iSenseVR - Toward A Low-Cost Virtual Reality Solution for Exposure Therapy in Busy Environments

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ABSTRACT

This paper presents the research outcomes from a pilot project which investigates the use of Virtual Reality through smartphones in order to empower people with hidden disabilities to overcome stress eliciting situations by experiencing controlled exposure to busy environments in digitally reconstructed airport areas from the comfort of their own safe environment.

Following a participatory design and a usability testing, a semi-controlled 7-day longitudinal study aiming at assessing the responses of our targeted users, was conducted. Results revealed the enthusiasm of participants for such innovation applied to the airports context, although some cyber-sickness symptoms were punctually experienced.

1. INTRODUCTION

Many individuals with Autistic Spectrum Disorder (ASD), acute sensory hypersensitivity, mental health conditions and anxiety experience extreme difficulties with heightened noise and/or crowded situations within environments. These sensory cues can act as social barriers, impeding them doing what most may consider as everyday activities.

Although strategies such as Social Stories™ which consists of a sequence of images along with situation descriptions (Karayazi et al., 2014; OHandley et al., 2015); and organised pre-visits of facilities as a reasonable adjustment, are already in place to familiarise those who live with hidden disabilities with critical places, they are often not enough to increase individuals' confidence as they do not contribute effectively to desensitise from environmental stressors. Thus, there is a need for a more "out-of-the-box" approach.

Virtual reality (VR) consists of an immersive computing experience which empowers an individual to interact within a digital responsive environment (LaValle, 2016). VR can induce presence, the psychological sensation of being present in a virtual environment, which arises from a coherent association between users' perceptual responses to the narrative and immersion (Slater, 2003). Immersion and presence in VR are believed to enable triggering of strong emotional responses (Wilson and Soranzo, 2015; Miller and Bugnariu, 2016) and more particularly the physiological components of anxiety, capable of provoking psychophysiological arousal in all individuals (Diemer et al., 2014). In addition, previous research has shown that VR has high degree of acceptance among users who are typically subject to distress in stress eliciting situations (Newbutt et al., 2016a). For these reasons, VR is considered as a promising facilitator of exposure therapy for the improvement of psychological wellbeing offering opportunities to tackle mental and developmental disorders such as acute stress (Serino et al., 2014), Post-Traumatic Stress Disorder (PTSD) (Botella et al., 2015), dementia (Garcia-Betances et al., 2015), anxiety disorders (Diemer et al., 2014) and ASD (Grynszpan et al., 2014; Maskey et al., 2014; Miller and Bugnariu, 2016; Newbutt et al., 2016b).

VR exposure therapy allows the controlled delivery of sensory stimulation (Maples-Keller et al., 2017). It has demonstrated to be at least as effective as conventional exposure therapy for certain types of disorders (Morina et al., 2015; Botella et al., 2015). However, when traditional exposure therapy becomes complex to set up due to difficulties to control specific environmental cues, VR offers opportunities for highly controllable settings empowering sensory exposure with the presence of the therapist, which would not be possible otherwise (Maples-Keller et al., 2017).

Although, VR presents interesting alternatives to support traditional strategies for tackling anxiety and stress induced by mental and developmental disorders, such advances should be more practically applied rather than being limited to the laboratory settings (Grynszpan et al., 2014). This implies artists, technologists and professionals in the field must endeavour to solve the challenges associated to interventions that are not only effective, but also accessible and usable by most (Grynszpan et al., 2014). One of the possible challenges consists of the limited accessibility of the VR technology in terms of price. Effectively, while recent technological advances are currently contributing to the wider commercial acceptance of VR in gaming, immersive VR technology such as cutting-edge computer-ready Head Mounted Displays (HMDs), still relies on relatively expensive equipment investment and is therefore not yet affordable by most. In contrast, modern smartphones, already owned by many, offer incredible opportunities for designing affordable experiences, building upon reliable graphical capabilities, stereoscopic and spatial audio cues, and head tracking interaction using pre-embedded gyroscopes.

This paper presents a pilot research which investigates the use of VR provided through mobile technology to help individuals with hidden disabilities and mental health conditions to access public places which many consider to be everyday activities. We have designed an experiment to assess the value and potential of iSenseVR, a proof of concept of a VR application for Android smartphones, which aims to familiarise and desensitise individuals with hidden disabilities to busy environments such as Aberdeen International Airport, by gradually increasing environmental stressors in VR throughout repeated use from the comfort of their own safe environment.

2. METHODS

2.1   Participants

7 participants (5 females, 2 males) (M_{age} = 36.571, σ = 17.709) were identified among 25 individuals with hidden disabilities, who were recruited across the UK, using contacts found by Friendly Access, a social firm which promotes reasonable adjustments across society for individuals with hidden disabilities. The inclusion criterion of the study was the ownership of a VR-ready Android smartphone with technical specifications similar or above to a Samsung Galaxy S6, which was released in 2015.

Among the 7 participants, 5 live with anxiety disorder and 4 with depression; 2 suffer from PTSD; 2 individuals have ASD and 2 others have Asperger Syndrome. Finally, one participant experiences severe learning difficulties and none experience seizure activities. All participants reported to be frequent game players on computers and mobile devices, and to be novices using VR.

All participants were asked to fill in an online consent form which presented the objectives of the study and informed them about their rights as participants. In addition, they were instructed about the experimental procedure and the risks typically associated to the use of VR.

2.2   Apparatus

iSenseVR is a non-commercial mobile application for Android VR-ready smartphones. It aims to help individuals with hidden disabilities to develop tolerance to the environmental stressors that are typically found in busy environments. It provides gradual sensory exposure in digital reconstructions of environments that cannot be controlled. Aberdeen International Airport kindly accepted to be a case study.

The application was developed building upon interactions between user-centered interaction design and software engineering design methodologies. We have engaged with different cohorts of end-users to co-design and assess all virtual environments in iSenseVR, to propose sensory realistic experiences (Poyade et al., 2017a). Initially, 26 volunteers with hidden disabilities across Scotland helped identify those typical environmental stressors in busy environments that often lead them to experience high levels of anxiety and stress.

Standardised design methods in the fields of systems and software engineering allowed producing a uniform description of customer needs and requirements for virtual environments. Sixty-six user and system requirements

were generated using System Modelling Language (SysML) (Figure 1), providing basis for a unified description of the functional and interaction design of the application using Unified Modelling Language (UML).
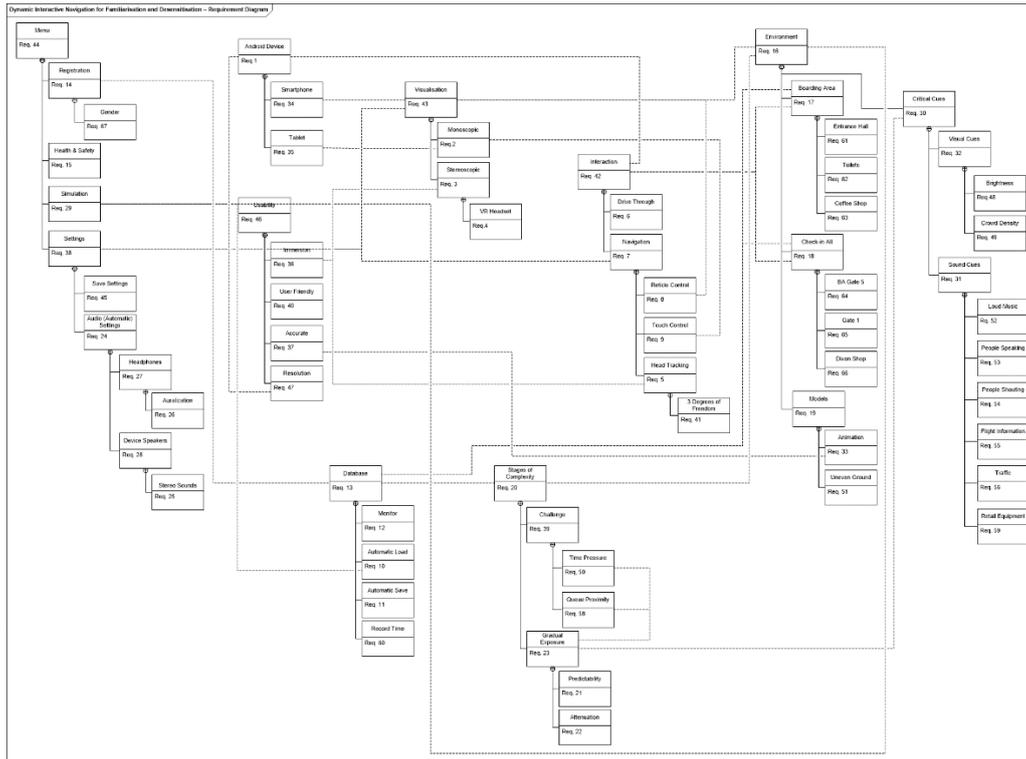

Figure 1. *iSenseVR Requirements Diagram*

iSenseVR was developed for Android mobile devices using Unity 5.6, a cross-platform game engine widely used in the video game industry, however further research iterations will aim at providing a development compatible with VR-ready IOS devices. It provides a series of immersive experiences in digitally reconstructed airport environments that allow exposing individuals with hidden disabilities, in a controlled manner, to critical sensory cues such as ambient sounds (e.g. loud shop music, conversations, announcements and equipment noises) and crowds. In addition, the application supports stereoscopic visualisation, audio spatialisation and head tracking using the Google VR SDK for Unity.

The application initially requires the user to undergo a series of sensory attenuated experiences within each environment. Four environments have been digitally reconstructed and populated with animated digital characters (Figure 2): (a) the entrance hall; (b) a café; (c) gender-specific toilets; and (d) a boarding gate.
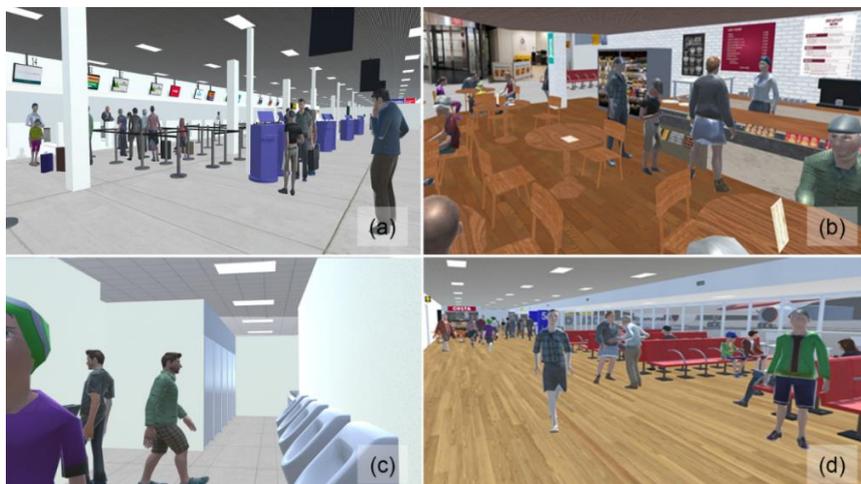
Figure 2. *Digitally reconstructed environments in iSenseVR.*

On launching an environment, the user is randomly driven through one of three possible paths, making each use less repetitive. Each path describes a motion pattern for the user's point of view within the environment. Although paths are fixed, the user can still explore the environment rotating its point of view on 3 degrees of freedom. Paths last no more than 3 minutes in order to minimise users' boredom and cyber-sickness (Davis et al. (2014)). On completion of a path, the user is removed from the virtual environment and presented with the main menu interface.

The gradual increase of environmental stressors ensures each environment becomes more challenging throughout repeated use. This increase is managed by a database located on a remote server. This database assigns a level of complexity per environment for each user. Levels of complexity are associated to pre-set configurations of the audio landscape and the density and activity of the crowd in each environment. On launching an environment, the crowd component is diversified by randomly loading the required amount of animated digital characters from an extensive preloaded collection of characters.

In total, 7 levels of complexity were defined for each environment. The level of complexity of each environment increases when users complete a path, demonstrating their capability to tolerate the displayed sensory cues.

The usability of the application was tested with 11 postgraduate students from the Glasgow School of Art, with no previous experience in VR (Poyade et al., 2017b). They were required to experience each of the aforementioned environments with no sensory attenuation through a Samsung Galaxy S7, while sitting down.

Overall, students were enthusiastic using the application, finding it very intuitive and provided valuable information that helped enhance user experience. Some felt a little eye strain, although no cyber-sickness was experienced.

In this pilot study, participants were required to use their own headphones and smartphones, and download iSenseVR from a temporary link on Google Play Store to install it on their device. Although different models of Android smartphones were used, all were equivalent to or newer than the Samsung Galaxy S6.

After consenting to take part into the study, participants received a Virtual Reality Scope Headset for Smartphones (Figure 3), an affordable and reliable device in which they can mount their smartphone, so they could use the application in VR from a safe and reliable place.

Figure 3. *Virtual Reality Scope Headset for Smartphones (£5.99).*

2.3   Procedure

Participants were asked to use the application on a daily basis for 7 consecutive days, using their smartphones mounted on the VR headset and their own headphones. They were required to attempt to complete one level of complexity for each environment every day, ensuring they were exposed to increasingly challenging environmental cues. They were informed they could plan their daily exposure as they wish, by either experiencing all environments in one session or spreading them throughout the day in case they felt overwhelmed. Each experience lasted no more than 3 minutes, so to minimise loss of interest, discomfort, and side effects typically associated to VR.

Participants were asked to set their smartphone to half volume and recommended to remain seated ideally in a swivel chair and under supervision if support was required, while immersed in VR.

The daily use of the application was reported in an external server allowing researchers monitoring the dedication and progress of each participant through the several levels of complexity for each environment.

2.4   Data Analysis

On completing the experiment, participants were required to rate a series of statements using a typical 5-point Likert Scale: (1) Strongly Disagree; (2) Disagree; (3) Neutral; (4) Agree; and (5) Strongly Agree. Statements aim to inform about the usability of the system and the quality of the interaction, audio samples and visuals. In addition, participants were encouraged to provide comments to support their responses.

Mean values and standard deviations were calculated for each statement, and building upon a Theme-Based Content Analysis (TBCA) (Neale and Nichols (2001)) alike approach helped classifying ordering participants comments and reporting them in a consistent way.

2.5   Ethics Approval

Ethical considerations and safety concerns of participants were paramount to this research, considering the possible negative effects of visualisation through HMDs highlighted by previous research (Sharples et al., 2008), and to the panels of hidden disabilities and symptoms that participants were dealing with in their daily life. This study followed "Principles of Consent" as outlined under Adults with Incapacity (Scotland) Act 2000. This research is non-Clinical Trial of an Investigational Medicinal Products. This legal framework covers many aspects of research and governs the inclusion of adults with incapacity in research in Scotland. Prior to this study, institutional ethics approval was obtained from the research office at the Glasgow School of Art.

3. RESULTS

All participants but two were able to use iSenseVR throughout the whole testing period. Effectively, two participants mentioned experiencing cyber-sickness symptoms and therefore opted for withdrawing from the study after 4 days (Table 1). Overall, participants seemed enthusiastic concerning their experiences in VR, qualifying the application as ''excellent app'', ''a great idea'', and ''a brilliant tool''. Although, in the overall, participants moderately enjoyed their experience (M = 3.286, σ = 1.113). Among those participants who completed the study, no major differences of enjoyment were noted (M = 3.6, σ = 1.14).

All participants who pursued the study but one achieved all levels of complexity in all environments (Table 1), and were using iSenseVR for an average total time of 4284.2 seconds (σ = 829.36) over 7 days (Table 2).

Table 1. *Levels of complexity completed by users as recorded on the database.*

User ID	Entrance Hall	Café	Boarding Gate	Toilets
1	Level 7	Level 7	Level 7	Level 7
2	Level 7	Level 7	Level 7	Level 7
3	Level 6	Level 6	Level 3	Level 6
4*	Level 3	Level 3	Level 3	Level 3
5*	Level 4	Level 3	Level 2	Level 3
6	Level 7	Level 7	Level 7	Level 7
7	Level 7	Level 7	Level 7	Level 7

* Withdrawn participants

Table 2. *Participants total exposure time to each environment in seconds.*

User ID	Entrance Hall	Café	Boarding Gate	Toilets
1	1439	1360	1211	693
2	1054	1114	1027	607
3	891	935	704	538
4*	351	378	315	200
5*	620	402	211	219
6	1427	1481	1357	810
7	1381	1325	1374	693
Mean	1023	999	886	537
σ	428	452	483	239

* Withdrawn participants

Overall, all participants felt confident using the application (M = 4.286, σ = 0.756) finding it easy to use (M = 4.429, σ = 0.787) and intuitive (M = 3.857, σ = 0.9). They felt comfortable wearing the headset (M = 3.857, σ = 0.9). Overall, they did not experience much eye strain (M = 2.143, σ = 1.345), fatigue (M = 2.429, σ = 1.512) headache (M = 1.571, σ = 1.134), or dizziness (M = 2.429, σ = 1.813). However, experiences in virtual environments were reported to be a bit disorientating (M = 3.143, σ = 1.215), with the two withdrawn participants experiencing nausea and dizziness ("it made me feel dizzy", "it made me feel a little sick"), that are consistent with typical symptoms of cyber-sickness.

Participants mentioned feeling psychologically engaged within environments ("I felt as if I was there", "It felt like super natural"), suggesting they experienced realistic immersion and high degree of presence in VR. Although they appreciated the changing narrative throughout repeated use allowed them to build up the density of the crowd and sounds ("I get a bit scared by these noises in real life in busy places so it definitely helped me and each day slowly got busier/more noises"), and change the storyline of their experiences ("I liked that over the week it built up the levels of people, noises and changed the surroundings and routes taken each time I used the application"), they suggested the provision of more realistic cues as denser crowds with more natural use of animations throughout environments ("the sceneries needed to be much busier for a more realistic experience") and enhanced interaction paradigms ("I could not actually control the movement", "little boring as I couldn't interact", "I'd have liked to explore some things in the environment more") could eventually contribute improving user experience in the digital environments.

Although remaining participants felt moderately more confident going into busy environments after 7 days (M = 3, σ = 0.707), all participants concurred iSenseVR "would be really beneficial for a lot of people with hidden disabilities" and "could actually help over time". They would thus recommend it to others (M = 4.429, σ = 0.535) ("it would be really beneficial for a lot of people with hidden disabilities") as the experience was perceived to ''be so useful to do if going to airport for first time", and "would definitely buy this app if it came out" as some reported that it" could actually help over time".

4. DISCUSSION

People with hidden disabilities such as autism, learning disabilities and mental health problems are far more likely to experience high levels of discrimination, isolation, fear, anxiety, unemployment and poverty. Environmental stressors such like sounds, light and crowds can become huge barriers to independent living.

This research provides a draft of a methodological and technological framework to support the design of immersive VR applications for Android smartphones, aiming to empower those who live with hidden disabilities and mental health conditions to overcome their barriers through repeated rehearsals of a critical situation in a

controlled digital environment, from the safety of their home. Our project consists of a demonstration that VR on smartphones mounted on affordable headsets allow people to experience realistic exposure to busy situations in digitally reconstructed airports areas.

Overall, our evaluation reported positive responses from participants and infatuation for the application of VR in the context of busy environments as airports. Although due to a limited sample of participants, our findings need to be carefully considered, they seem to be consistent with previous research outcomes, showing a high degree of presence and acceptance among users (Newbutt et al., 2016a; Newbutt et al., 2016b). Participants felt a little disorientated while visualising digital environments through HMDs, and two of them experienced cyber-sickness symptoms, consistently with indications from previous research outcomes (Sharples et al., 2008).

Consequently, enjoyment was moderately reported, suggesting both, the seriousness of the stress and anxiety elicitation from the simulated situations despite the gradual exposure to sensory stimulation, and the limitations of passively guided navigation leading possibly to disorientation and cyber-sickness. This must be taken into consideration in further research to aspire for a more effective design of an attenuation strategy resulting in a more enjoyable and interactive experience able to tackle user's discomfort.

Our main research outcome, iSenseVR, contributes effectively to the practicality of VR exposure therapy, by bringing it outside laboratory settings towards one's safely considered environments and making it therefore more accessible to most in terms of cost and technical requirements. In that way, our approach is aligned with the recommendations made by Grynszpan et al. (2014) for the design of more accessible interventions. However, the lack of accompanying therapist obliges us to recognize the limitation of our approach, and disqualify, for the moment, iSenseVR as a tool for genuine controlled exposure therapy intervention for helping people with hidden disabilities in order to help them to manage better their anxiety and stress in busy environments. Nonetheless, this does not impede us hypothesising the adequacy and effectiveness of our approach to complement already in-place strategies for reasonable adjustments in airports (Karayazi et al., 2014; OHandley et al., 2015), in further research.

5. CONCLUSION

This paper presents the outcomes of a preliminary evaluation of iSenseVR, a proof of concept of a VR application for Android smartphones, which enables the gradual exposure to environmental stressors in busy places. Results highlighted high user acceptance and increased sense of presence within digital environments. Although further improvements are needed to tackle user disorientation and cyber-sickness, and strategies need to be developed to increase users' confidence after using the application, iSenseVR consists of a low cost and user-friendly solution for gradual familiarisation and desensitisation to some of the critical environmental cues that are typically eliciting distress among individuals with hidden disabilities.

However, in the future, iSenseVR aims to become a domestic practical solution to support conventional and experimental exposure therapies for busy environments such as airports. This will be achieved focusing on design refinements in order to enhance interaction, navigation and user's comfort, and by involving therapeutics into a participatory design approach in order to capture their expertise into more effective gradual exposure interventions that can be conducted from the safety of one's place. An evaluation framework will be designed along with therapists in order to assess the internal, external and ecological validity of iSenseVR.

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