Providing Psychological Support after Miscarriage through a Customizable Virtual Reality Experience

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***Abstract*—A miscarriage, an unintentional pregnancy loss before the 20th week of gestation, can be a traumatic experience. The psychological impact that miscarriage often has on parents, especially on women, is substantial. Nevertheless, social and professional support often fall short for those who go through it. Here, we describe the development process of AViR (Adaptive Virtual Reality), an immersive Virtual Reality (VR) system for delivering psychological support after miscarriage. AViR merges standard protocols of psychological support with procedural VR scenarios and user-generated content to deliver customized restorative experiences. This innovative approach to using VR for this target population expands research on a substantially understudied topic. The impact AViR could have is significant and it has the potential to make a difference in the lives of many women.**

Keywords—miscarriage, Virtual Reality, procedural content generation, psychological support

I. Introduction

Each year, about 23 million miscarriages occur worldwide, affecting up to 25% of all recognized pregnancies [1]. This means that 1 in 4 women will go through this experience. Despite its high prevalence, miscarriage is still surrounded by secrecy and its impact on the lives of those who go through it is often overlooked. However, miscarriage can lead to emotional distress and psychological complications that persist for months and even years after the event [2]. A recent survey with 873 women that experienced a miscarriage has shown that 7 to 12 months post-loss, 56% of women had symptoms of anxiety, 31% of depression, and 25% of posttraumatic stress [3]. Psychological interventions to help parents manage their grief are effective at reducing these symptoms [4], [5]. However, only a limited number of women have access to professional support, as this service is often not available in the context of miscarriage [3]. To address this lack of support, technology-based self-management tools are promising for increasing access to psychological assistance.

The use of technology-mediated support approaches targeted specifically at pregnancy loss is still an understudied area, with most proposals being internet-based, but the available results are promising [6]. For example, Wagner and co-authors developed an internet-based Cognitive Behavioral Therapy (CBT) protocol for pregnancy loss, whose impact was assessed in 29 women with complicated grief compared to a waiting group [7]. It was a 5-weeks treatment, during which patients were given writing assignments twice a week and communicated with a therapist by e-mail. The results of this study showed a decrease in avoidance, feelings of failure, and a general improvement in depression symptoms, with over 80% reporting positive attitudes toward internet-based treatments compared to face-to-face [7]. In a subsequent study, a different internet-based CBT intervention was examined with 115 participants who experienced the loss of a child during pregnancy. The effectiveness of this intervention was compared to a waiting list condition of 113 individuals [8]. It was a 5-weeks treatment with bi-weekly writing assignments that addressed self-confrontation, cognitive reappraisal, and social sharing. Results showed a significant reduction in prolonged grief, depression, anxiety, and post-traumatic stress, which were maintained at 3 and 12 months after treatment [8]. Despite existing barriers to the widespread use of computer-based interventions (e.g., therapist competence and training, communication issues, privacy issues, absent guidelines), the results of the scarcely available studies highlight the significant benefits these approaches have, particularly for those that have no access to other means of psychological support. This field is constantly evolving, particularly with the numerous benefits that technologies such as Virtual Reality (VR) offer for mental health treatment.

VR-based experiences have been used in many clinical areas, among them phobia training, treatment of post-traumatic stress disorder (PTSD), addiction and relapse prevention, pain perception, and body image disturbances [9]. The possibility of controlling the VR environment facilitates the presentation of contexts, tasks, and other stimuli that are either difficult or impossible to achieve in in-vivo exposure therapy, all within a safe and ecologically valid environment [10], [11]. Additionally, VR enables customization and personalization based on the patient's needs, with an appropriate gradation of the stimuli and tasks. Further, the gamification of such tasks has proven to promote motivation and engagement, especially in self-help platforms [11].

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Unfortunately, there is almost no research on the use of VR to help parents adapt to pregnancy loss. One study that used VR (EMMA's World) to cope with grief after losing a significant other, which included some participants who had suffered a pregnancy loss showed encouraging results [12]. This system is being used specifically for providing psychological support after pregnancy loss, but no results have been published so far [13]. More recently, the Chelsea and Westminster Hospital NHS Foundation Trust, and its official charity CW+, have launched the Eirene project, whose goal is to use VR as a distraction technique in patients undergoing manual vacuum aspiration for miscarriage [14]. Its purpose is to manage acute pain and anxiety during the procedure to prevent the onset of psychological disorders. There is no information on the specific details of this VR experience and to what extent it is customized to each participant. Also, to our best knowledge, no results on the effectiveness of this approach have been published so far.

Our goal is to expand research in this field by introducing the concept of AViR (Adaptive Virtual Reality), a multi-scenario VR system that utilizes the flexibility of VR and conventional psychological support protocols to provide a customized intervention designed exclusively for individuals who have experienced a miscarriage. We use procedural generation, user co-creation of content, empathetic avatars, and content curated by health professionals with experience in psychological support after pregnancy loss, to offer a comprehensive protocol that addresses different domains in the grief management process. Here we describe the theoretical foundation of each module of AViR and its technical implementation, as well as the studies conducted to define the content of each module.

II. Methods

AViR encompasses four modules (Psychoeducation, Validation of the loss, Social sharing, and Adaptation to the loss) based on existing and validated protocols for providing support after grief, adapted to the specificity of pregnancy loss and VR [7], [15]. These four modules are to be delivered in a sequential order, supervised by the psychologist, following a structured arrangement of tasks that address different elements of the grief adaptation process, in line with what is traditionally done in psychological intervention. The experience is designed such that achievements in each module are persistent and identifiable in the environment, so that the user can quickly and easily revisit them and receive positive reinforcement of her progress.

A. Setup and user interaction

The VR scenarios were developed in Unity and are rendered on a Head-Mounted Display (HMD, Oculus Quest 2), which is connected to a laptop (Asus TUF F15 15.6" FX516PM i7 8GB 512GB RTX) where the psychologist oversees the session and overrules the system when required. The HMD consists of inside-out head tracking, a high-resolution display, and two wireless hand-held controllers with buttons and a joypad [16]. The user moves in the scenario by teleportation and the selection of existing objects is done through proximity with the object. The interaction with the menus and with the user-generated content is done through point-and-click.

In the following, we describe the theoretical foundations and studies that underpin the design of the VR experience and content presented to the user for each module.

B. Psychoeducation

Psychoeducation aims at educating patients about the different aspects of an illness or condition to help them integrate the emotional aspects, and facilitate the acceptance of the loss and the development of coping mechanisms [17]. Hence, the goal of this module is to provide structured and didactic information about miscarriage and the usual emotional, behavioral, and physiological manifestations experienced after such an event. The user should explore, at her own pace, a relaxing scenario and find text- and audio-based psychoeducation information. We decided to develop a nature-based setting because of its restorative properties regarding the reduction of stress and anxiety [18]. To create valid and significant content for the psychoeducation module, we ran focus groups with 6 health professionals (4 psychologists and 2 nurses) with experience in providing psychological support to parents who experienced a pregnancy loss. We conducted two sessions with 3 participants each. Both sessions (4 hours in total) were conducted remotely via Zoom and were recorded for later transcription. To organize and display the content during the sessions, we used the Miro platform (https://miro.com), an online collaborative tool that helps information organization. The goals for the focus groups were 1) the identification of the main topics to be addressed in psychoeducation directed towards miscarriage; 2) the creation of psychoeducational messages for women that experienced a miscarriage; and 3) the allocation of those messages to the topics identified in 1). This study was approved by the Ethics Committee of Universidade da Madeira (CEUMa, P42/2022).

C. Validation of the loss

A miscarriage is often invisible to others and not seen as a legitimate loss. However, grieving parents need to acknowledge that the pregnancy has existed and validate its loss so that the healing process can occur. One way to do this is through rituals and memorials that honor the memory of the lost baby [19]. We conducted an online survey in Portugal to register the experiences of women that had suffered a miscarriage, for which we had 873 valid answers [3]. One topic addressed in the survey was which rituals these women had performed after the miscarriage. We analyzed the data to identify the most recurrent practices and defined virtual scenarios to recreate those rituals and have memorials. These memorials should be persistent in AViR, allowing users to revisit them anytime.

D. Social sharing

Miscarriage is still a cultural taboo, and parents often do not have the opportunity to share their feelings and mourn their loss openly. However, sharing experiences about the loss is known to reduce negative mental health responses [20]. The goal of this module is to promote social sharing in two ways. First, by exposing the user to the experiences of other women that suffered a pregnancy loss. Sharing experiences in social media has been shown to be an effective resort for people to share their feelings of loss with others who underwent similar experiences [21]. To that end, we used social media to advertise our project and ask for testimonials from women who underwent pregnancy loss. Volunteers were informed about the purpose of the project and the testimonials they would share and provided their written informed consent. The second way to promote social sharing is by encouraging the user to voice her own experience and share it with an artificial agent of her choosing. Virtual human characters have been

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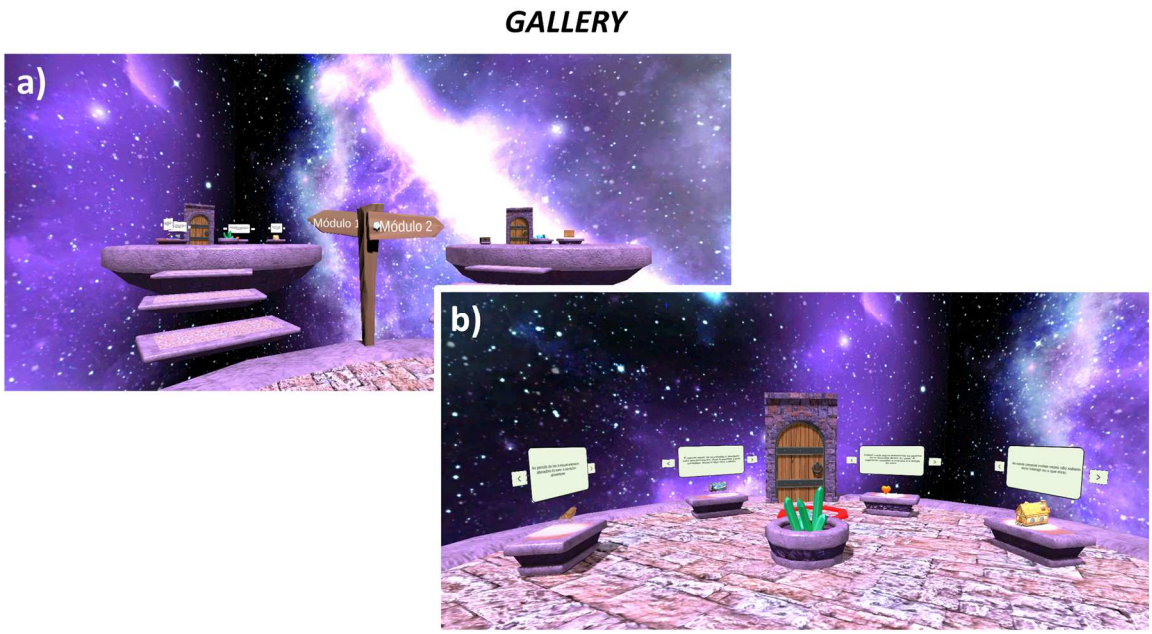

Fig. 1. Gallery. The place where the user a) can find gateways to the different modules and b) where she can revisit all her achievements in AViR, which are represented by tokens and text placed on tables.

shown to be adequate as stimuli in different mental health applications [22]. In the particular case of virtual health assistants, research has shown that interventions are more effective when conversational agents show verbal and behavioral empathy [23]. Hence, our goal is to have customizable agents with different characteristics that display behaviors of empathy and active listening. The user should have the option to select an agent that suits her preferences.

E. Adaptation to the loss

An essential part of the grieving process is the reconstruction of a meaningful life after the loss, which is key for future positive emotions and well-being [24]. Hence, the goal of this last module concerns promoting the resumption of normal functioning by providing recommendations on healthy life choices. We developed the content of this module based on the approaches proposed by different authors with experience in delivering grief therapy [25], [26].

III. Results

Here, we present the resulting implementation of AViR. In its current form, the system is to be used under the supervision of a psychologist that assists the user and provides guidance on which modules to experience in each session. The following sections describe the four modules of the AViR system, each of which is accompanied by a narrator (represented by a purple sphere) who provides the user with information and assistance as needed.

Taking into account that AViR has different modules, some of these with different topics, we felt the need to have a virtual place where the user starts and ends each session, and where she can revisit all her achievements in AViR. For this purpose, we created the *Gallery*, a fictional place free from any contextual connotations, so that the user, for example, does not associate it with any personal experiences or religious beliefs (Fig. 1). The *Gallery* has different platforms with gateways to each of the modules of AViR. In addition, this is where all the achievements can be revisited. For this purpose, a platform was created for each module with several tables, one table per topic, displaying the achievements each time a module/topic is concluded.

A. Psychoeducation

From the focus groups, sixty-four psychoeducational messages were defined and allocated to the four different topics to be delivered as messages in this module: 1) *Introduction* (transversal introductory content on miscarriage); 2) *Feelings and Emotions*; 3) *Family and Social Relations*; and 4) *Conjugal Relationship*. Before starting the psychoeducation module, the user selects which topic to address during the session. Therefore, it takes four sessions to visit all psychoeducational messages in this module.

To deliver these messages, we developed a pleasant nature-based scenario using Procedural Content Generation (PCG) for the user to have a never-repeating experience in subsequent sessions. To achieve this, we generated pseudo-random terrain meshes and spawned vegetation using a pattern derived from Perlin noise (Fig. 2a). A path for the user is then generated using NavMesh agents, with the primary agent starting at a random position (path origin) and moving towards another distant random location (path end), drawing a colored trail on the ground that simulates a dirt path (Fig. 2b). As the NavMesh agent generates the path, it places level-specific tokens that the user can collect through proximity-based triggered interactions. Upon collection of each token, a different psychoeducational message is displayed (Fig. 2c).

B. Validation of the loss

From the online survey, the most reported rituals performed by women were having a memory box with items that belonged to their baby, planting a tree/plant, and writing a poem/letter. Hence, in this module we created two scenarios that allow performing all those rituals, namely, 1) *Chest of Messages* and 2) *Garden*.

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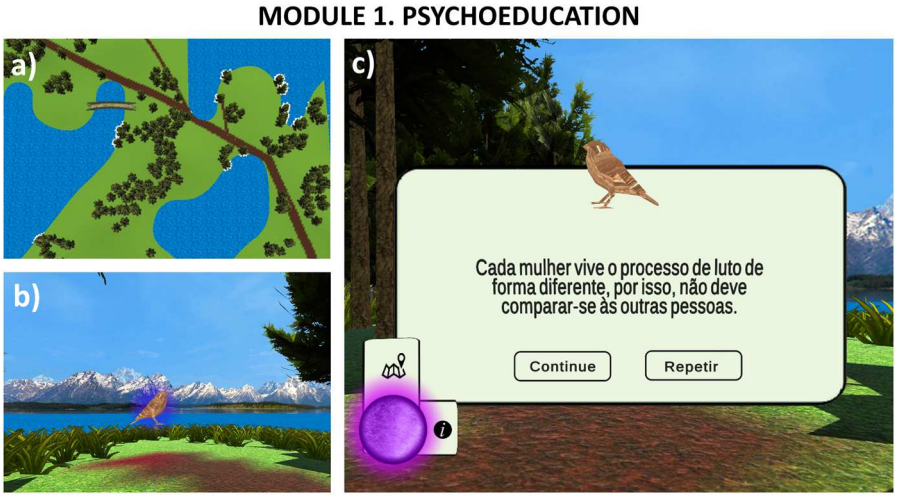

Fig. 2. Psychoeducation. a) The user follows a path and b) finds tokens, which c) display psychoeducation content. The message in this example reads "Every woman experiences the grieving process differently, so you should not compare yourself to other people".

- *Chest of Messages*: this scenario allows the user to create text and audio messages, store them in a chest, and read/listen to them later. Users can record their voice messages using a microphone, which are then associated with interactable Unity game objects representing an antique cassette spawned inside a chest. The cassette features buttons for playing and deleting the recorded message (Fig. 3a). The cassette ID and associated recording are saved to a JSON file in a user-specific folder, respectively, allowing access in future sessions. In addition, users can create a memorial with a written message that functions similarly to the cassette. Instead of a voice recording, the user inputs a written message, placed within a letter inside an envelope Unity game object (Fig. 3b).
- *Garden:* in this scenario, the user can create a personalized persistent virtual garden in any place in the environment (Fig. 4). Elements can be placed, changed and moved in different sessions. Users are presented with a menu for creating their garden in the selected location. They can choose the items they wish to place from a repository of assets organized in categories such as trees, flowers, benches, and fountains. Once an item is inserted, users can interact with it using its interface buttons to resize, enlarge, shrink, or delete it. Users can also take a picture of the garden, which is saved to their personal user folder.

C. *Social sharing*

In this module, we created two scenarios, 1) *Testimonials* for viewing the collected testimonials of other women, and 2) *Sharing* for the user to share her own experience.

- *Testimonials*: in this scenario, the user enters a virtual round agora where different video testimonials are displayed as floating canvases. Under each video canvas, a classic playback user interface is provided, which includes buttons to play, stop, fast-forward, or rewind the video by 10-second increments.
- *Sharing*: this scenario allows the user to select a virtual character whom to share her experience of miscarriage with (Fig. 5). To enable the best sharing experience, three avatars were created: 1) *conversational humanoid*, 2) *nonconversational humanoid*, and 3) *conversational nonhumanoid*. Humanoids allow the customizations of eye color, and hair style and color. In the current form of AViR, speech lines and animations are triggered by a psychologist through the Wizard of Oz method, using a stream deck with different buttons for each reaction. The humanoid's animations were divided into multiple layers, including eyebrows, mouth, eyes, head, arms, legs, and torso, blended at runtime to generate full-body rich animations to depict accurate gestures and postures. For both conversational agents, we recorded a pre-defined set of lines, which are triggered together with the animations as each key is pressed. Finally, the conversational nonhumanoid agent features hover and spinning animations, and the visual representation of speech is achieved through a circular spectrogram.

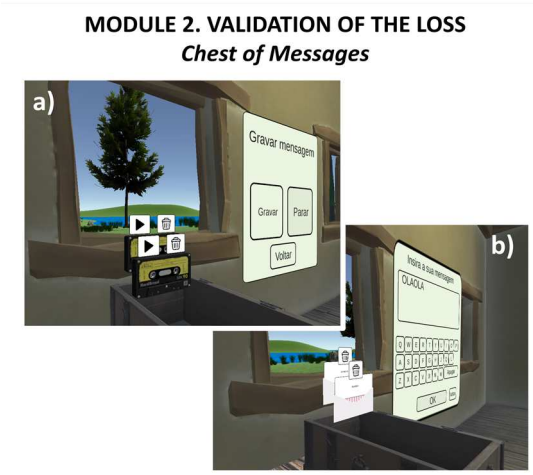

Fig. 3. Chest of Messages. The user can record a) audio and b) text messages.

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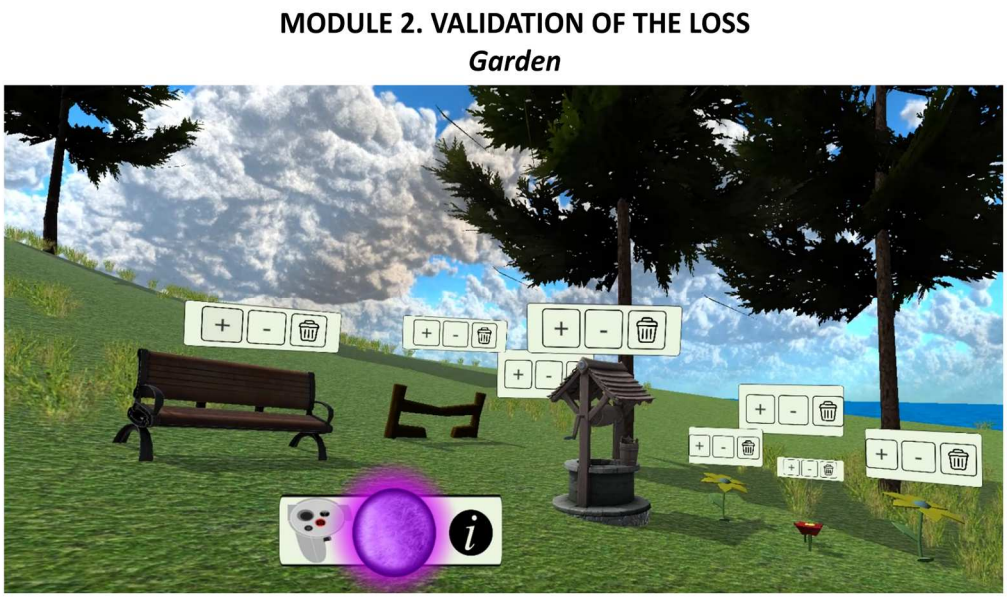

Fig. 4. Garden. The user can create a garden in a place of her choosing. The garden can be visited and edited in subsequent sessions.

D. Adaptation to the loss

In this module, the user enters a virtual exhibition room with four tables, each table dedicated to a theme to promote healthy lifestyles and well-being (Fig. 6). The following themes were defined: 1) *Mental Health and Self-care* (recommendations about self-care routines, like emotional regulation and mental health habits, for example, meditation or walking in nature); 2) *Physical Health and Exercise* (general health habits and physical activities that promote well-being, for example, suggestions on having a balanced diet and practicing physical exercise); 3) *Social Life* (recommendations on how to re-establish social contacts in a healthy way and to express feelings to friends and family); and 4) *Return to Routine* (simple and practical information to help the return to the daily routine, such as the suggestion to define small and achievable everyday goals). Each theme has a pictorial representation on a medallion positioned on the table. When the user approaches a medallion, an interface associated with it appears, displaying the specific content of that theme. The content consists of pre-defined statements containing information and recommendations, which the user can browse through.

Fig. 5. Sharing. The user can share her experience of miscarriage with a virtual character of her choosing.

IV. Evaluation Plan

While the proposed protocol is heavily based on established protocols that have shown good results, the features specific to VR render the AViR as a novel approach that requires validation. We are currently recruiting participants for a controlled study to evaluate the feasibility of the proposed VR paradigm in women that experienced a pregnancy loss within the first 20 weeks (study registered in ClinicalTrials.gov, NCT05880381). Recruitment of participants is being done in collaboration with the Obstetrics-Gynecology Service of SESARAM – Serviço de Saúde da Região Autónoma da Madeira, in Portugal. We envisage recruiting a sample of 20 participants to be randomly allocated into two groups, a VR intervention group or a standard-of-care group. The VR intervention group will undergo two weekly sessions of 45-60 minutes for four weeks with AViR. The standard-of-care group will receive the standard medical care offered in SESARAM to patients of the target population. Both groups will be assessed for grief, post-traumatic stress, anxiety, and depression symptoms before and after the intervention using psychological assessment scales validated for the Portuguese population. We will assess perinatal grief using the Perinatal Grief Scale adapted to the Portuguese population by Rocha and Afonso in 2004 [27]. For evaluating post-traumatic stress, we will use the Posttraumatic Stress Disorder Checklist for DSM-5 (PCL-5) [28]. Anxiety and depression will be assessed using the Hospital Anxiety and Depression Scale (HADS) [29]. For evaluating the usability

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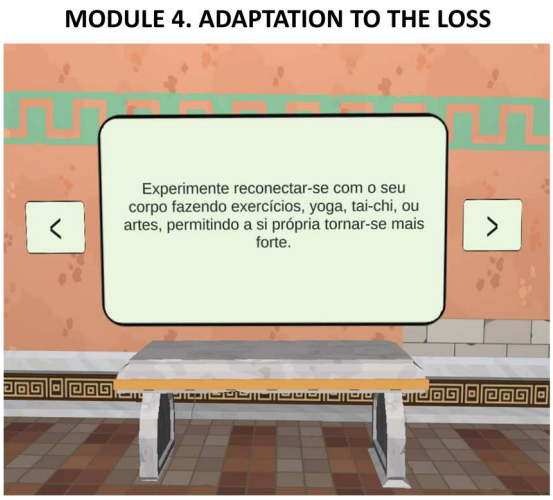

Fig. 6. Adaptation to the loss. Recommendations are given to the user, regarding healthy lifestyle choices. The message in this example reads "Try reconnecting with your body by doing exercises, yoga, tai-chi, or arts, allowing yourself to become stronger".

and user experience of the VR prototype, at the end of the intervention, patients allocated to the VR group will fill-out validated questionnaires with different purposes. For assessing the overall usability of the prototype, we will use the System Usability Scale (SUS), a widely used scale that provides a global view of subjective assessments of usability [30]. To assess the VR user experience, we will use the ITC - Sense of Presence Inventory adapted to the Portuguese population by Raposo-Vasconcelos *et al.* [31]. This inventory has two parts, the first addressing the user's feelings after the experience, and the second related to the characterization of the experience during the simulation. It includes a total of 44 items organized into four factors, namely, Sense of physical space, Engagement, Ecological validity, and Negative effects. In addition to these instruments, we will also use a customized questionnaire with open questions where participants can freely elaborate on any issues related to the technology such as acceptance of the headset. This study has been approved by the Ethics Committee of SESARAM.

V. Discussion and Conclusions

The lack of psychological support for women who have experienced a miscarriage can lead to persistent psychological disorders. VR is a powerful technology for mental health treatment that has shown potential for supporting this population. However, no VR systems have been specifically designed to provide support after miscarriage nor results on the effects of any dedicated VR-based approach have been published. As such, AViR is an innovative contribution to the literature by delivering a VR system that has been strictly conceptualized to address the different domains in the grief process after miscarriage. Four modules and their specific elements have been developed following traditional psychological support protocols, theoretical foundations, input gathered from health professionals in this domain, and first-hand experiences from women who underwent a miscarriage. All these have been combined to create a system that has the potential to serve as a valid alternative for psychological support when no other means are available.

VR possesses several characteristics that make it an ideal medium for implementing this approach. Its ability to create a safe place where users can express and share their feelings, develop coping skills, or just retreat in the middle of a forest for relaxation, renders VR as a promising technology for addressing traumatic experiences like pregnancy loss [32]. The social taboo surrounding the topic often means that some of these women may grieve alone, isolated from their friends and family, and may not have even shared their loss with anyone. This is why a system that can be easily accessed from the privacy of their homes, is economically accessible, and has been proven effective in addressing any possible symptoms of clinical illness, is essential. One may consider that immersive VR technologies are still expensive for a large number of the population. However, technologies such as HMDs are expected to grow cheaper and be standard home-entertainment equipment in the next few years. While in its current prototype AViR is not yet delivered as a self-guided standalone application in an all-in-one HMD, this work is a first step in that direction.

It is worthwhile mentioning the fact that AViR currently only considers psychological support to women that physically experienced a miscarriage. We would like to stress that we acknowledge the psychological impact that such an event can also have on fathers and partners in LGBTQ+ couples. Ideally, a system such as AViR should be designed to include both members of the couple in the process. However, the fact that men and women, and gestational or non-gestational mothers reportedly have different coping styles, grieve at a different pace, and may have different types of attachment to the lost baby makes it more complex to design something suitable for all [33]–[35]. Moreover, because the feasibility of AViR is yet to be evaluated and compared to traditional protocols, we are focusing on gestating women because there is a more extensive literature body and protocols for contrast.

This work has some limitations that should be mentioned. First, because some content of AViR was developed based on the experiences of women and health professionals living in Portugal, this approach may not be fully generalizable to other countries and cultures. And second, because of funding limitations, after participants conclude the 4 weeks intervention with AViR, we are unable provide participants a follow-up with health professionals to accompany their evolution in the bereavement journey.

To conclude, we believe this research can have an important impact at scientific, technological, and societal levels, namely it: 1) contributes to further understand the process of psychological recovery after a miscarriage; 2) adds to the advancement of evidence-based technologies for psychological support; 3) has the potential to bring psychological support to women that have no access to other means of support; and 4) contributes to reducing the societal and economic healthcare burden by providing tools to improve the well-being of patients.

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