. Several participants explicitly stated that it felt unrelatable, specifically one participant stated: *“No, maybe not in that personal way, but because I do know that it's not really how I feel in real life.”*. There are several possible explanations for this discrepancy between the quantitative and qualitative findings. The questionnaire directly measures associative empathy, whereas in the interview the participants had to express relatability spontaneously, as none of the interview questions asked about the VR in relation to their own experiences. Furthermore, the vignette describes a general school situation of feeling overwhelmed. Participants may have related to the scenario on a general emotional level, recognizing overwhelm, whereas the VR experience showcased overstimulation visually and auditorily in a way that most participants did not personally recognize. Although this is not surprising as none of the participants themselves were diagnosed with ASD or other disorders. Despite participants reporting that the VR experience felt unrelatable, associative empathy may have increased in the questionnaire because the VR simulation provided a recent concrete example of overstimulation. Even if participants could not personally identify with the experience, having just observed it likely made it easier for them to relate their own experience in the VR to the situation in the vignette when responding.

Affective empathy did not increase at all, but remained the highest scoring sub-scale before and after the intervention. The SD decreased slightly, showing more consistent responses after the intervention. One explanation is a ceiling effect, where participants might already have had a strong baseline level of affective empathy, making less room for increasing it. The VR Simulation focused on realism and showcasing overstimulation through visual and auditory stimuli. It did not include storytelling or character-building of the avatar, which the participants were embodying. This might have limited the emotional connection to the avatar. While participants frequently described their own feelings of irritation, stress, and distraction, they rarely described emotional concern for another person. Only 2 participants mentioned affective empathy, where one participant stated: *“I could really feel what it would be like for a person with autism.”*. To increase affective empathy, the experience could in the future work on creating a stronger persona to embody with more storytelling and showcasing of emotional reactions to the overstimulation.

The empathy results suggest that the VR intervention had a modest impact on cognitive and associative empathy but did not influence affective empathy. With a larger sample size, some of these effects may have reached statistical significance.

The IPQ results indicate a moderate but mixed sense of presence. GP had the highest score ($M =$

1.50), indicating that participants felt moderately there in the simulation. However, the relatively large SD (1.17) reflects considerable variability in presence experience, and the wide confidence interval suggests that the true population mean remains uncertain due to the small sample size. SP was the second-highest score ($M = 0.88$) and the only sub-scale with acceptable internal consistency ($\alpha = 0.83$). Participants experienced some sense of physically being in the virtual environment, yet the variability and moderate mean might be influenced by the limited interactivity and movement within the simulation, which can reduce the sense of embodiment and immersion in the virtual space. Despite these moderate scores, the interviews indicated that all but one participant did experience emotional reactions during the VR simulation, such as irritation, stress, confusion, and discomfort. These negative emotional reactions suggest that the simulation successfully affected participants' experience on an emotional level and that their response might resemble how they would have reacted in the real world, which is an indicator of presence. Together, this suggests that the VR experience successfully, to some degree, did succeed in simulating overstimulation. The participants' responses regarding sensory perception provides further insight into how the VR simulation was experienced. The Auditory stimuli were clearly the most noticeable, with General Sound mentioned, Talking/whispering, Pen-clicking being mentioned the most by most participants. The auditory stimuli were often described in relation to emotional reactions. For example, one participant stated: *"And everyone was talking around me, and there was someone who had a pen and stuff, yeah, looked at it. It was quite annoying."* This suggests that the feelings of irritation, stress, and distraction reported by the participants were primarily elicited by auditory stimuli.

In contrast, visual cues were much less frequently mentioned. Only a few participants noted the general environment, vignette/blur and the lights. Furthermore, there were no mentions of changes in color, clutter, or other visual manipulations. This suggests that the visual stimuli were less noticeable and less impactful compared to auditory stimuli. These findings suggest that while the VR simulation successfully created an overstimulating auditory environment, the visual elements were relatively unnoticed in participants' experience. For future iterations, enhancing the integration of visual overstimulation could strengthen the overstimulation from visual stimuli. While auditory triggers were the most commonly reported trigger of SOR according to related work, more attention should be given to effectively convey visual overstimulation.

INV and REAL showed low mean scores and low internal consistency, indicating that these results should be interpreted with caution. However, the interview data provide insight into how participants experienced these dimensions.

The REAL sub-scale had the lowest mean score of all IPQ measures ($M = 0.08$) and the highest standard deviation ($SD = 1.72$), indicating substantial spread in participants' perception of realism. The 95% confidence interval $[-0.42, 0.58]$ suggests that the true population mean is uncertain and might range from slightly negative to moderately positive. Despite being the lowest scoring sub-scale, participants frequently described the environment as realistic. 7 participants described the overall setting as realistic, and several mentioned the classroom and students as realistic. One participant stated: *"I definitely thought it felt really realistic, because the classroom looked like real classrooms, the chairs were the same."* Participants' descriptions of the classroom suggest that the environment successfully achieved ecological validity, as it resembled real-world classrooms. The NPC-students were described as realistic due to their behavior, specifically their talking, one participant stated: *"I thought that thing with people*

kind of talking in the background, I feel was quite realistic.” However, 4 participants also described the students as unrealistic, mainly due to their cartoon-like design and disproportionate bodies. One participant stated: *“The people just didnt look real. Everything just looks kind of cartoonish.”*. The character design took away from the ecological validity and perceived realism of the environment. Improving avatar proportions and adopting a more neutral visual style could enhance realism in future iterations. Additionally, future work should include preliminary testing of character-design to ensure that design choices align with participants perceptions before full implementation.

The INV sub-scale also had a relatively low mean-score ($M = 0.31$) and a high SD ($SD = 1.70$). Participants were unable to move freely, and could not engage actively with the environment, which likely reduced their sense of presence and active participation. While the sensory stimuli successfully elicited emotional reactions such as irritation, stress, and distraction, there was a lack of agency and no clearly defined objectives. The experience focused more on perception, the visual and auditory stimuli to be experienced, than having tasks to do. This might may have limited the overall involvement in the simulation. For future work, increasing interactivity, allowing movement, including more meaning full interactions with the environment and more clear tasks or goals, could strengthen the engagement and enhance the subjective experience of involvement in future iterations.

The low Cronbachs alpha for both REAL ($\alpha = 0.27$) and INV ($\alpha = 0.41$) further suggests limited internal consistency. This could be because of several reasons. This could be due to the variability in how the participants interpreted the individual items, the small sample size, and potential effects of translating the questionnaire into Danish. Some items may have been interpreted inconsistently, leading to divergent responses across participants. The low alpha values suggest that these sub-scales may not have fully captured the participants experience, and should be interpreted with caution in this study. Future studies should focus on improving Cronbachs alpha and pre-test translated versions.

In summary, the VR overstimulation simulation increased cognitive and associative empathy toward individuals with ASD moderately and elicited clear emotional reactions, particularly through auditory overstimulation. The experience successfully conveyed aspects of overstimulation, although limited interactivity and goals, low salience to visual stimuli, and low internal consistency in IPQ sub-scales suggest room for improvement. Future iterations could focus on enhancing visual overstimulation, increasing interactivity, and redesigning characters.

6 CONCLUSION

In this study, a qualitative and quantitative evaluation was conducted of the proposed VR simulation designed to show the experience of sensory overstimulation in a school environment. The evaluation combined empathy questionnaire, presence questionnaire (IPQ), and semi-structured interviews to investigate if the VR experience could enhance empathy among students in 7th-9th. The results suggests a modest increase in overall and cognitive empathy, though these changes were not statistically significant, which is likely due to the small sample size. Associative empathy did show a statistically significant increase, suggesting that the VR simulation helped participants relate the experience of overstimulation in VR to the general experiences described in the vignette, even if the VR was not directly personally relatable. Affective empathy remained is the highest mean score but unchanged pre to post intervention, possibly due to a ceiling effect and the limited emotional narrative within the

VR experience.

The IPQ results suggested that participants experienced a moderate sense of presence, with the strongest responses for general and spatial presence. In contrast, involvement and realism scored lower and showed inconsistent responses. Even so, interviews revealed that most participants still felt emotional reactions, including irritation, stress, and distraction, mostly triggered by auditory overstimulation. This indicates that the VR simulation successfully conveyed aspects of sensory overload, although factors like limited interactivity, absence of clear objectives, and character design may have lessened the overall sense of presence. Future iterations could improve the experience by enhancing visual overstimulation, increasing interactivity, adding clear tasks, and redesigning characters. Incorporating more storytelling to communicate the avatars feelings could also help strengthen affective empathy. Additionally, using a larger sample and refining the IPQ to improve consistency would allow future studies to more reliably detect statistically significant effects.

In relation to the research question: *“To what degree can a VR simulation of overstimulation increase empathy towards individuals with ASD among students in 7th to 9th grade?”*, this study proposed a VR simulation that allowed participants to experience overstimulation in a classroom. The virtual environment was designed as a realistic replica of a classroom, featuring a detailed 3D environment with stylized and naturally animated NPCs, as well as spatialized audio and visual effects. Results and feedback from the qualitative and quantitative evaluation (N = 12) demonstrate that VR-based overstimulation simulations can increase empathy toward individuals with ASD, particularly in terms of cognitive and associative empathy, and help peers gain a better understanding of the daily challenges faced by individuals with ASD in overstimulating environments such as classrooms.

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1 Appendix

1.1 Appendix A - Prototype Test, Procedure

Formål med testen:

At se om applikationen er funktionel og få feedback på de forskellige effekter og lyde, samt andre kommentarer.

Introduktion:

Hej! Tak fordi du vil være med i vores lille test. Du skal prøve en kort oplevelse med de her VR-briller, det hele varer mindre end 15 minutter, og du kan ikke gøre noget forkert så bare vær nysgerrig og åben.

Efter VR-Oplevelsen skal du udfylde et lille spørgeskema med 6 spørgsmål, omkring din oplevelse. Det er helt frivilligt at være med, og du kan stoppe eller holde pause når som helst, uden at skulle forklare hvorfor. Hvis du bliver utilpas, siger du bare til, så stopper vi med det samme.

Inden vi starter, vil vi lige høre:

- Lider du af epilepsi, hjerteproblemer eller noget andet, vi skal være opmærksomme på?
- Har du en diagnose inden for autismspektret?

Alt det, vi samler ind, bliver behandlet fuldstændigt anonymt, så ingen kan se, hvem du er. Dine oplysninger bliver kun brugt til vores projekt, og vi deler dem ikke med andre. Kender du til begrebet sensorisk overstimulation som folk på autismspektrummet kan opleve? Og kan du forklare kort hvordan du forstår begrebet? (en tilstand hvor man reagerer mere intenst eller overdrevent på sensoriske stimuli som lyd, lys, berøring eller lugt)

Netop dette kommer du til at opleve i den her simulation, hvor du befinder dig i et klasselokale. For kan du ikke interagere med verden, men blot opleve og undersøge dine omgivelser og se hvordan det hele udvikler sig.

Tak fordi du hjælper os og husk, du bestemmer selv hele tiden, om du vil fortsætte eller stoppe.

- Monter headset og juster stropper og placering så default verden ikke er sløret

Fremgangsmåde:

Kort intro til applikationen og content warnings (flashing lights), og at vi efterfølgende giver nogle korte spørgsmål omkring applikationen. - Spil-test de prøver applikationen - Questionnaire - Efter spørgeskema, et kort interview / nogle spørgsmål.

Generelt

- Hvordan oplevede du lydene lagde du mærke til bestemte ting?
 - Svar: Især tastaturet, og dem der hviskede bliver overstimuleret skal jeg lokalisere lydende

kunne ikke placere hvor det var henne, det tilføjede at man ikke kunne finde ud af hvor hvisken var

- Hvordan oplevede du de visuelle elementer lagde du mærke til bestemte ting?
 - Svar: Tingene på bordet, klikken af penden, forsvandt lidt, mest lydende, blev lidt slørret til sidst.

Følelser

- Hvordan følte det at opleve alle sanseindtrykkene samlet?
 - Svar: Det var virkelig ubehageligt, ting som selv har oplevet i mindre klasser og nu her, har ikke kontrol, var sendt på en opgave at lytte efter læren men det kunne man ikke med hvad der foregik.
- Hvordan fik oplevelsen dig til at føle generelt? Stress, Ubefrag?
 - Svar: Ubefrag, stress især med hvisken.
- Kunne du følge med? Var der elementer, der forstyrrede dig i at følge med?
 - Svar: Tastatureklikken, hvisken, og uret var stressende, og den der klikken med ikke så længe.

Forståelse og Mening

- Gav det dig en ny forståelse eller perspektiv ift. hvordan det kan være at opleve overstimulation? Var der noget specifikt ved oplevelsen, der gjorde indtryk på dig?
 - Svar: Generelt kom ind med forventningen at det ikke ville virke, men overrasket for overstimuleret man blev af det.
- Følte oplevelsen i sin helhed oplysende for dig? (SOR)
 - Svar: Ingen kommentarer.

Forbedring

- Var der noget, du ville ændre? (fx lydstyrke, tempo, farver)
 - Svar: Flickering lys (men lagde ikke mærke til dem) så kan være mere flickery.
- Hvad fungerede bedst og hvad fungerede mindre godt?
 - Svar: Bedst: hvisken den fungerer bedst, kunne ikke finde hvor det kom fra, mindst: lysene siden lagde ikke mærke til det pga lydene.
- Er der noget, du savnede i oplevelsen?
 - Svar: Intet Svar.
- Andre Kommentarer?
 - Svar: Føler nu jeg lægger selv mere mærke til hvad jeg oplever. Men ellers, at man kunne se nederst i headsættet tog en lidt ud af det, og håbede man kunne bruge hænderne.

1.2 Appendix B - Final Test, Interview Questions

Debrief Interview

1. Kropslig og følelsesmæssig reaktion
 - (a) Hvordan har du det lige nu efter oplevelsen? Føler du noget kvalme, svimmelhed eller anden ubehag? (Vær opmærksom på kvalme eller ubehag)
2. Følelser og indtryk under oplevelsen
 - (a) Hvilke tanker eller følelser havde du, imens du var i oplevelsen? (Mulig Opfølgning: Var der noget særligt, der gjorde, at du fik det sådan?)
3. Forståelse og perspektiv (empati-relateret)
 - (a) Hvad synes du, oplevelsen prøvede at vise eller fortælle dig? (Mulig Opfølgning: Hvad i oplevelsen gjorde, at du tænker sådan?)
 - (b) Har oplevelsen givet dig anden eller ny forståelse af, hvordan det kan være at have autisme og sensorisk sensitivitet? (Mulig Opfølgning: Hvilken forståelse føler du, du har fået og hvad i oplevelsen gjorde, at du forstod det bedre?)
4. Realisme og tilstedeværelse (IPQ-relateret)
 - (a) Hvordan følte det at være i oplevelsen? Følte det virkelig? (Mulig Opfølgning: Hvorfor synes du oplevelsen følte virkelig / ikke virkelig)
5. Helhedsindtryk og refleksion
 - (a) Var der noget i oplevelsen, du hæftede dig særligt ved noget, du syntes var spændende, forvirrende eller ubehageligt? (Mulig Opfølgning: Hvad gjorde det indtryk på dig?)

1.3 Appendix C - Vignette Questionnaires

Vignette 1: På et bord i hjørnet af kantinen sidder Luca og spiser sin frokost. Ved siden af sidder en gruppe elever og diskuterer. De snakker meget højt. Luca prøver at koncentrere sig om sin mad, men lydene fra stemmer og klirrende bestik gør det svært. Så kommer en hel klasse stormende ind. Pausen er lige begyndt. Larmen stiger, og Luca begynder at sidde uroligt på stolen. Luca tager sine hovedtelefoner på for at lukke lydene ude, men støjen trænger stadig igennem. Til sidst tager Luca sin taske og skynder sig ud af kantinen.

Vignette 2: Klokkerne ringer, og eleverne begynder at strømme ud på gangen. Luca går langs væggen med sin taske på ryggen. Rundt omkring fylder lyden og skoene klapper mod gulvet, stemmer skaber ekko, og undervisere åbner og lukker døre. Lamperne ovenover skinner skarpt, og det skarpe hvide lys får Luca til at knibe øjnene sammen. En elev løber forbi og støder ind i Luca uden at sige undskyld. Luca mærker, at pulsen stiger og skuldrene spænder. Stemmer blandes, hvert skridt føles højere, og Lucus hovedet begynder at rumle. Til sidst tager Luca sin taske og skynder sig ud af gangen og ind i klasselokalet for at finde lidt ro.

Questions:

1. Jeg føler med Luca, fordi situationen virker svær.
2. Jeg synes synd for Luca, fordi det ser ud til, at Luca har det ubehageligt.
3. Jeg føler omsorg for Luca og vil gerne have, at Luca får det bedre.
4. Jeg bliver bekymret for Luca, når jeg forestiller mig, hvordan Luca har det.
5. Jeg bliver selv lidt urolig, når jeg tænker på det, Luca oplever.
6. Jeg får en følelse af stress, når jeg forestiller mig at være i Lucas situation.
7. Jeg mærker spænding i kroppen, når jeg tænker på, hvordan Luca har det.
8. Jeg får det lidt utilpas, når jeg forestiller mig, at jeg var Luca.
9. Jeg kan sætte mig i Lucas sted og forestille mig, hvordan situationen føles.
10. Jeg forstår godt, hvorfor Luca vælger at forlade stedet for at finde ro.
11. Jeg kan nemt leve mig ind i, hvordan lydene og stemningen påvirker Luca.
12. Jeg kan se situationen fra Lucas perspektiv.

1.4 Appendix D - Codebook

Theme	Sub-Theme	Codes		
Emotion & Effect	Negative	Irritation		
		Stress		
		Confusion		
		Discomfort		
		Loss of focus		
Understanding	Empathy	Cognitive		
		Affective		
	None	Surface-level understanding		
Perception	Sounds	General sounds		
		Pen-clicking		
		Keyboard-clicking		
		Talking / whispering		
		Clock ticking		
		Teacher talking		
		Vignette/blur		
		Lights		
		Immersion	Environment	Classroom
				Students
General	Realistic			
	Unrealistic			
Relatability	Relatable			
	Unrelatable			

Figure 15: Codebook.**1.5 Appendix E - Transcribed Interviews**

View the zipfile "Raw_Data" for the transcribed interviews