



Research article

Conceptual knowledge and sensitization on Asperger's syndrome based on the constructivist approach through virtual reality

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ABSTRACT

The immense capabilities provided by virtual reality for enhancing empathy and altering social behaviors, make it possible to use virtual reality for the promotion of the understanding between individuals. A social issue that needs to be addressed is the discrimination and marginalization of people with Asperger's syndrome (AS) from the working force, stemming from the lack of recognition and justification of their oddities. In this paper, the effectiveness of a virtual reality simulation, raising awareness on this specific issue, is evaluated. Awareness is a term used in this research to refer to the combination of conceptual knowledge and sensitization on a specific issue. An experiment with between-group design has been carried out, where half of the participants used the simulation via a VR headset device and the other half was given a transcript of relevant medical articles instead. The comparison between the two groups indicates that the group which used the simulation gained more knowledge on AS than the group which used the transcript. Moreover, the parameter of sensitization indicates positive correlations with place illusion in the VR group.

1. Introduction

The present paper focuses on the fields of Virtual Reality (VR) technologies and rehabilitation psychology. VR techniques, if used appropriately, benefit both clinical and research domains within the field of psychology, as the critical role of computer simulation continuously increases in all areas of science and engineering [1]. Specifically, this paper attempts to assess a 3D computer simulation, created from square one for the purposes of this research, following the paradigm of many similar pieces of research concerning simulations of people with disabilities, racial differences, etc. In a similar manner, this research focuses on a marginalized and often stigmatized minority as the out-group, namely people with Asperger's syndrome (AS). This syndrome often goes undetected in the early stages of a person with AS and this may cause problems in later life, such as unemployment, depletion of social relationships, depression, and anxiety [2,3]. However, if the person is early diagnosed with AS, the proper conditions for building a safe, understanding, social

environment during the upbringing can be applied in order to benefit the person's quality of life [2].

VR technology offers the opportunity of demonstration of critical conditions, on which there is a limited understanding of the functional impact concerning physical, cognitive and perceptual abilities [1]. In other words, the simulation aims to enhance the knowledge and provide a deeper understanding of neurotypical individuals toward "aspergic" individuals and not to be therapeutic toward AS. The term neurotypical refers to the majority of people, who do not have any autistic spectrum disorder such as AS [4]. The VR simulation focuses on a certain incident, in which neurotypical users have no real impact on the turn of events but they are assigned the role of mere observers from the perspective of a man with AS. Raising awareness by using VR technology is the main focus of the project, whereas awareness is a term used in this research to refer to the combination of conceptual knowledge and sensitization on a specific issue. For the current paper, conceptual "knowledge" refers to the understanding of abstract ideas as well as their interconnectivity and the term "sensitization" refers to the positive attitude toward a situation,

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which requires some more thorough attention from an empathic perspective. More explanatory, this work deals with ways of conveying information and emotions, which can hardly be mediated between individuals or groups of people.

VR has been specifically chosen, between other media on purpose, in order to be studied on the subject of raising awareness for social issues. VR technologies are highly valued for their empirical learning capabilities, through the constructivist approach, which treats knowledge as a dynamic construct affected by the conscious participation in certain experiences [5]. The constructivist approach suggests that the active construction of knowledge is interconnected with free discovery [5]. Relevant to problem-solving and free discovery are innovative, technology-assisted learning environments, which are breaching the gap between knowledge acquirement and personal experience [6]. Human interactions and behaviors in a Virtual Environment (VE), which can also be considered as a learning environment, tend to alter according to the perceived properties of the avatar by its user [7]. The playful approach of VR technology in conjunction with constructivist learning is found to magnify the curiosity of learning more about a specific topic, which in turn contributes to the success of the learning process [8]. Based on these findings, a 3D avatar is an adequate medium for raising awareness, by urging the individual to focus more on situational rather than dispositional factors associated with a person's behavior, thereby realizing their actions and attributing meaning to them [9].

Huang, Rauch, and Liaw enumerate a number of constructivist approach learning strategies for VR learning environments [5]. Three of these strategies were considered to be essential for the VR simulation of the present project. Firstly, "situated learning" refers to the use of immersion, the deep engagement which is offered through the interaction between the user and the tasks of the VE. The deep reflection and experimentation on subjects and events of the virtual world carry over into the real world as well. Secondly, "role-playing" offers the capability to the users of having experiences through different personalities (e.g. with the assistance of 3D avatars) and experimenting with various attitudes, characteristics and points of views. The chances of such experimentation are rarely offered in the real world [10]. "Creative learning", requires the use of imagination for the visualization and construction of concepts from stimuli provided in a VE [5].

This research is more relevant to the topics of disability, senility simulations, simulations of psychological disorders and social issues in VR rather than the use of VR for the treatment of AS or any autistic spectrum disorders, which is also a common practice [11]. Schultheis & Rizzo addressed some potential areas of VR technology applications, which were categorized as "rehabilitation interventions and training", "vocational and social training" and "client and family education" [1]. The last area falls in the domain of the present research, taking into consideration the crucial task of cultivating understanding in the difficult situation of another person or even allowing a third party to have a glimpse of such a situation, by experiencing it first-hand. Examples of such applications are the promotion of empathy in families of people who survived a stroke or faced visual, perceptual difficulties and motor disabilities [1].

Other similar VR simulations, recreate the hallucinations and the skewed reality of a person with schizophrenia, supporting the use of head mount displays. A piece of research by Penn, Ivory & Judge, about schizophrenia in particular has similarities in methodological approach with the present research, examining the effectiveness of a VR simulation in "inducing empathy", in an attempt to combat the stereotypical views on schizophrenia. The VR simulation has been contrasted with a written transcript about schizophrenia as well and the results showed that the VR simulation was inducing more empathy than the transcript [12]. The efficacy of VR simulations in the experience of the positive symptomatology associated with schizophrenic spectrum and other psychotic disorders suggests that VR systems have a tremendous potential in utilizing the constructionist learning approach within psychology education [13].

1.1. Motivation

People with AS rarely decide to actively address any issues regarding their peculiar case and the difficulty of coping with the rest of the community they live in. Instead, they focus on ways to invent mechanisms for making themselves less visible, as a countermeasure for the severe social anxiety people with AS experience and their struggle for self-acceptance [14]. This tactic, as comforting as it may be for the individuals with AS, sometimes consolidates the broader issue: The lack of general awareness regarding AS in society. Social deficiencies of people with AS often make them being perceived as eccentric and awkward but if their behavior could be correctly acknowledged, specified and justified then there would be less room for negative interpretations. Unfortunately, the lack of cognitive deficiencies in children with AS prevents early diagnosis [15]. The ratio of children born with AS worldwide ranges roughly from 0.67 to 48 in every 10,000 children. These statistics require further investigation [16]. "It is estimated that about 50% of children with Asperger's disorder reach adulthood without ever being evaluated, diagnosed, or treated" according to researchers [17].

The scenario of the application is about a person with AS at a workplace, who faces interpersonal difficulties with his co-workers because of AS. The concept of the scenario has been selected to be as such since it is very common for AS patients to end up in extremely awkward social situations with co-workers or clients, which ultimately result in "severely damaging the employment histories of AS patients" [18]. Research reveals high rates of unemployment or underemployment of people with AS, with unemployment ranging from 5% to 55%. All of the employees with AS have a high chance of having a great variation in their professions as well as negative experience patterns at their workplace. Some of these negative experience patterns could include the inability to adapt to new work routines, problems with interactions between employers and co-workers and the lack of their competence recognition [2]. The motivation behind this research is the rising of awareness toward AS on a larger scale, mainly for the benefit of individuals with AS, concerning their often mistreatment at the workplace.

1.2. Asperger's syndrome

Social behavior and interaction are some of the most serious challenges people with AS have to face. They hardly comprehend humoristic representations, which rely on mentalistic explanations, such as semantic relations and most prominently, the theory of mind. To put it simply, they struggle to comprehend jokes, which require a change of perspective in social situations. Instead, they prefer to focus on more pragmatic aspects of the humoristic representation [19]. People with AS tend to have a significantly higher verbal intelligence quotient [17,20,21] even though their language may be overly pragmatic, repetitive and often needlessly formal. Wing and Gould, in their study, suggested that children with AS could be labelled as "active and odd" in their social behavior [21].

Also, AS is not limited to the social communication and behavior of the patient. People with AS are known to share a set of similar characteristics, such as idiosyncratic humor, inability to maintain eye contact, extreme interest in memorizing trivial information on certain subjects, brief attention spans, narrow interests, repetitive routines and motor clumsiness [2,17,22]. People with AS have a more sensory way of processing the stimuli in their environment than neurotypical people. Some of them require increased sensory stimulus and others take a defensive stance to stimuli. Like every neurotypical person has unique characteristics, which vary, the same applies to AS patients. Not every person with AS displays the same characteristics at the same intensity [22,23].

A final layer of complexity amasses on AS diagnosis by gender. Statistic researches regarding the prevalence of AS on males and females incline disproportionately toward males [16]. This inclination leads to the hypothesis that either males are more biologically prone to having AS or females are too good in faking the diagnostic criteria of AS and pass on undetected. Males and females cope with AS in a different manner.

Females are more empathetic and understanding of emotions. Instead of empathizing, females with AS observe, analyze and imitate social behaviors in order to “fit in”. Even though the imitation offers them surface sociability, it deprives their social and self-identity, causing them feelings of anxiety and stress [24]. The “chameleon” cases of women with AS renders any awareness-raising attempts obsolete when it comes to non-professional learners. In order to avoid any confusion and because this research is on an initial stage, the present research will focus exclusively on men with AS. The ways that people with AS behave and interact in social circumstances, as described above, are presented in the VR application's scenario, as explained in section 2.2.

1.3. Designating empathy

The cultivation of empathy through VR is not the main focus of this research but it is definitely one of the advantages of VR technologies, assisting a better understanding of another person's perspective and a component of raising awareness. Virtual Environments and 3D avatars representing people, who appear to belong in a different racial group than their users, were used to study racial bias. An experiment included 60 light-skinned females who were evenly distributed in 4 groups. Each group was exposed in the condition of embodying a light-skinned, dark-skinned, and “alien-skinned” avatar or watching a disembodied dark-skinned avatar move in a mirror inside the VE. The participants used a Head Mount Display (HMD) and a motion capture suit to synchronize their movements with the avatar's movements. Before and after the exposure in VE, the participants underwent an IAT test, a psychometric tool that assesses personal bias toward specific groups. The VE simulation had the theme of a yoga classroom and the participants were able to watch their avatar moving in a mirror, while they were watching the virtual environment of the classroom and the yoga teacher from a first-person perspective. The results of the experiment showed a decrease in racial bias for the participants who embodied the dark-skinned avatar [25].

The present simulation can not be considered as educational but rather as informational due to the fluidity of AS symptoms. The different perspective provided through the experience will hopefully contribute in raising awareness and a sense of empathy toward people with AS. By this vantage point, the present VR application overlaps with immersive journalism, as it sheds light on an existing social issue while virtually transporting the user at the place where the reported social issue takes place. This transportation to the virtual place of the event is found to be of high importance because it enhances the emotional impact of the social issue, which is essential for having a lasting effect in the memory of the receptor [26]. Studies on works of immersive journalism, and specifically “Clouds Over Sidra” [27] and “The Displaced” [28] testify on the effectiveness of VR in eliciting empathy.

The term of empathy plays a dual role in the present research. On the one side there is the empathy of the neurotypical participants, who have to utilize their empathy during the experimental procedure and on the other side there is the empathy of people with AS, influenced by their condition. In either case, empathy is used by the definition described by Davis [29]. It consists of two major components, the cognitive capacity to acknowledge the feelings of others (cognitive empathy) and the affective reactivity toward other people (affective empathy) [29]. Davis decomposed further cognitive empathy into “fantasy” and “perspective taking” and affective empathy into “empathic concern” and “personal distress”. Fantasy refers to the ability to identify with fictional characters and perspective taking refers to the ability of understanding the motives of other people's behaviors. Empathic concern and personal distress refer to the level of compassion and discomfort respectively, experienced when witnessing another person going through hardship [29].

1.4. Research question

The research question focuses on the informational and emotional capacity of the application, in relation to other forms of media such as the transcribed text. The VR application could be a successful awareness tool if the exposure in the VE of the application is found to be a better contributor of conceptual knowledge and sensitization on the issue than the reading of brief articles on the same issue. On the basis of the scientific literature cited thus far, it is hypothesized that both conceptual knowledge and sensitization will show higher results for VR compared to transcribed text [6,12].

Furthermore, the study investigates the potential link between the illusion of being in a VE and sensitization. As suggested by studies on immersive journalism, the empathic response evoked by the journalistic narrative becomes amplified as the receptor feels present at the place of the reported incident while it is happening [27,28]. It is hypothesized that the illusion of being in the VE of the present application will have a significant effect on sensitization as well.

2. Methods

2.1. Research design

This is a quasi-experimental research, which follows a pre-test/post-test design and a between-subjects approach. The experimental group is exposed in the VR simulation in which each participant takes over the body of an avatar representing a person with AS and the relevant, brief scenario described in section 2.2 plays out. Instead, the control group is given a paper which contains all the essential information of the application in the form of a transcribed text.

2.2. VR application scenario

The knowledge regarding the thoughts, feelings and visceral reactions of the AS patient in the scenario was accumulated through the corresponding scientific bibliography and mostly through personal narratives of the patients. In order to outline a realistic representation of an “aspergic” person's psyche, the scientific literature alone is insufficient but combined with the subjectivity of different narratives makes up for a fairly intact representation. The personal narratives were collected through scientific papers, which have the same constructivist approach as this research, but also through videos, documentaries, and blogs of people with AS talking about their own experiences [15,17].

The scenario application begins with the man explaining his unfortunate situation for approximately 40 s. Inside the virtual office, ten points of interest (PoI) can be found. The stimuli trigger voice clips to convey the experience to the user. The stimulus about the inability of people with AS to maintain eye contact is simulated by visual cues. The target of the headset making “eye contact” with the executive (PoI 1) causes the visual output of the application to quake, forcing the user of the application to look away (Figure 1). The feeling of anxiety when an AS patient makes eye contact with an unfamiliar person is described in detail by Derrat and the scripted interaction between the AS patient and his executive is based on his description [30].

A birthday-cake with unfamiliar smell, taste, and texture became the cause of severe pain through the sensory input of the man, a typical reaction of AS patients [16]. Coming across the executive's share of the same cake (PoI 2), placed on the desk behind her, the man recalls his daunting experience with it.

In addition, the coffee mug (PoI 3) on the executive's desk activates a voice clip recounting the everyday routine of the man with AS. The man goes into necessary detail with his recount, stressing that he always



Figure 1. The white spot and the closing arc indicate the activation of the gaze control for the interaction with one of the points of interest.

follows the same routine, without giving out any complaints. The inflexible, fixed routines feel comforting for people with AS and this is the symptom which the coffee mug as a stimulus touches on. This lack of flexibility in adapting to daily schedule changes and working conditions is a major characteristic of people with AS [2].

Some stimuli found in the office concern the limited ability of people with AS to attribute social meaning through representations of social dynamics between individuals [24]. These social dynamics appear in the office in the form of depictions, like photographs and posters. Through various depictions, the man with AS reveals his obsessions and his overly pragmatic and literal interpretations, lacking in theory of mind and empathy [16].

Namely, the man with AS, coming across to a family photo (PoI 4) positioned on the top of the executive's desk (Figure 2, Left), is having a hard time reading the facial expressions of the people in the photo. He erroneously assumes that the two family members of his executive in the photo are expressing sadness when in reality they look rather cheerful. This assumption perplexes the man about his executive's motives for putting such a photo into display. Actually, people with AS are able to detect basic mental states, by watching facial expressions, but not complex ones. Detecting mental states by watching the expression of the eyes alone is found to be even harder for them [31].

Consequently, the man with AS fails to decode the social context behind the representation of a poster on the wall. The poster (PoI 5) displays a boy with a mischievous grin handing over a ball to a frustrated girl while behind them there is a broken window (Figure 2, Right). This depiction was inspired by a photo on a conversation card used for

education in the theory of mind for children with AS [25]. The man with AS hesitates to make any assumptions beyond what he is watching on the poster.

One last depiction can be found in the office. The artwork "A Golden Afternoon" [32] appears as part of a calendar (PoI 6) on the wall. The man with AS reacts in an odd way to the sight of the calendar, by bluntly starting to recite in his mind information about Ptolemy's astrolabe (the round object on the stack of books). The recited pieces of information are obscure and hard to follow, as the man goes on for a long time without reaching any vital conclusion. By the end, the man with AS is wondering if the books underneath the astrolabe are also related to astronomy, as an indication that the triggering point of his reaction to the astrolabe was actually his extreme fascination with anything that has to do with space. Neither the dragon nor the chess are as related to space as Ptolemy's astrolabe, so the man with AS completely bypassed the main part of the illustration and focused on the one part from the surroundings that piqued his interest the most.

People with AS tend to talk a lot about their obsessive interests when the proper chance is given. They tend to recite statistics or other kinds of data, which make perfect sense for them but are incomprehensible to others [16,24]. At this point, it must be noted that the obsessive interests vary from a person with AS to another. These interests may span from the compulsive memorization of the details of bus and train schedules to obsessions about sex [2,33]. This specific obsessive interest, about everything related to outer space, was chosen to be attributed to the man with AS in the application for the sake of convenience.



Figure 2. The placement of some of the points of interest inside the office: The family photo (Left) and the poster (Right).

There is also a quote sign (PoI 7) hanging on the wall. The quote says “Everyone Brings Joy To This Office, Some As They Enter And Some As They Live”. People with AS are extremely literal-minded so the man with AS chose to interpret “JOY” as “Joy” the person instead of “joy” the feeling. Of course, by the interpretation of the man with AS, the quote fails to make any rational sense, so he ponders intently upon this fact. The struggle of people with AS to understand metaphors, allegories, and idiomatic language is described by Dailor, a person with AS. When Dailor was asked by his teacher to “try getting into the shoes of another person” his initial reaction was “Why would I do that? My shoes are clean, I don’t know about theirs!” [34]. Also, people with AS find it difficult to think in terms of emotions and they hardly ever get the opportunity to define their feelings [20].

Other, more visibly observable characteristics include the motor clumsiness and stimming of people with AS [16]. Throughout the whole VR experience, the avatar’s legs (PoI 8) are bouncing repetitively. Even if the user misses the respective voice clip, stating that it is common for his legs to start moving so nervously, the animated stimming of the legs of the 3D avatar is very acute. A final stimulus constitutes a plastic glass (PoI 9) resting on the table next to the man with AS to the left side. He accidentally knocks down the glass while shouting “Not again!”, as an indication that this accident is a common occurrence.

The story of this scenario remains inconclusive on purpose. By looking at the door (PoI 10) behind the avatar, the man with AS claims that he would rather not be at this place right now. This piece of information indicates nothing related to AS but it was put in the application just for the sake of the given story plot, stressing the difficulty of the situation in which the man with AS was brought into. The man with AS remains stuck in this stressful situation while the participants are allowed to exit the application any time they wish. A video that demonstrates the scenario of the VR application can be found at the Supplementary Material - VR_Asperger’s_Syndrome_Video.mp4.

Supplementary content related to this article has been published online at <https://doi.org/10.1016/j.heliyon.2020.e04145>.

2.3. Materials

The VR application developed and designed for the purposes of this research resembles an interactive, virtual environment created using the Unity 3D game engine. Most assets were created from square one. The human 3D models were downloaded from mixamo.com and some textures from textures.com and freeimages.com. The artworks appearing in the environment were either created via Adobe Photoshop CS6 or downloaded from online sources. The artwork “A Golden Afternoon” featured on the calendar object of the virtual environment is created by the artist Tony DiTerlizzi [32]. The set-up of the application was made possible thanks to the help of tools provided by game developers online [35]. The rest of the 3D models were created using the Autodesk Maya modeling software. The voice clips were recorded by a consenting adult in the Greek language.

The programming language used for the scripting is C#. The experiment was carried out using a PC with an Intel Core i-7 processor, 16GB RAM and equipped with an NVidia GeForce GTX graphics card. The setup included the Oculus Rift (CV1) head-mounted display (HMD) with 2160×1200 resolution (1080×1200 per eye), 110° field of view and 90 Hz refresh rate for 3D immersive viewing, head rotational and positional tracking, and providing spatialized audio.

The controls of the application have been implemented in such a way that require no use of any buttons, thus allowing a more physical interaction with the system. The gaze control of the system suffices, by using ray-casting for the target of the headset to meet the collider of an object. The animated models of the man with AS and his executive are seated one across the other while the user inhabits the body of the man with AS (Figure 1). The user is allowed to turn their head in any direction while being tracked by the Oculus Rift head tracking system, which is used to synchronize the orientation of the avatar’s head.

Regarding the materials used for the control group, the hardcopy text refers to two online articles from a medical website [36,37]. Apart from the validity of the information, these articles were chosen by a) the Greek language because it is the native language, in which all the participants are familiar with, b) the high simplicity of the meaning of the text, which is directed to a broad audience and c) the compatibility of information provided in the text with the VR application. It is worth noted that despite that the information provided in hardcopy text and VR application vary, it is common for the most part. The transcript text used for the control group, directly translated into English, can be found with the Supplementary Material - VR_Asperger’s_Syndrome_ControlGroupTranscriptText_inEnglish.pdf.

2.4. Participants

Neurotypical adults over 18 years old are the population of this research, in which the sample is selected using convenience sampling. Each group consists of half of the sample. Both experimental and control group, consists of 10 males and 10 females, for a sum of 20 participants at each group. The total number of participants for both groups is 40. The age group of participants ranged between 18 and 68, and most of them ($n = 27$) completed higher education.

2.5. Procedures

Before the beginning of the experiment, the required questionnaires and consent forms were prepared. Pilot experimentation was carried out and any emerging problems were solved. The study has been approved by the Research’s Ethics and Deontology committee of the Cyprus University of Technology. All participants were asked to sign the consent form before beginning the experiment, after addressing their queries. Written informed consent was obtained from the individuals for the publication of any

potentially identifiable images or data included in this article and in the video within the supplementary material. The approximate time of participation was set to 30 min, whereas half of this time was distributed to the VR experience or text-reading, depending on the group, and the other half to the completion of questionnaires. The amount of required time was determined based on the pilot study.

Participants of the experimental group (VR), after completing their demographics and “Pre Measurements” (Table 1), were given directions for the use of the VR Oculus and equipped with the VR Oculus head mount display. Afterward, they were encouraged to explore the virtual office for 15 min. Instead, participants of the control group were given the brief articles in hardcopy form, after completing their demographics and “Pre Measurements” as well. The procedure concluded with the experimental group (VR) completing all the “Post Measurements” whereas the VR Experience Questionnaire (VRQ) (Table 1) was excluded from the control group, as its items strictly relate to the VR experience. The experimental procedures were carried out inside indoor environments, secluded from external distractions, and all participants were being supervised during their participation.

2.6. Measures

Before and after the experiment, the participants of both groups underwent a series of tests (Table 1). Before the experiment, participants provided demographic information and self-reported their level of knowledge in relation to AS (KL). Also, they completed the empathy questionnaire (EQ) of 28 items, which relies on the Interpersonal Reactivity Index (IRI) questionnaire of Davis translated and validated in Greek [29,38]. After the interventions, participants of both groups were given the same knowledge test (KT) for the assessment of their knowledge in relation to symptoms of AS and self-reported their sensitization level (SL) in relation to people with AS. Regarding the KT, in order to secure the validity of the comparison between the two groups, only the common pieces of information, which the two media share, are included in the

Table 1. Samples of questions in pre and post questionnaires.

Samples of Measures	
Pre Measurements (Sample Questions)	
Self-Reported Level of Knowledge (KL) [both groups]	
1	How much would you rate your level of knowledge in relation to Asperger's Syndrome?
Empathy Questionnaire for the VR and Control Group (EQ)	
1	I try to look at everybody's side of a disagreement before I make a decision.
2	I sometimes feel helpless when I am in the middle of a very emotional situation.
Post Measurements (Sample Questions)	
Knowledge Test (KT) [both groups]	
Please indicate which of the following items fall under the category of symptoms of Asperger's Syndrome:	
1	Overuse of metaphors and abstract language (false)
2	Obsessive interests (true)
3	Motor clumsiness (true)
Self-Reported Level of Sensitization (SL) [both groups]	
1	Following your VR experience, how much would you rate your sensibility level in relation to people with Asperger's Syndrome?
VR Experience Questionnaire (VRQ) [VR group only]	
<i>Immersive Response/Functionality (IR)</i>	
1	How well could you concentrate on the assigned tasks or required activities rather than on the mechanisms used to perform those tasks or activities?
2	How much did the auditory aspects of the environment involve you?
<i>Presense/Place illusion (Pi)</i>	
1	To what extent were there times during the experience when the virtual environment was the reality for you?
2	During the experience, which was stronger on the whole? Your sense of being in the virtual environment or the real world?

Knowledge Test (KT). KT comprises of 12 questions with a boolean answer (true/false) each.

Moreover, the participants of the experimental group were given an additional questionnaire to assess their VR experience (VRQ), with 18 questions associated with the immersion response (ImR) and the place illusion (Pi) (Table 1). The terms of ImR and Pi in this study are used as defined by Slater [39]. The VR experience questionnaire was amended according to the specific features of the VR application and used on a 7 point Likert scale. Value 7 of VRQ's Likert scale represented the best possible experience but reversed-scale questions were also included. ImR relies heavily on the users' reactivity to the system, such as the realism of the VE, their ability to interact with the VE and explore it, the quality of the interaction, the quality of the sound, and their self-evaluation of the tasks performed in the VE [40]. Immersive response is the response toward immersion, "the psychological state characterized by perceiving oneself to be enveloped by, included in, and interacting with an environment that provides a continuous stream of stimuli and experiences" [39–41]. Pi, a component relating to the sense of presence, focuses on the feeling of "being" in a VE, in spite of the certainty that the physical body is in the real world [42,43]. Generally, Pi has been adopted by several similar studies and it is often used as an equivalent to "presence" [43, 44, 45].

Raising awareness on any cause requires the sensitization of the involved individuals, presupposing that the individuals have the empathic capacity to be sensitized. SL was adopted as a post measurement relating to the empathic response on the specific social issue of AS, as designated in the introduction. The single-item SL was used during the post measurements instead of reusing the EQ because the latter measures the capacity for their overall empathy for any subject and investigating the changes of the empathic capacity of the participants after the interventions goes beyond the scope of this study. For this reason, the empathy of each participant from both the experimental and the control group is assessed before the interventions, on its original 5 point Likert scale, using EQ and SL is assessed on a 5 point Likert scale at face value, after the experiment [29]. Value 5 of EQ's and SL's Likert scale represented the highest level of empathic capacity and sensitization respectively. In addition, EQ included reversed-scale questions. Ideally, the empathy levels (EQ) of the two groups should be at the same level, in order for the two groups to have an equal capacity of being sensitized and

allow a valid comparison of sensitization (SL) after the experiment. The distribution of participants with almost the same initial knowledge (KL) between the two groups is an important factor in comparing sensitization levels (SL). If one of the two groups is found to be significantly more knowledgeable prior to the experiment (KL), it could be assumed that the level of awareness regarding the issue has been polarized, thus the groups are likely to have a different awareness baseline. KL is assessed on a 7 point Likert scale before the experiment, with 7 indicating the highest level of knowledge.

Furthermore, the KT was provided only after the intervention to avoid the anchoring of its 12 items to the content of each intervention. If the participants knew prior to the intervention for which information to look out for, then, extraneous variables, relating to attention and tracing of information, could interfere with the post results of the same test. Consequently, applying the same test before and after the intervention is more relevant to the evaluation of the procedural as opposed to the conceptual knowledge. To avoid this issue and ensure the validity of conceptual knowledge, as designated in the introduction, the single-item KL was used as a "pre-examiner" of knowledge on AS at face value.

2.7. Data analysis

The data has been analysed using a data analysis software (SPSS). Given the sample size of each group ($N \leq 20$), data were tested for normality and homogeneity of variance using the Shapiro-Wilk test. All data were analyzed using parametric tests, except for data which failed to meet the normality assumptions and thus required non-parametric tests. All the generated data are provided with the Supplementary Material - VR_Asperger's_Syndrome_RawDataSet.sav.

3. Results

Independent Samples T-tests were conducted for the pre-measurement on empathic capacity (EQ scores) between a) genders and b) the two groups. There was a significant difference in the empathic capacity (EQ scores) of males ($M = 3.29$, $SD = 0.42$) and females ($M = 3.58$, $SD = 0.38$), $t(38) = -2.32$, $p = 0.02$. There was not a significant difference in the empathic capacity (EQ scores) of the experimental group ($M = 3.43$, $SD = 0.46$) and the control group ($M = 3.43$, $SD =$

0.38), $t(38) = -0.03$, $p = 0.97$, thus it is concluded that the two groups had almost the same level of empathic capacity (EQ scores) before the intervention.

Also, there was not a significant difference in the KL of the experimental group (Mean Rank = 23.81) and the control group (Mean Rank = 17.88), $U = 147.50$, $p = 0.07$, thus it is concluded that the two groups had almost the same KL before the experiment. The insignificant difference between the two groups, EQ and KL, suggest that the two groups met all the thresholds for allowing a valid comparison of SL and KT after the interventions.

A Mann-Whitney test indicated that the overall score on the KT was greater for the experimental group (VR) (Mean Rank = 24.15) than for the control group (Mean Rank = 16.85), $U = 127$, $p = 0.04$ (Figure 3). However, other significant differences between the two groups could not be found, including sensitization. Regarding the levels of SL, the experimental group (VR) (Mean Rank = 19.25) was less great than the control group (Mean Rank = 20.79), $U = 175$, $p = 0.66$ (Figure 4).

The participants for the experimental group rated the ImR and Pi of the application. The total range of the scale was 1–7, with “1” being the lowest rating and “7” the highest (Mdn = 4). The total mean of ImR was (M = 5.59, SD = 0.81) and Pi was (M = 4.13, SD = 1.50).

Empathy (EQ scores) and SL correlate neither for the experimental condition, $r = 0.30$, $n = 20$, $p = 0.19$, nor for the control condition, $r = -0.09$, $n = 19$, $p = 0.71$. SL and Pi (which applies to the experimental group only) are positively correlated, $\rho = 0.55$, $p = 0.01$ (Figure 5).

4. Discussion

The statistic results partly support the main hypothesis. The participants of the experimental group (VR) became more knowledgeable on AS compared to those of the control group, as expected. This result, with the fact that the sense of knowledge on AS before the experiment (KL) was reported to be relatively low, without any significant difference between the two groups, indicate VR as a suitable technology toward this end.

The significance of this result has been driven by a small number of participants of the control group who scored lower than average in the knowledge test (KT) (Figure 3). A possible explanation would be that these values derive from outliers because of factors relating to attention span, information retention, or even response bias that could have possibly interfered with the outcome. However, there are indications suggesting that these scores are just extreme values and not outliers and as such it was proper for them to be kept in the analyzed data. All three participants, that score very low, fall within the same group. There is a lower probability for this to happen by chance, compared to the case of

outliers being distributed in both groups. Moreover, there are quite a few participants (3 out of 20 of the control group) who scored that low, and not only one participant, in which case that would be a stronger indication that this happened by chance. Besides, the score by chance at the KT is 6 out of 12 since the knowledge test comprises of 12 questions with a boolean answer each (true/false). The scores with extreme values (i.e. participants that scored very low) are not near the score by chance. In any way, to minimize any potential influence by outliers, we used a robust against outliers analysis method, that of the Mann-Whitney U test. This method compares the sums of ranks, and not means, thus it is less likely than the t-test to spuriously indicate significance because of the presence of outliers.

Empathy levels of both groups were found to be almost identical, which is the ideal outcome for comparing sensitization. A positive correlation between sensitization (SL) and place illusion (Pi) for the experimental group (VR) is eminently acute. On the other hand, the participants of the experimental group (VR) did not become more sensitized than those of the control group. One of the main reasons sensitization levels were low could be the marginally low ImR and Pi rates of the application. Looking at the results, one could suggest that place illusion (Pi) was a more effective carrier of sensitization rather than the empathic capacity of each individual. Since a strong and positive correlation is found between sensitization and place illusion for the experimental (VR) group, it is safe to assume that mediocre levels of immersive response and place illusion have caused lower levels of sensitization as well. The essence of this finding is that the higher the feeling of “being” in a VE, the higher the capacity for sensitization, or vice versa. The aforementioned finding indicates that VR technology could be extremely useful on the evocation of sensitization by the use of specialized VR applications, which is consistent with the existing literature [26, 46].

4.1. Research limitations

After the conclusion of the data analysis, a self-evaluation applied to the practical procedures of this research. It could be argued that the VR condition was less informative and more conceptual than the transcribed text condition, thus the participants of the experimental (VR) group felt “disoriented” regarding the general nature of AS as a neurological disorder. The fact that the participants experienced a specific incident of a specific man did not make them confident enough in generalizing the man's condition. For example, the borders of the generalization to the fact that “the man with AS has an unhealthy obsession with outer space” could not be clearly set. One can erroneously assume that “all men with

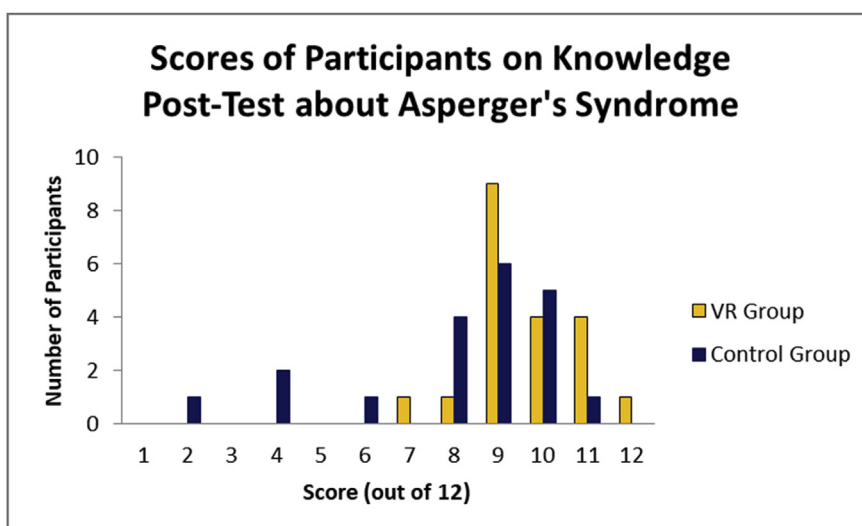


Figure 3. Comparison between VR and control conditions on the scores of neurotypical participants for the KT, showing better performance for the VR group.

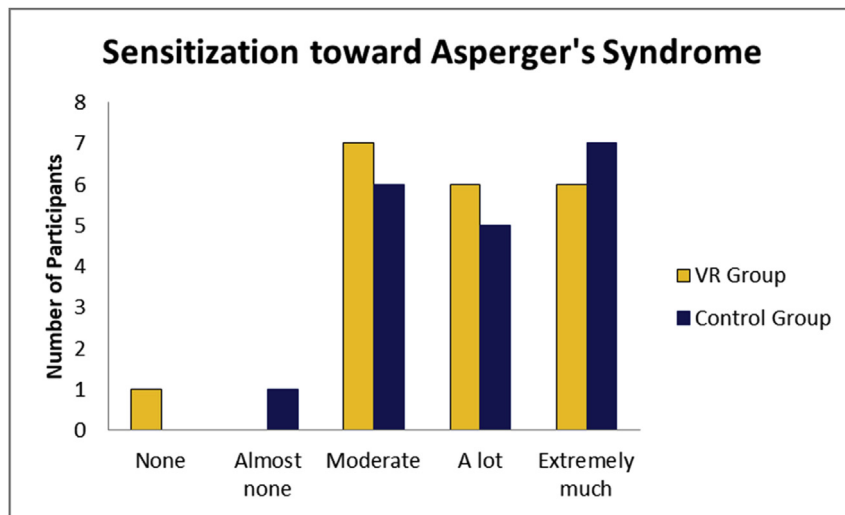


Figure 4. Comparison between VR and control conditions on the SL of neurotypical people toward people with Asperger's syndrome, after the experiment. The two groups met all the criteria required for the comparison.

AS have an unhealthy obsession with outer space” instead of “all men with AS have an unhealthy obsession, each on a random subject”. When these two assumptions exist simultaneously, they are bound to conflict and confusion arises as a consequence.

Apart from the practical procedures, through the data analysis and discussion of the presented findings, some theoretical approaches have been re-evaluated. The two articles provided to the control group, as a medium of raising awareness for AS, were able to compete very well with the VR simulation in terms of informational capacity. The problem is that the contents of the two media (text and VR) have nothing comparable between them, except for their informational capacity. From the one side, the VR simulation is approaching the raising awareness procedure in a very constructivist point of view and from the other side, the articles follow a rather positivist way for achieving the same goal. In other words, the VR simulation resembles a narrative, allowing the participants to gain knowledge through their own experience and perception, while the articles are very expository, catering all the medical information to the participants as if talking about an occurring phenomenon, without referring to any individual human experiences. This problem did not arise sooner maybe because of the concerns of the many limitations applied to the selection of the most suitable text, which are the validity of information, the language barrier, the simplicity of the text and most importantly the compatibility between the information provided from

the two media. The present research was intended to follow a constructivist approach from the beginning and compare the effects of two different media but not two different learning approaches.

The selection of medium for the control group was insufficient probably but at least the scenario of someone coming across an online article about AS is much more plausible than someone coming across a VR application about AS. Raising awareness becomes futile if the medium providing the awareness is inaccessible to the target audience. Potential clients of VR systems rarely find the content of VR systems as worthwhile as the content of other similar systems [9,47]. Because the medium is accessible only to a small group of the target audience, namely the technology-savvy neurotypical people who have access firstly to VR sets and secondly to the specific application, the level of impact on which the application is tackling the social issue is admittedly questionable, when it comes to real-life circumstances.

Despite the limitation of accessibility, which was evident before the start of this project, VR is still a growing sector of computer science with tremendous potential to contribute in education and entertainment because of its powerful connection with the concept of reality. VR is going through an ever-growing popularity the latest decades and it is not an exaggeration to say that this technology could meet the “unrealistic” expectations of its creators someday [48]. Therefore, the present project

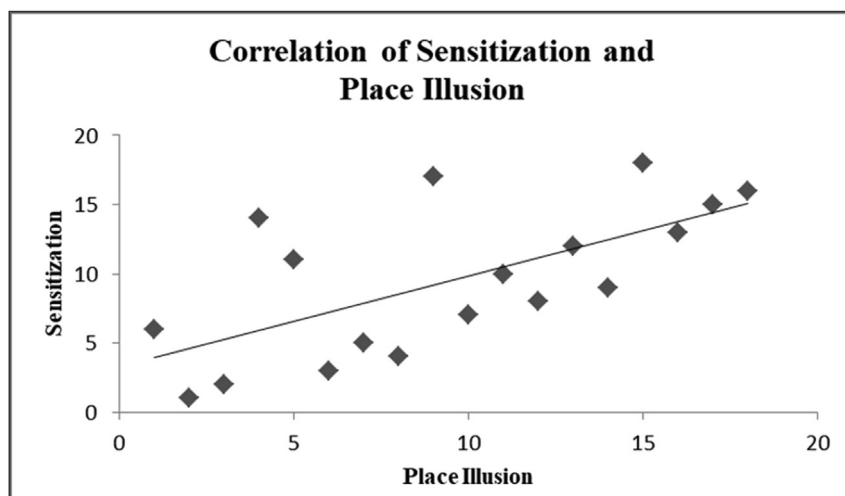


Figure 5. Sensitization (SL) is positively correlated with Place Illusion (Pi) on a very significant degree.

is founded on this prospect and it is not seeking for application outside the boundaries of the present research - at least not for now.

5. Conclusions

To sum up, the use of VR systems for raising awareness for social issues had a satisfactory result on the knowledge aspect of awareness, compared to more traditional media, such as online medical articles. The participants for the experimental (VR) group appeared to have learned a lot about AS, even though they did not become any more sensitized toward people with AS, by experiencing a difficult situation from the point of view of a man with AS. Levels on empathy were found to be almost equal between groups but significantly different between genders. The levels of place illusion for the VR application are found to be possibly responsible for the sensitization levels of the participants. This incident led to the reconsideration of place illusion as a more important catalyst for sensitization rather than empathy, regarding raising awareness for social issues. The latter is of high importance since it indicates that VR is indeed a tool that can be used for raising social awareness.

VR technology could provide valuable capabilities if used wisely, not only for education and entertainment but also for raising awareness on social issues. In this paper, some of the most common social issues regarding AS and the act of raising awareness around them have been examined under the scope of VR technology. Many interesting conclusions have been drawn from the findings of this research, which could be put to the test for further investigation. This research could further contribute to the improvement and preservation of social coherence in the future, by advocating, against the ignorance of society, to the oppression of inconspicuous social groups.

As another future direction, the effect of the embodiment VR illusion (body ownership) could be exploited to investigate whether awareness on social issues could be further developed through VR. The theory of "Proteus Effect" [49], suggesting that 3D avatars in VEs enforce behaviors on the user, related to the socially perceived and expected attributes of the avatar's representation might have an impact toward sensitization to people with AS. Additionally, it could be investigated whether VR could be used for the sensitization of people with AS toward others, having people with AS as participants, who experience the analogous interventions. People with AS face impairments related to empathy, which can be improved through proper education [34]. VR could act as an educational tool for teaching sensitization toward others [11].

Declarations

Author contribution statement

Despina Michael-Grigoriou: Conceived and designed the experiments; Analyzed and interpreted the data; Wrote the paper.

Christos Hadjipanayi: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

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Competing interest statement

The authors declare no conflict of interest.

Additional information

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