Pragati: Design and Evaluation of a Mobile Phone-Based Head Mounted Virtual Reality Interface to Train Community Health Workers in Rural India

Shimmila Bhowmick, Rajkumar Darbar, Keyur Sorathia
Embedded Interaction Lab
Indian Institute of Technology (IIT) Guwahati, India
shimmila.bhowmick, rajdarbar.r, keyurbsorathia}@gmail.com

ABSTRACT
Community Health Workers (CHWs), specially Accredited Social Health Activists (ASHAs) play a significant role in improving healthcare services in developing countries like India. Although ASHAs are key-actors influencing rural health care, they are inefficiently trained. This leads to sub-optimal knowledge and skill sets, hence poor information delivery among community members. In this paper, we present the design and evaluation of *Pragati*, a mobile-based Head Mounted Display (HMD) enabled Virtual Reality (VR) interface for training ASHAs. A user study conducted among 19 users revealed significant learnability and self-efficacy post-*Pragati* usage. Further, we conducted a between-group study among 57 CHWs to assess effects of 3 platforms (i) *Pragati*, (ii) mobile phone-based traditional videos and (iii) mobile phone-based 360-degree video on measures of learnability, self-efficacy, engagement, and presence. The results showed no impact of the platform for learnability and self-efficacy, whereas a significant increase in engagement and presence was observed for *Pragati*.

Author Keywords
ICT4D; HCI4D; CHWs; ASHA; Maternal and Child Health; Training; Virtual Reality.

ACM Classification Keywords
H.5.m. Information interfaces and presentation (e.g., HCI):

INTRODUCTION
Community Health Workers (CHWs), especially Accredited Social Health Activists (ASHAs) provide well-being to Indian households by attending to their needs and solving their healthcare problems. They are primarily women and often the only point of contact as health promoters in the rural communities. They act as a primary entity against the menace of child malnourishment, infant mortality, and in curbing preventable diseases in a local community [40,25].

Despite being an important part of the healthcare ecosystem, ASHAs are often ignored from getting competent training and skill education [27]. They are unable to achieve a certain standard of skill sets and health education due to delayed and insufficient training [2], use of traditional & non-engaging teaching methods at training centers [42], and shyness among ASHAs to discuss sensitive topics.

We conducted a focus group study with 7 ASHAs and 4 ASHA trainers to further understand the challenges of traditional training sessions. While the issues of poor feedback, delayed and insufficient training and passive learning were confirmed, we also identified challenges of difficulty in visualizing complex healthcare concepts (e.g. position of the baby inside the womb) and inability to relate these concepts and related tasks in the real world (e.g. ensuring appropriate temperature for newborn in a home environment). This results in a poor understanding of complex healthcare contents and causes a disconnect between the field reality and what is learnt - thus resulting in low confidence in information delivery among community members.

Virtual Reality (VR) has shown potential through improved knowledge gain and self-efficacy in the context of training and education [16,4,12]. It simulates a real-world environment, demonstrates difficult concepts with ease [19, 22], and provides control to the viewing contexts [20,17]. Further, virtual environments accessed through Head Mounted Displays (HMDs) have shown improved learning outcomes [10,15,18], increased confidence [43,44] and positive behavior change [36]. The increasing availability of the low-cost viewers (such as Google Cardboard viewer) [29] is creating opportunities to adapt to VR's potential in training and education, including solutions for underserved communities [24].

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In this paper, we present the design and evaluation of *Pragati* (meaning Progress) - a mobile phone enabled HMD-VR platform to train the ASHAs. We designed audio-visual information modules by simulating a traditional home environment and characters to educate on maternal and child healthcare contents. To the best of our knowledge, this is the first attempt exploring a low-cost HMD-VR to train ASHAs/CHWs in rural India. We evaluated the impact of *Pragati* in increasing the learnability and self-efficacy among ASHAs. We further compared *Pragati* to traditional mobile phone-based videos and 360-degree videos to study the impact of these technology platforms on learnability, self-efficacy, engagement, and sense of presence.

The contributions of this paper are twofold - (1) design and evaluation of *Pragati* and (2) a validation of the suitability of *Pragati* over traditional mobile phone-based videos and 360 degree videos.

RELATED WORK

We present the related work in two sections. We start with Information Communication Technology (ICT) interventions targeted to CHWs training, followed by VR supported educational and training interfaces.

ICTs in CHWs Training

ICTs, especially mHealth tools have been well explored in training of CHWs. Sangoshthi [42] used Interactive Voice Response (IVR) to provide training sessions to CHWs. While it increased peer communication and access to basic phones, it lacked learner-content interaction and knowledge acquisition of complex healthcare information. Ramachandran et al., [26] created a series of 7 mobile-based video modules and testimonials to motivate and educate rural ASHAs in Karnataka, India. Key influencers of the community enacted in the education modules and testimonials to motivate local health workers. Another notable ICT enabled dedicated health education and learning system is Healthline [34]. It is a speech input based service that provides easy access to health information by conversing in the local language to an automated dialogic system. The results suggest increased health information knowledge among CHWs. "CommCare" [36] suggested increased credibility and engagement between CHWs and clients during counseling sessions with the inclusion of localized multimedia. The perception of the information, which came from an expert or doctor made it appealing and deemed increased acceptance [38]. Bajpai et al., [2] designed a system that used local radio channels through passive audio messages in order to provide training as well as health information about the child and maternal health, immunization, family planning etc. In another study, Silfvast et al., [35] used mobile health intervention leveraging visuals and audio to support patient education in a maternal and child health by nurse midwives in rural India. Interviews with midwives, observation of patient visits, and an analysis of logs deemed positive acceptance of mobile devices as part of the workflow and resulted in more focused activity. Subsequent research by Molapo and Marsden [21] showed the effectiveness of deporting training content to low literate populations in non-textual and locally relevant formats. This system allows a trainer to load images and record descriptive voice which is formatted to play on mobile phones thereby increasing the credibility of the content.

VR Interfaces for Training and Education

The potential of VR for training and education is well known, including school education [20,33], safety training [16,35,38], language learning [6], medical education [11,8] and vocational education and training [24]. Li, C. et al. [16] developed a virtual environment for earthquake safety training, which exposes a user to simulated earthquakes in realistically modeled scenes. The results suggest improved visual attention in the scene, increased attentiveness to potential dangers and higher retention as compared to other training methods (video and safety-manual). Zhang, H. [12] used leap motion device with HMD-VR to provide training on drilling methods in underground mines. The comparative study showed that HMD-based system is more immersive, intuitive, realistic, and easy to use than a controlled screen-based system. Buttussi and Chittaro [4] studied the effects of different types of display (desktop VR, an HMD with a narrow field of view and HMD with the wide field of view) for procedural training in aviation safety procedures. The results indicate increased sense of engagement, self-efficacy, and presence for HMD with the wide field of view compared to other methods. In [6], Cheng et al. adapted Crystallize [7], a 3D video game for learning Japanese, in VR to teach language and embodied cultural interaction, such as bowing in Japanese greetings. This increased user's sense of involvement, learning of words from context, encouraged long-term learning and motivation. J. H. Seo et al. [33] examined a VR system to support embodied learning in canine anatomy education and mentioned that students preferred a VR system than conventional bone-box to assemble and orient bones in 3D space. A promising work is shown by Minosha et. al [20], in which the benefits of using mobile-based HMD-VR during geography field trips was highlighted. The users perceived an accurate representation of space, sense of spatial presence, and experienced higher immersion. This strengthened the approach that users could view details those are not visible to the naked eye, see its different points and observe a scenario in different conditions. In another work, Vishwanath et. al. [39] used VR to demonstrate real-world phenomena and illustrate various educational concepts. This representation evoked users' curiosity and reflected enhanced engagement with the content among the users. Rasheed et al. [28] performed a preliminary experiment with rural students in India to see the effectiveness of VR for teaching the subject of history.

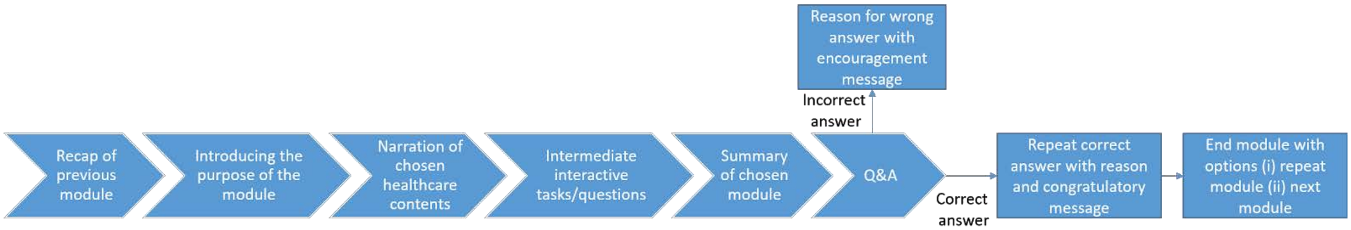


Figure 1. Framework of information exchange in creating training and educational modules for *Pragati*

The results indicate increased spatial awareness (observation, color, direction) of the content, curiosity, and interest among the users.

Overall, VR based training platforms have been well accepted to actively engage learners resulting in faster learning, better retention, increased engagement and improved decision-making. With the cost of HMD-VR dramatically reducing, the potential of VR interfaces must be deployed and studied for underserved communities in resource-constrained regions.

INTRODUCTION TO ASHA

ASHAs are women chosen by the community and trained to act as health educators and promoters. They mobilize the community in accessing health services and promote uptake of skilled birth attendance in collaboration with Auxiliary Nurse Midwives (ANMs). They bridge the gap between communities and health facilitators, create awareness on government health services and mobilize the community towards their utilization. Each ASHA covers a population of 1000 community members and receive performance-based compensation for facilitating immunization and referral services [31]. For this effort, the national guidelines stipulate that ASHAs receive 23 days of training in the first year and 12 days of training every subsequent year after that. The aim is to impart health education and skill sets, and attitudes required of an ASHA to effectively perform their roles and responsibilities. However, in practice, the amount of training received by ASHAs varied. The training was imparted only for 5 days in some cases.

DESIGN AND DEVELOPMENT OF PRAGATI

Introduction to Pragati

We designed and developed *Pragati*, a mobile phone-based HMD-VR platform to train and educate ASHAs. A virtual environment consisting of 3D characters and audio-visual animations was designed to present information modules in local Assamese language. Two personas (i) 'ASHA baidew'- who acted as a virtual guide through each information module and (ii) 'Meera' - who acted as a pregnant woman were designed to increase familiarity to *Pragati* interface. We used Google Cardboard as HMD viewer due to its lower cost, adaptability to most of the smartphones and potential future scalability. Gaze was used as an input method for selection. A joystick (connected to mobile phones via Bluetooth) was used to navigate inside the virtual environment.

Figure 2. Landing interface of *Pragati*

Pragati starts with a landing page showcasing 3 information modules on maternal and child healthcare. Users are asked to choose a specific information module from the interface. Figure 2 showcases the landing interface for *Pragati*. Each information module is narrated in 6 stages - (i) recap of the previous module (if any) (ii) introduction to the purpose of the module by the 'ASHA baidew' (iii) narration of chosen module (iv) intermediate interactive questions and tasks (v) summary of the chosen module and (vi) Q&A section presenting questions relevant to the chosen module. Each incorrect answer given during Q&A is responded back with appropriate reason and a motivational message to continue learning. Each correct answer is appreciated by clapping (sound) followed by more details on the answer. Once the module is over, the user is given a choice to replay the module or move to the next module. Figure 1 presents the schematic framework of information exchange of the healthcare modules of *Pragati.*

We present the details of healthcare contents in the following section. We further explain the design of proposed VR interface in 3 sections - (i) design of virtual environment and persona (ii) intermediate interactive questions and tasks and (iii) input interactions.

Details of Healthcare Contents

We chose maternal and child healthcare modules due to (i) its immediate need to curb Maternal Mortality Rate (MMR) and Infant Mortality Rate (IMR) [14] and (ii) recommendations from the National Health Mission (NHM) (Assam, India). The health contents are adapted from existing ASHA training modules, booklet no. 6 & 7 to ensure content authenticity. Booklet 6 focuses on

Figure 3. Interface screenshot of module 1 - (a) ASHA baidew explaining the baby's position inside Meera's womb (standing position) (b) visualization of the path (side-view) of baby coming out of womb in sleeping position during the second stage of labor (c) After the second stage of labor, 'ASHA baidew' instructing the way to hold the baby as the baby comes out of the womb.

Figure 4. Interface screenshots of module 2 - (a) Cleaning the baby after birth with a gauze piece (b) observing for baby's limbs movement as one of the 3 indicators of a live birth (c) giving the baby back to mother after live-birth examination.

Figure 5. Interface screenshots of module 3 - (a) noting the time of birth (b) Clothing the baby to maintain body temperature (c) closing the window to maintain room temperature and placing the baby near mother.

maternal and newborn health while module 7 focuses on child health and nutrition. These booklets are approved and used by NHM in India. The developed modules were further approved by maternal health consultant of NHM. 3 following modules were developed for this study - (i) stage of labor & child delivery (ii) examining the newborn at birth and (iii) providing newborn care immediately after the birth.

Module 1 – Stages of Labor and Child Delivery

This module presented stages of pregnancy delivery in a home setting - (a) explanation of the baby's position inside the womb (b) visualization of the path of the baby as it comes out of the womb (c) explanation of the way to hold the baby as it comes out of the womb; Figure 3 shows interfaces demonstrating 3 stages in delivery

Module 2 – Examining Newborn at Birth

This module interprets the need to examine a newborn at birth for live-birth or any other health-related precautions. It is further divided into following tasks - (1) cleaning the baby after birth with a gauze piece; (2) checking for baby's crying, limb movement and breathing as signs of live birth; (3) giving the baby to the mother after live birth examination. Figure 4 represents interfaces to examine the newborn baby.

Module 3 – Providing Newborn Care

This module presents the methods of newborn care immediately after the birth. The module also explains some general precautions that the family should take after the baby is born. It is further divided into following tasks - (1) noting the time of birth (2) clothing the baby to maintain baby's temperature; (3) closing the window and placing the baby near mother's chest and abdomen to maintain suitable body temperature. Figure 5 shows interfaces to provide normal care after the baby is born.

Design of Virtual Environment and Persona

As recommended in [21], we used contextually appropriate design elements to increase familiarity and acceptance among targeted users. First, we created a virtual simulation of traditional Assamese rural home environment by creating a bamboo structured home and traditional home decorator Haloi. Second, we designed two personas - 'ASHA baidew (sister)' and "Meera". 'ASHA baidew' persona is modeled around an Assamese woman of approximately 45 years with over 10 years of experience as an ASHA worker.

'ASHA baidew' acted as a guide to introduce the importance of each module and provided a live commentary on various conditions of 'Meera' (e.g. Meera is experiencing labor pain, let us bring her to the bed). She recommended preventive steps suitable to the healthcare contents presented in each module (e.g. if the fluid of the womb is green in color, it indicates infection and is a cause of concern. Meera should be immediately referred to the nearest doctor). She also gave tasks to the users (e.g. bring the baby near to Meera's chest to keep her warm).

Figure 6. The virtual environment of traditional Assamese home, the persona of ASHA baidew (left) and Meera (right)

'Meera' is a second persona, whose character is designed around a young Assamese mother, undergoing pregnancy for the first time. 'Meera' enacts all the conditions experienced by a pregnant woman during and after the pregnancy. Relevant audio-visual animations are demonstrated to support the activities explained by 'ASHA baidew' and 'Meera'. Figure 6 showcases the virtual simulation of Assamese rural home along with personas of 'ASHA baidew' and 'Meera' respectively.

Interactive Dialogue

We used dialogic based narrative style [4] to keep the user engaged and focused during each module. They are divided into two modes - (i) interactive questions and (ii) tasks. For instance, after demonstrating the first stage of labor in module 1, the ASHA baidew prompts, "Did you notice the process of delivery and the way a baby progresses inside a womb?" with options to select "Yes" and "No". If the user selects "Yes" the module proceeds whereas selecting "No" repeats the process. Similarly, intermediate tasks are given to the users. For example, ASHA baidew assigns a task to the user to clean the newborn immediately after the birth. Here, the user walks (using joystick) towards the newborn. Once the user reaches near to newborn, hands are automatically triggered to clean the baby. The hands are showcased in a way that it feels as if the user herself is cleaning the newborn (see figure 4 (a) for visual reference).

Input Interactions

We used gaze input for object selection in *Pragati*. Gaze interaction was considered because of its fast, natural and more effortless way of interacting than manual interaction. The gaze input was complemented by a visual timer of 2 seconds. A joystick was used to navigate inside the virtual environment. It allowed users to view the healthcare contents from different viewpoints. For example, viewing of the delivery process from the side view as well as a front view to understand the sequence of events experienced inside the womb. Similarly, the user can navigate towards the baby to closely view the limb movements. The joystick was connected to the mobile phone via Bluetooth.

Technical Implementation

We used Maya, 3D computer animation software to create the characters and the virtual environment. They were further exported in Unity3D to create animations. We used Android SDK for VR stimulation. Android devices support VR from version 4.4 (API level 19) which provides compatibility with a wide range of smartphones. Google's VR SDK for Unity was used to enable head tracking, side-by-side stereo rendering, detecting user interaction with the system. To maintain the file size and rendering speed in mobile phones, we decreased the size of audios, images and also used device filter (ARMv7).

USER EVALUATION OF PRAGATI

We conducted the user evaluation with two objectives. Our first objective was to study the impact of *Pragati* on users' knowledge acquisition of healthcare contents and confidence in dealing with issues related to maternal and child care during the field visits. Our second objective was to discover whether *Pragati* performs better in increasing learnability, self-efficacy, engagement, and presence as compared to traditionally known platforms of mobile phone-based video modules and mobile phone-based 360-degree video modules. We will refer "2D video" and "360 video" for mobile phone-based video modules and mobile phone-based 360-degree video modules respectively for this paper.

Design Differences – Pragati vs 2D video vs 360 video

All the three platforms were identical in terms of healthcare contents, audio-visual animation, virtual environment, personas and method of information delivery. The input methods and users' navigation ability inside the virtual environment differentiated these 3 platforms. *Pragati* used gaze & joystick as an input method for object selection and navigation inside the virtual environment respectively. 2D videos used touch-based input method for object selection (e.g. selecting a module or selecting an answer in Q&A section). 360 video modules used gaze as an input method for object selection and allowed a 360-degree view of information modules. No platform allowed navigation inside the virtual environment except *Pragati*. Hence, intermediate tasks presented inside each module were automated in 2D video and 360 video.

Measures

Learnability

We measured learnability through a questionnaire adapted from ASHA module 6 & 7 booklets and converted in the Assamese language. They were further verified by a maternal health consultant of NHM for this study. We formulated 11 questions for all the modules as follows - (1) What is the time the first stage of labor usually take? (2) What is the color of the fluid that is discharged during delivery? (3) What is the time the second stage of labor usually takes? (4) What is the direction of infant's face during birth? (5) How long does the placenta take to come out? (6) What kind of cloth should you use to clean the mouth of the baby? (7) What are the steps you should take as soon as the baby is born? (8) Should you completely rub off the thin protective layer on the baby? (9) What is the time interval for which you observe the baby for the sign of live birth? (10) What are the three signs of live birth? (11) Where should you keep the baby on the mother's body to keep her warm? We asked participants to answer the questions orally. The questions were asked in the Assamese language. The question-answer interview sessions were audio recorded, and later labeled by the moderator as correct or wrong. Learning was measured on the basis of how many questions they answered correctly. Thus the range of each participant's score was between 0 and 11. We conducted the learning test two times: before using the training modules (i.e., pre-test), and after using it (i.e., post-test). This was done to understand their knowledge acquisition pre and post technology usage.

Self-efficacy

To evaluate the users' confidence to deal with issues of maternal and child healthcare, we adopted eight items from 'general self-efficacy scale' [32] and modified according to our context. The questions were - (1) I can manage to solve delivery related problems; (2) I can find the ways to get solutions to problems faced during pregnancy; (3) I am confident that I can deal efficiently with unexpected events during delivery; (4) I know how to handle unforeseen healthcare situation; (5) I can handle whatever delivery related problems come my way; (6) When I am confronted with delivery-related problem, I can usually find several solutions; (7) I can remain calm when facing difficulties during the childbirth; (8) If I face delivery related problem, I can usually think of a solution.

The participants rated each item on a 5-point scale where 1 means strongly disagree, and 5 means strongly agree. In our study, we administered the self-efficacy questionnaire twice - pre-test and post-test. The self-efficacy scores were computed by averaging participants' answers to all eight questions. Cronbach's alpha (pre-test = 0.837 and post-test = 0.877) suggested that the items had relatively high internal consistency (i.e. "reliability").

Engagement

To measure the level of engagement experienced by the participants, we used a questionnaire with eight statements adopted from [3,13] which were - (1) I was much involved while going through the delivery related task; (2) I lost track of time while performing these activities; (3) I was absorbed while using this system; (4) I would want to watch this again; (5) I felt interested in this system; (6) I felt frustrated while using this system; (7) I felt the system was confusing to use; (8) I felt in control of the experience. After watching the training modules, participants rated each statement on a 5-point Likert scale (1 - strongly disagree to 5 - strongly agree). The self-reported engagement scores were computed by averaging participants' answers to all eight questions. Cronbach's alpha for engagement was found to have medium internal consistency (α=0.668).

Presence

We used subjective self-assessment questionnaires provided by the Igroup Presence Questionnaire (IPQ) to measure the sense of presence experienced by the participants. We adopted 10 questions from IPQ and categorized into four subscales: a sense of being there (1 item), spatial presence (5 items), involvement (2 items), and experienced realism (2 items). The questions were - sense of being there: (1) using the system, I had a sense of being there; spatial presence: (2) somehow I felt that the virtual world surrounded me; (3) I felt like I was just perceiving pictures; (4) I did not feel present in the virtual space; (5) I felt present in the virtual space; (6) I was not aware of my real environment; involvement: (7) I still paid attention to the real environment; (8) I was completely captivated by the virtual world; experienced realism: (9) The virtual world seemed real to me; (10) The virtual world seemed more realistic than the real-world. The participants rated their degree of agreement with IPQ statements on a 5- point Likert scale (1 = strongly disagree and 5 = strongly agree).

Subjects and recruitment

We collected the list of participants (ASHAs) from NHM. The list included participants of 5 rural health centers in the vicinity of 20 km of the university. Further, we followed a stratified sampling procedure (e.g. number of years of experience) and recruited 57 participants. All participants had completed their schooling in the Assamese language. A total of 10 participants did their schooling up to eighth grade, 13 participants finished their studies up to tenth grade, 31 participants completed their studies till twelfth grade, and 3 participants finished up to graduate level studies. Their age ranged from 27 to 51 years (M = 38.2, SD = 3.51). 53 participants had low-end feature phones, and 4 owned a smartphone. 48 participants were newly inducted with less than one year of experience and assisted once in the delivery of a pregnant woman. The remaining participants had 12 to 15 years of experience.

We randomly allocated the selected participants into 3 groups (i.e., 2D video, 360 video, and *Pragati*) in such a way that18 each group had 19 participants (16 new ASHAs + 3 experienced ASHAs). The participants were remunerated with INR 200 (USD 3) for their participation in the experiment.

Apparatus

Participants of the 2D video group and the 360 video group watched the modules on a Google LG Nexus 5. The *Pragati* group used Google Cardboard viewer using the same mobile phone. All the participants listened to audio through

Sony MDR-EX250AP earphones.

Procedure

We conducted the experiment at a rural primary health center in Changsari (Assam), located 20 km away from the university. We introduced each platform and the 3 healthcare modules to the participants. This was followed by a training session to each group to familiarize them with given technology platform. Each training session lasted about 8-10 minutes. In the case of *Pragati*, we trained them to use gaze and joystick for object selection and navigation inside the virtual environment. We also trained them to use touch input for selection in case of a 2D video modules. Similar to *Pragati*, we trained participants to use gaze for object selection and phone movements to experience 360-degree view. We encouraged them to ask questions immediately if they faced any problem during the study. The study was moderated by a female researcher of the team in the Assamese language.

After initial training, participants filled an initial demographic questionnaire (e.g. age, education, working experience, and frequency of field visits). This was followed by a pre-learnability and pre-self-efficacy questionnaire. We asked all participants to watch each module is a sequential manner, e.g., module 1 followed by module 2 & 3. When they finished watching modules, we asked post-study questionnaire to measure learnability and self-efficacy. Learnability was measured through verbally answering the questions whereas questions on self-efficacy were self-reported through a 5-point Likert scale. We further gathered data on engagement and presence through a self-reported 5-point Likert scale. All the questions were converted into the Assamese language for easy self-reporting of the measures. Participants took 25-30 minutes to view training modules and report the measures. Figure 7 showcases the users interacting with all 3 platforms. We concluded the study followed by a personal interview to understand their impressions about all three platforms, usability issues, and their motivation to use such platforms further.

Figure 7. ASHAs watching training modules using (a) 2D video (b) 360 video and (c) *Pragati* viewer during the field study

Data Collection Method

Data on measures of self-efficacy, engagement, and presence were collected in written format through questions which were presented in the Assamese language. A five- point Likert scale was used for self-reported data collection. Questions to measure learnability were verbally asked by the moderator and further reported in written format. We also took photographs and videos to observe and analyze qualitative findings. Consent was taken before capturing the video.

RESULTS

The results are divided into two subsections according to our defined objectives. We first report learnability and self-efficacy results of *Pragati* followed by the results of the comparative study investigating the influence of different technology platforms on learnability, self-efficacy, engagement, and presence.

Results of Pragati Evaluation

The analysis revealed that participants' learnability and self-efficacy before using *Pragati* were 5.01 (SD = 2.28) and 2.94 (SD = 0.63) respectively whereas post-test learnability was 8.36 (SD = 1.34) and self-efficacy was 3.47 (SD = 0.32). We conducted a paired-sample t-test to investigate learnability and self-efficacy in pre and post *Pragati* usage. We observed significant increase in learnability ($t(18) = -8.087$, $p < 0.001$) and self-efficacy ($t(18) = -4.066$, $p = 0.001$) among participants after using *Pragati*.

Results of the Comparative Study

We report the results of learnability, self-efficacy, engagement, and presence across the 3 technology platform.

Learnability

Mean pre-test learning score for the 2D video was 5.26 (SD= 2.20) and the post-test score was 8 (SD= 1.82). Mean pre-test learning score for *Pragati* was 5.10 (SD= 2.10) and the post-test score was 8.3 (SD= 1.34). Mean pre-test learning scores across all three groups was 4.84 (SD = 2.08), whereas the post-test score was 7.78 (SD = 1.88) (see Figure 8(a)). Levene's test of homogeneity of variances ($F(2,54) = 0.551$, $p = 0.579$) showed no significant difference in the initial knowledge among three groups.

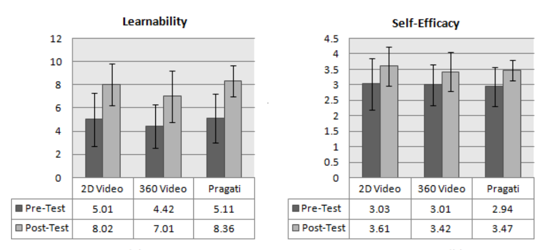


Figure 8. (a) Means of the learnability score at pre-test and post-test; (b) Means of the self-efficacy score at pre-test and post-test. The capped vertical bars indicate ±SE

We conducted paired-sample t-test for each group to determine whether there were improvements in participants' knowledge after the use of 3 platforms. The result showed that there was a significant improvement in the post-test score to the pre-test learning score for all three groups (2D video group: t(18) = -6.829, p < 0.001; 360 video group: t(18) = -5.066, p < 0.001; *Pragati*: t(18) = -8.087, p < 0.001). The effect of different platforms in learning was analyzed using one-way between-subjects ANOVA. The analysis revealed that the training modules significantly increased participants' post-test knowledge regardless of the technology platform (F(2, 54) = 2.851, p > 0.05).

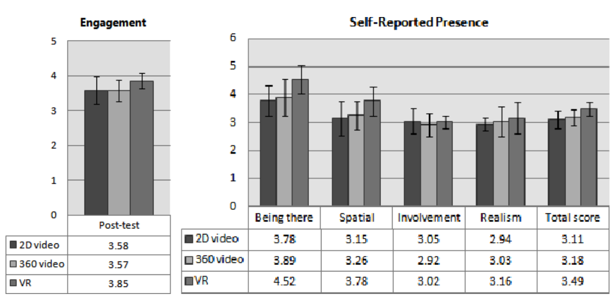
Self-efficacy

The mean pre-test self-efficacy score for 2D video was 3.03 (SD=0.50) and post-test was 3.59 (SD= 0.48) whereas Mean pre-test for *Pragati* was 2.94 (SD= 0.65) and post-test was 3.47 (SD= 0.68). Mean pre-test self-efficacy scores across all three groups was 2.99 (SD = 0.71), whereas the post-test score was 3.51 (SD = 0.54) (see Figure 8 (b)). Levene's test of homogeneity of variances (F(2,54) = 0.346, p = 0.709) showed that there was no significant difference in the initial self-efficacy score among 3 groups− 2D video, 360 video, and *Pragati*.

We conducted paired-sample t-test for each group to determine whether there were improvements in participants' self-efficacy due to proposed 3 platforms. The result showed that there was a significant improvement in the post-test score with respect to the pre-test self-efficacy score for all three groups (2D video group: t(18) = -5.929, p < 0.001; 360 video group: t(18) = -5.386, p < 0.001; *Pragati*: t(18)= -4.066, p = 0.001). The effect of different platforms in self-efficacy was analyzed using one-way between-subjects ANOVA. The analysis revealed that the training modules significantly increased participants' self-efficacy regardless of the technology platform (F(2, 54) = 0.498, p > 0.05.

Engagement

The level of engagement experienced by the participants was analyzed using one-way between-subjects ANOVA. The analysis showed a significant effect of engagement for the 3 different platforms, F(2, 54) = 4.836, p = 0.012 (see Figure 9(a)). Tukey post-hoc test indicated a significant difference (p = 0.029) between the 2D video group (M = 3.58, SD = 0.39) and *Pragati* (M = 3.85, SD = 0.22).



	Post-test
2D video	3.58
360 video	3.57
VR	3.85

	Being there	Spatial	Involvement	Realism	Total score
2D video	3.78	3.15	3.05	2.94	3.11
360 video	3.89	3.26	2.92	3.03	3.18
VR	4.52	3.78	3.02	3.16	3.49

Figure 9. (a) Means of self-reported engagement. (b) Means of self-reported presence. The capped vertical bars indicate ±SE

Cohen's effect size value (d = 0.853) suggested high practical significance. Similarly, we observed a significant difference (p = 0.022) between 360 video group (M = 3.57, SD = 0.31) and *Pragati*. Cohen's effect size value (d = 1.042) suggested high practical significance. However, there was no significant difference between the 2D video group and 360 video group. Cohen's effect size value (d = 0.028) suggested low practical significance.

Presence

The sense of presence experienced by the participants was analyzed using one-way between-subjects ANOVA. Considering the IPQ total score, the analysis showed a significant effect of presence for the three different technology platforms, F(2, 54) = 8.898, p < 0.001 (see Figure 9 (b)). Tukey post-hoc test indicated that the difference between the 2D video group (M = 3.11, SD = 0.32) and *Pragati* (M = 3.49, SD = 0.25) was significant (p < 0.001). Cohen's effect size value (d = 1.284) suggested a high practical significance. Similarly, the difference between 360 video group (M = 3.18, SD = 0.29) and *Pragati* was also significant (p = 0.003). Cohen's effect size value (d = 1.182) suggested high practical significance. However, there was no significant difference between the 2D video group and 360 video group in our study. Cohen's effect size value (d = 0.164) suggested low practical significance. Considering the general item about the sense of "being there", the analysis revealed a significant difference, F (2, 54) = 9.214, p < 0.001 across technology platform. Tukey post-hoc test indicated that there was no significant difference between the 2D video group (M = 3.78, SD = 0.54) and the 360 video group (M = 3.89, SD = 0.65). Cohen's effect size value (d = 0.185) suggested low practical significance. However, a significant difference was observed between the 2D video group and *Pragati* (M = 4.52, SD = 0.51). Cohen's effect size value (d= 1.078) suggested high practical significance. Similarly, the difference between 360 video group and *Pragati* was also statistically significant. Cohen's effect size value (d = 1.423) suggested a high practical significance.

For "spatial presence" subscale, there was significant difference between platforms, F(2, 54) = 7.214, p = 0.002. According to Tukey post-hoc test, the difference between the 2D video group (M = 3.15, SD = 0.62) and *Pragati* (M = 3.78, SD = 0.52) was statistically significant. Cohen's effect size value (d = 1.101) suggested high practical significance. The 360 video group (M = 3.26, SD = 0.5) and *Pragati* was also significant for spatial presence. Cohen's effect size value (d = 1.019) suggested high practical significance. No significant difference was observed between the 2D video group and the 360◦ video group. Cohen's effect size value (d = 0.195) suggested low practical significance. No statistically significant differences were found for the "involvement" subscale of the IPQ, F(2, 54) = 0.657, p >0.05.

For "realism" subscale, the analysis showed a statistically significant difference between platforms, F (2, 54) = 5.634, p= 0.006. Tukey post-hoc test reported significant difference between the 2D video group (M = 2.94, SD =

Measure	Platform	Pre-test	Post-test	T-test	ANOVA	Tukey-post hoc
Learnability	2D video (1)	5.01 (2.28)	8.02(1.82)	t(18)= -6.829, p<0.001	F(2,54)=2.851, p>0.05	-
	360 video (2)	4.42 (1.86)	7.01(2.21)	t(18)= -5.066, p<0.001		
	Pragati (3)	5.11 (2.11)	8.36(1.34)	t(18)= -8.087, p<0.001		
Self- efficacy	2D video (1)	3.03 (0.83)	3.61(0.63)	t(18)= -5.929, p<0.001	F(2,54)=0.498, p>0.05	-
	360 video (2)	3.01 (0.66)	3.42(0.63)	t(18)= -5.386, p<0.001		
	Pragati (3)	2.94 (0.63)	3.47(0.32)	t(18)= -4.066, p=0.001		
Engagement	2D video (1)	-	3.58(0.39)	-	F(2,54)=4.836, p<0.05	2-3, 3-1
	360 video (2)	-	3.57(0.31)	-		
	Pragati (3)	-	3.85(0.22)	-		
Presence	2D video (1)	-	3.11(0.32)	-	F(2,54)=8.898, p<0.001	2-3, 3-1
	360 video (2)	-	3.18(0.29)	-		
	Pragati (3)	-	3.49(0.25)	-		

Figure 10. Table for comparative results of t-test, one-way ANOVA and Tukey's post-hoc multiple comparisons.

0.21) and *Pragati* (M = 3.16, SD = 0.55). Cohen's effect size value (d = 0.528) suggested medium practical significance. There were no significant differences between the 2D video group and the 360 video group (M = 3.03, SD= 0.54). Cohen's effect size value (d = 0.221) suggested low practical significance. No significant difference was observed between 360 video group and *Pragati*. Cohen's effect size value (d = 0.239) suggested low practical significance. Figure 10 shows the summary of comparative results.

QUALITATIVE FINDINGS AND DISCUSSION

The study observed increased learnability of healthcare contents and self-efficacy independent of the technology platform. This is contradictory to the findings presented in [33,5,30] where VR has shown increased learnability compared to other platforms. Despite the non-significant statistical findings to 2D video and 360 video, post-study interview sessions revealed a positive outlook towards the use of *Pragati.* The participants showed increased enthusiasm after using *Pragati.* For instance, a senior ASHA claimed that "*this is the first time (in many years of my job) I have seen baby's position inside the womb and the process of delivery so closely. Moreover, viewing them from different sides helps to understand more in detail the position of the baby and the complications associated with it*". The participants also liked the intermediate tasks as it provided a feeling that they were performing the task. It provided them a sense of responsibility to ensure a safe delivery.

Post-study interviews revealed that participants took two factors (a) ability to relate the modules in a real-world setting and (b) ability to operate the device independently as important indicators in order to increase confidence. They showed increased confidence in communicating newborn care methods to new mothers. A newly inducted ASHA stated that "*I feel that I will be able to effectively communicate all the methods to keep the baby warm, as I have myself taken care of a newborn in a home setup (through Pragati)".* Similarly, experienced ASHAs showed the confidence in *Pragati* in training new ASHAs. In this context, an experienced ASHA stated, "*Pragati will be very helpful for newly inducted ASHAs, and they experience field environment without visiting the village. This will boost their field confidence".*

Participants were found less confident in using Cardboard [23] as compared to traditional touch-based mobile phones. One ASHA commented that *"Although I liked using Pragati, I need someone's help initially for few times to independently operate this (cardboard)".* This was further amplified due to increased fatigue while continuously holding the HMD, especially among older ASHAs. Despite the cardboard allowed headrest, they held it during the complete modules. This resulted in shoulder pain and fatigue among older ASHAs.

Similar to the findings of Vishwanath et. al [39], the participants demonstrated a deeper level of engagement with the modules of *Pragati*. They started asking doubts (e.g. can we use a Gamosa - a locally available cloth, to clean the baby) and discussed it among themselves. Some participants even made a reference to add more information (e.g. washing hands before the delivery, cleaning the bedsheet, place etc.) while using *Pragati* as they were taught to them during traditional training. This indicates that while *Pragati* may be useful in triggering curiosity, it must be complemented with traditional training to solve the doubts of the users.

The engagement was found significantly higher in *Pragati* compared to 2D video and 360 video which is pertinent to previous studies [23,9]. Post-study interviews revealed the ability to navigate the environment and viewing healthcare contents from different viewpoints and distances as primary reasons to increase engagement among participants. For example, one participant navigated inside the storeroom of Meera's house using a joystick. Although the storeroom did not demonstrate any healthcare contents, its ability to navigate made her confident in using *Pragati*. The participants also engaged more with *Pragati* due to its ability to experience healthcare contents from different viewpoints and distances which was appreciated by the participants. One ASHA stated that "*I like that I can view it (healthcare contents) nearby or from a far distance whenever I want*".

Similar to engagement, participants perceived significantly higher presence including the subscales of being there, spatial presence and realism in *Pragati* as compared to 2D video and 360◦ video. Participants found that the isolation from the outside world and use of the realistic environment, characters, and task similar to real-world counterparts associated with each module increased immersion and presence in *Pragati*. For instance, one ASHA mentioned that "*It disconnects me from the outside noise and disturbance which allows me to focus entirely on Pragati*". Our study confirms the results of previous studies about the sense of presence being high for VR interfaces due to richer engagement with elements and deep immersion [4,37,41].

LIMITATIONS OF THE STUDY

One of the reasons for *Pragati* being designed for a mobile phone supported low-cost HMD VR is due to its potential scalability among targeted users. However, the issues impacting the scalability of *Pragati* in a rural environment is beyond the scope of this study. Moreover, the results of increased engagement and presence compared to 2D video and 360 video is evaluated after one-time use of *Pragati*. The question remains unanswered in this study whether similar results will be repeated for a longitudinal study.

The results and findings presented here are limited to mobile VR interfaces supported on a low-cost HMD and may not be entirely applicable to the advanced HMDs (e.g. Oculus Rift, HTC Vive etc.) as it did not deploy advance VR capabilities such as object manipulation and position tracking. Further studies are needed to learn about acceptance and adoption of advanced HMD VR platforms among underserved communities.

CONCLUSION

In this paper, we presented the design and evaluation of Pragati, a mobile phone-based HMD VR interface to train and educate ASHAs in rural Assam in India. Our user evaluation showed that the participants increased their knowledge and confidence after using *Pragati*. We further compared *Pragati* with mobile phone-based traditional videos and mobile phone with 360 video. Our between group experiment revealed no impact of the technology platform in learnability and self-efficacy, whereas a significant increase in engagement and presence was observed for *Pragati*. The post-study interviews revealed positive outlook due to participants' ability to relate the modules with field realities, ease of navigation inside the virtual environment, different viewpoints, and distances to see healthcare contents and deeper level of engagement with *Pragati*. It also revealed the need for training and high fatigue in using *Pragati*.

Overall, these results are encouraging in exploring the use of VR for underserved communities. However, we believe that more studies are needed to understand its long-term usage and scalability. Further, there is also a need to understand knowledge retention of information modules using *Pragati*. Our future work includes incorporating new information modules on maternal and child healthcare to increase its utility among ASHAs and further measure the knowledge translated in the rural communities.

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