Visual impairment sensitization: Co-designing a virtual reality tool with sensitization instructors

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Abstract. Sensitization procedures often make use of the simulation of visual impairments (VI). The use of Virtual Reality (VR) is particularly promising due to easy modification of the visual scenery and the high level of immersion. Existing implementations often focus on the demonstration of difficulties that arise from VI and do not embed the simulation into a structured sensitization procedure—they provide no information about adaptive behaviors, adaptations to the environment, or assistive technologies that can mitigate the problems experienced in the simulation. This can foster stereotypes of persons with VI as not being able to perform activities of daily living rather than sensitize with regard to their actual experiences. In this work, we co-designed a VR tool for professional sensitization sessions with a group of four sensitization instructors. The tool provides a large number of scripted interactions with the environment and allows the selective activation of different VI, barriers, and facilitators. Its design prioritizes the communication of solutions over the mere demonstration of what persons with VI cannot see. Preprint authors'version. See https://link.springer.com/chapter/10.1007/978-3-031-08645-8$_2$8$fortheeditorversion.$

Keywords: Virtual reality · sensitization · visual impairments.

1 Introduction

Unstructured contact with people with impairments can result in stereotypes and negative attitudes [5]. For instance, sighted people often show misconceptions about the perceptual and behavioral consequences of visual impairments (VI). This is likely due to the fact that persons without VI rely heavily on visual information during daily activities (from grabbing a mug of coffee to negotiating obstacles and changes in level [12], to social interactions [19]). In fact, the subjectively perceived reliance on vision is so high that people without a VI may even feel uncomfortable using non-visual technology even if it imposes no extra costs [7, 9]. As a result, they may be under the impression that having a VI is deleterious to performing daily activities autonomously. Sensitization is a structured procedure that aims to avoid such pitfalls. The goal is to convey a realistic impression of the abilities and challenges of persons with impairments in everyday life.

Critically, a sensitization procedure should convey the fact that a perceptual limitation or a VI does not necessarily lead to behavioral limitations [18, 11], as described in the Disability Creation Process Conceptual Scheme [8]. Persons with VI often adapted their behavior to comply to the requirements of their residual vision, e.g., they bring a book close to their face to retain a standard reading speed. In addition, cognitive strategies can replace perceptual ones [10]. Virtual Reality (VR) approaches allow to generate arbitrary, high-fidelity stimuli and environments that can then be explored under simulated VI [6]. Unfortunately, digital simulation tools are often presented by themselves, i.e., without a systematic integration of interactions with the environment, responsible for the disabling situation [18, 11]. Additionally, the emphasis is typically on the problems the VI introduces for persons without such impairements. An example would be the overlay of a virtual scotoma over real-world images without further instructions regarding compensation strategies that are typically used by persons with scotomas. Often, it is unclear whether these simulation tools increase awareness about an impairment, as intended, or whether they may even convey the wrong message (e.g., "low or no vision is the problem").

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In this work, we collaborated over the course of six months with four sensitization instructors to study the field's needs and the relevance of VR for sensitization. In particular, VR and immersive visual interfaces provide flexible and controlled VI simulation and environment. In the proposed solution, and in contrast to previous work and in accordance with current models of how disability emerges, each disabling situation within the simulation is presented with compensatory solutions, either through behavioral strategies, environmental modifications, or assistive technologies. Further, we elicit misconceptions of the general public from the knowledge of the four instructors.

In sum, the main contributions of our work are: (1) a realistic and scripted scenario to study sensitization to VI in VR and in a real world setting, and (2) to our knowledge, the first study on sensitization including instructors as participants.

2 Related work

2.1 Sensitization by Instructors: Tools and Theoretical Framework

Optical simulation goggles are widely used by instructors during sensitization. These glasses are modified to simulate VI, e.g., with a restricted acuity or field of view. Simulation goggles support sensitization to identify issues in daily life activities. In general, the instructors craft their own goggles, although commercial glasses exist (e.g. [2]). Aballéa and Tsuchiya [3] positively evaluated the feasibility of experiencing VI with glasses through three conditions of blurred vision. The instructors we interviewed (see our *Method*) use the Disability Creation Process Conceptual Scheme (DCPCS)[8]. The DCPCS posits that the disabling situation is modified by an interaction of personal factors (an impairment) with environmental factors (facilitators and barriers) and life habits (social participation or disabling situations). In particular for healthcare trainees, understanding VI in interaction with the environment is imperative to diagnose and propose solutions. Simulating impairments and disabilities without solutions may focus on problems only, convey the wrong messages and reinforce stereotypes and counterproductive beliefs, such as [16]: (i) The impairments and the disabilities are the problem or the source of the problem. In the worst case: the person with impairments is the source of the problem. (ii) The people with disabilities are not "capable"/ "able". In the worst case: the impression that it is horrible to have an impairment, as it leads to not being able or autonomous. (iii) Feeling happy not having disabilities. (iv) There is nothing that can be done in case of disabilities and impairments. These wrong conclusions may have a huge impact, particularly for sensitization of relatives and caregivers. It may reinforce existing behaviors towards people with impairments, such as considering them as not autonomous (e.g., helping without asking, talking to the accompanying person), rather than adapting building and environmental conditions. By including non-personal factors in sensitization tools, it is possible to convey the following messages: (I) The interaction of impairment and environment is the source of the problem. (II) The impairment does not make somebody incapable, and strategies exist to overcome difficulties. (III) Not having pity for people with disabilities, but rather gaining awareness. (IV) We can propose solutions and modifications to make situations accessible and inclusive.

2.2 Visual Impairment Sensitization

Based on computer graphics, digital VI simulation tools were proposed in research as an alternative to the traditional simulation goggles. Computer serious games are an opportunity to sensitize, for instance with *Vie Ma Vue* [1]. The application proposes to play eight missions in school that may lead to difficulties for people with VI. The quiz at the end of every quest proposes adaptations and strategies. Multiple VR and virtual environment simulators were proposed. In [4], a virtual apartment, which can be explored with VI simulation to understand and recognize the problems described by a patient. However, this tool was not evaluated with participants. In 2011, Lewis et al. [14] proposed a realistic VR simulation in a restaurant environment, to raise awareness regarding the symptoms of eye diseases and demonstrate the difficulties and challenging tasks faced by people with VI. Four opticians validated the benefits of the Virtual Environment (VE) for VI simulation. An expert used the system for 15 min to verify the features. From our understanding of the experimental protocol, twenty-one participants explored the simulator in a one-by-one setting with two tasks (navigation, reading). They had pre-and post-exploration questionnaires about VI and of the problems faced by people with VI. The participants subjectively increased their understanding of problems faced by people with VI, and more participants were able to describe eye diseases. These studies demonstrate the interest for awareness about problems related to VI. However, they were not used by instructors running sensitization sessions. There are various works that use VI simulation in desktop and VR applications for sensitization [15, 6, 13, 18]. The previous works validated the VI simulation in VR and VI simulation for sensitization. However, their conclusions answer only partially whether the objectives of instructors running a sensitization session are reached.

3 Method

Research Question: Our goal is to understand the factors that support and hinder sensitization in VR: Can VR fulfill the requirements of professional sensitization? The interactive design process, with stakeholders, enables to elicit the requirements of a professional sensitization system. These requirements are linked to VR systems, through prototyping and pretests. We gather these factors in an exploratory fashion.

Participants: Four instructors (all female) participated in the iterative design. They represent four occupations, i.e. O&M instructor, Orthoptist, Autonomy in daily life instructor, Consultant in adaptation and assistive technology. All work in a school for young people with VI. One of their responsibilities is to run sensitizations and train external groups regarding VI.

4 Results: co-design of environment and visual impairment simulation in VR

4.1 Usual Settings for Sensitization

In the usual settings, the instructors use modified glasses to simulate VI. These are crafted from conventional glasses by frosting (blurred vision), by adding opaque tape on the glasses except a pinhole for tunnel vision, and by adding opaque circular patches and blurring the remaining vision for scotoma. The sensitization starts with a welcoming and a 15 min theoretical presentation by the orthoptist to the group to be sensitized (generally between 6 and 12 people). After the presentation, the group is split into 3 parts and each sub-group participates in 3 workshops of 30 min each. The workshops are i) navigation by the OM instructors, ii) assistive technology and tools by the Consultant, and iii) home and daily life activities by the Autonomy instructor. After the 1h30 of workshops, the participants have a 15min debriefing with the instructors to comment on the scenario, the VIs, the disabling situations, and the solutions. The participants can take up one of two roles: “experiencing a situation with

VI" while wearing the glasses and performing interactions with the environment, or "observing the participants in situ".

4.2 Design steps

The iterative process to arrive at the final prototype consisted of the study stages (a to c) and the design stages (1 to 5), depicted in figure 1. In the following, we provide detailed results for each of these stages.

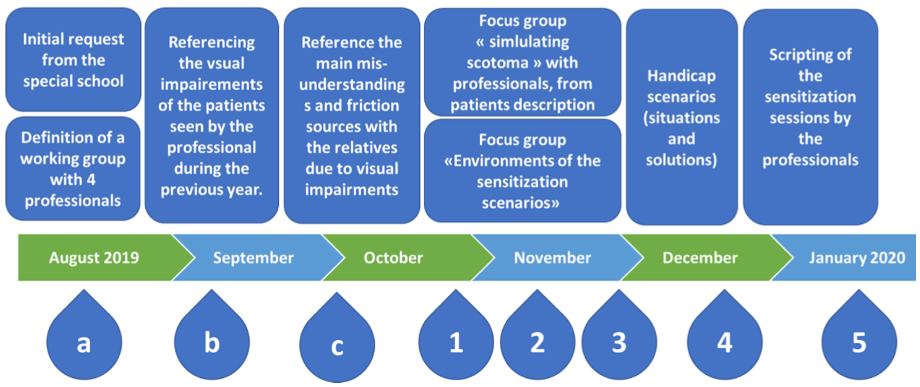

Fig. 1. Iterative design process, with the working group (stages a to c) and the co-designed prototypes (stages 1 to 5) before the final version.

a) In August 2019, we created the working group (WG) of four instructors (see participants subsection). We asked the WG about the objectives of a sensitization. There are three main types of participants in a sensitization session: wide audience, health-care professionals, and relatives. For all, the objectives are awareness about the main category of VI (**Objective O1**), and the associated problems for people with VI, if possible with a general awareness that solutions exist (**O2**). For health-care professionals and relatives, the sensitization aims to provide basic knowledge about the concrete solutions and typical compensatory strategies (**O3**). Finally, relatives may be interested in gaining knowledge about a particular type of VI (**O4)**. Demonstrations that VR and visual impairment simulation support O1 and partially O2 is sufficiently covered in related work.

b) To define the VI to simulate (O1 and O4), we studied official sources (the WHO and national categories of VI). The Orthoptist send us the VI from the consultations the past year. These sources suggest to simulate the field of view, the acuity, and blind spots (scotoma), in particular central scotoma.

c) To bring awareness about the problem faced by people with VI, we asked the working group to identify common misconceptions about VI they encounter in their field work. We found three.

Misconception#1: Why does a person with VI perceive some things and not others (e.g., sees bread crumbs but not the bag on the floor, a bird but not a sign)? Reasons are the type of impairment (tunnel vision for the first example), and multi-sensory perception (bird singing). **Conclusion to avoid #1:** The person is acting in bad faith. **Requirement for sensitization #1:** Provide situations where we can observe variability of functional vision in daily life scenarios.

Misconception #2: Why does a person with VI not search for things (e.g., claiming "I do not have a fork") using strategies appropriate to their VI (e.g., fixating to the side of their blind spot). Reason: The VI is not perceptible to the person with VI themselves because "What is not seen does not exist". **Conclusion to avoid #2**: Waiting for people with VI to know their own limitation compared to the perceptual capacities of people without VI. **Requirement for sensitization #2**: Create a VI simulation where the VI itself is not perceptible, only its consequences.

Misconception #3: Why is the person with VI not paying more attention to their environment, and does not constantly apply strategies to overcome the VI? Reason: Applying cognitive strategies instead of perceptual strategies, such as imposing strict order on the environment or memorizing locations of objects requires a large mental load and is tiring. Therefore, in particular in known environments, the person may not double check if an object is correctly identified or if there are obstacles on the floor. **Conclusion to avoid #3**: Ask the person to compensate constantly for the VI, rather than adapt the environment (house, school) or the habits of the other co-users of the environments. **Requirement for sensitization #3**: Create interactive situations in adapted and non-adapted environments and habits, demonstrate the efficiency of cognitive strategies and environmental strategies, as well as the effort required for cognitive strategies.

Along these requirements, we developed six consecutive prototypes, each tested by the instructors of the WG.

1) The first **prototype 1** (Unity desktop app) simulated blurred vision, tunnel vision (with restricted camera field of view), and a scotoma in 3D environments of a classroom and of a living room (Requirement 1). We simulated auto-completion on the scotoma by progressively losing details when looking at an object (such as writing details) or progressively making small objects disappear in the center of the vision (Requirement 2). To answer the limitation of having only a 2D rendering, we created a Cardboard smartphone VR application, with 3DoF (degrees of freedom, as the user can only influence the angle of the view by turning the head).

2) As the field of view was not editable, we adapted the tunnel vision to be done with a smooth vignetting in the **prototype 2**.

3) To enable the trainees to move (moving closer is an adaptive strategies used for scotoma and blurred vision, and tunnel vision a major implication in movement), we created the third **prototype 3** as a 6DoF VR VI simulation smartphone app. We integrated ARCore anchors to position the Cardboard camera at the position of the smartphone in the room in addition to VR stereoscopic rendering.

4) In order to add object manipulation, we moved to an HTC Vive Pro Eye application, to use eye-tracking, and with the possibility to enable and disable the visual impairments (O1, impact 2) in **prototype 4**.

5) In the **prototype 5,** we integrated complete scenarios of a sensitization session. Currently, we are finalizing the final application.

Final prototype, Hardware and Software. We developed our application using Unity, SteamVR plugin, HTC Vive Pro with an integrated eye tracker, and its controllers. To simulate central scotoma without masking environment (i.e., no black spot visualization), we simulated an auto-completion (or auto-fill) phenomenon by modifying the appearance of the objects themselves. We can extend this technique virtually to any blind spot shapes, by changing the blind spot texture. Acuity is modified with a post processing blur effect on the camera. Tunnel vision is complicated to recreate in virtual reality without creating strong cybersickness by modifying the field of view of the virtual camera. We created two levels of tunnel vision. A first version (25°), not too obvious, uses two mechanisms (the reduced field of view in VR headset of 110° and a blur edge vignette). The second version is a pinhole recreated with a mask (3°). **Environment, Activities, Adaptation and Strategies**. We developed three virtual environments: i) an indoor environment with a living room and a kitchen; ii) a street environment with a pedestrian crossing, a bus stop, and the entrance of a school, and iii) a classroom environment. Since handicaps result from interaction with the environment, the users perform daily life tasks in these virtual environments, interacting with objects through the Vive controllers to learn adaptive strategies (moving, holding an object closer, manipulating a virtual magnifier). The scripted VR scenario includes 24 different interactive tasks to be performed by the trainees. The tasks were chosen from three areas, in which persons with VI commonly receive training: autonomy of daily life tasks, mobility and orientation tasks, and environmental adaptations & assistive technology-related tasks.

5 Discussion

Does our VR application fulfill the requirements for structured sensitization? The VR tool meets Requirement 1. It simulates specific challenges for each type of visual impairment in daily-life situations. Regarding Requirement 2, VR experiences were designed such that the VI itself is mostly imperceptible (see also [17]). For example, scotoma were not simulated as a black spot but rather as an area that is filled-in by the surrounding visual information. Lastly, the tool meets requirement 3, by providing a large number of scripted activities, allowing for the exploration of these activities with and without compensatory strategies as well as providing the possibility to display adaptations of the VR environment that act as facilitators and barriers.

Limitations and perspectives In this work, we do not present quantitative results (including descriptive or inferential statistics). Our future work will be to verify the usability in a professional sensitization context in user study. In addition, we mainly address the potential of VR regarding the target group of health-care professionals, while close relatives and a more general audience would be relevant groups too.

Other approaches to sensitization While VR demonstrated its potential for application in a sensitization context, we did not studied VR as a tool to replace current sensitization means as a full alternative but rather as an additional tool. Other approaches to sensitization exist, including being in contact with people with impairments. We believe that such direct contact with people is essential and should not be replaced with simulations. Our argument is that a first-person experience oriented solution can bring a phenomenological insight, and change beliefs from "I would never be able to do that with an impairment", to succeeding through compensation, adaption, and assistive technology use.

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Actions	VI / VE	Solutions
Find the remote controller	CS / LR	Organization, keep elements always at the same place
Turn on the TV and put the channel 15	CS / LR	Color (red button on-off), bigger button, standard tactile marker on the "5"
Watch the TV	CS / LR	Get closer and neofixation to have visual element outside of the scotoma
Read the journal	CS / LR	Get closer and neofixation, magnifier and e-magnifier
Go to the kitchen	CS / LR	Keep the floor free of obstacle (in the scenario kid toys), contrasted elements, all open or all closed doors
Find a can of bean	CS, BV / K	Get closer and neofixation, organize, use stickers with big police, use Penfriend stickers, close the closets' door
Warm a deep pan	CS, BV / K	Contrasted fire places, logical location of the control buttons, physical buttons, contrasted and tactile indicators of the fire controlled by the button
Serve a liquid in a mug	CS, BV / K	Contrasted mug (depending on the liquid), sense of weight, index in the recipient for cold liquid, temperature on the exterior of the recipient (cold or warm), pitch of the sound, counting the time to fill a specific recipient, electronical sensors
Find a jogurt in a fridge	CS, BV / K	Organizing, contrasted tap on the edges of the frigde racks to understand the fridge organization even with the bloom from the fridge light, contrasted products
Open the door to go to outside with a key	CS, BV / K	Neofixation, organization
Find the number of the house and to go to the number 2	CS, BV / St	Logical research of visual cues, monocular glasses and e-magnifyer
Find the pedestrian crossing and reach it	TV, BV / St	Visual scanning to find the target and avoid obstacle, white cane
Find cues to decide how to cross and initiate the crossing	TV, BV / St	Search for traffic light, activate it through a button or a universal remote controller, listen the sound of the audio traffic light
Find the bus station and how to go to the city hall	TV, BV / St	Find the current stop and direction on the top of the bus station, search in the bus line map the stop, get closer to see the small letters
Find the entrance of the school (VR) or of the auditorium (glasses)	TV, BV / St	Find the signs with the names, and search the entrance doors with logical visual scanning
Count the number of steps	TV, BV / St	Use the line on the side of the stairs, standards (contrast and tactile warning bands)
Enter in the classroom and find and reach the black chair	PH / CR	Keep the floor free of obstacles, visual scanning
Find which of the 3 maps of the room is correct (VR) or draw the map of the room	PH / CR	Do not change the spatial organization, visual scanning

Actions (end)	VI / VE	Solutions
Read the content on the numerical board and find the newly added teacher's written note	PH / CR	Good positioning regarding to the board, second screen for the student, control on light, police, size, color and contrast
Read exercise instructions	BV / CR	Chose the color of the paper depending on contrast (white) and photophobia (ivory), adapt the size and the police
Measure with a ruler the triangle sides	BV / CR	Chose an adapted ruler (high contrast and big police), and a highly contrasted figure
Calculate the sum of the triangle sides	BV / CR	Use a speaking and big police calculator
Read a corrected copy of a student with visual impairments	BV / CR	Write with a black and contrasted pen, avoid cursive writing, learn dactylography to write, read, proofread and review the written information
Find the Word icon on a computer desktop	BV / CR	Organize, use bigger icons and text, zoom tool

Table 1. Steps of the scripted scenarios. Acronyms for VI(visual impairments) in the table: CS=central scotoma, BV= blurred vision, TV=tunnel vision, PH= pinhead vision. Acronyms for VE (virtual environments) in the table: LR= living room, K= kitchen, St=street, CR= classroom. Actions to perform in the sensitization scenarios (column 1), the associated VI simulated (col. 2), the proposed solution (col. 3).

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