Comparing Presence, Workload and Situational Awareness in a Collaborative Real World and Augmented Reality Scenario

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ABSTRACT
This paper compares presence, workload and situational awareness in a real world and augmented reality scenario when collaboratively solving a complex problem. A game of jointly building a tower of colored blocks is used as an approximation of a shared task. Individual expertise is modeled as the possibility to move blocks of a distinct color and shared expertise is modeled by the possibility of all players to move blocks of the same color. Such a setup scales down real-life, more complex problems such as in crime scene investigation domain or in engineering domain, to a level which allows for easily investigating the extent of which the current augmented reality oriented technology may be applicable for collaboration. An explorative study describes the first findings on the different perception of findings of presence, workload and situational awareness in a real world and augmented reality scenario.

Keywords: Collaboration, Augmented Reality, Presence, Workload, Situational Awareness.

Index Terms: H.1.2: User/Machine Systems; H.5.3 Group and Organization Interfaces; H.5.1.b Artificial, augmented, and virtual realities

1 INTRODUCTION
The mixed reality domain has become more and more mature and versatile nowadays, with even more products reaching the end-user, positioned towards the ‘real environment’ edge in the Milgram’s virtuality continuum [15].

Researchers from various disciplines have proposed and debated methods of studying and leveraging the feeling of (tele)presence [12], this being one of the most prominent characteristics when interacting with such systems. Yet, augmented reality applications that target the context of multiple users using such systems collaboratively with a common goal are still in their infancy. According to Ússelsteijn and Riva [9], presence is mediated by physical and as well as by culture dependent conceptual tools. As concluded by the authors, the presence in the physical environment is no more real or more true than the tele-presence or the immersion in a simulated virtual environment. Following this observation, this paper presents an explorative study that compares the perception of presence of users in a collaborative game in an augmented reality scenario and a real world scenario.

Crime scene investigation – CSI is one example among the multitude of domains for which the science of studying presence in augmented reality applies. This research stems from a joint project between Delft University of Technology, The Netherlands Forensic Institute – NFI in The Hague [19] aiming at the development of more efficient methods to analyse crime scenes collaboratively, by using augmented reality – AR technology.

In order to reach an equitable generalization level, the complex scenario of CSI work was scaled down to the context of a collaborative game in which players have to build a tower from real and virtual colored blocks. An explorative study evaluates the different perception of presence, workload and situational awareness when collaboratively playing the game in a real world and augmented reality scenario. Apart from the case of collocated users at the ‘building site’ wearing AR headsets, the study also discusses the perception of a remote AR user who gains access to the AR view of one of the collocated users to perform collaborative work. First findings indicate that compared with playing the game in real world, the AR collaborative experience has a better attention and situational awareness especially for the collocated users. The remote users though have a more artificial feeling interacting with the environment, with higher stress, lower performance and lower immersion in the environment.

These preliminary results as well as our previous findings on remote collaboration in mediated reality [13], point for the need to identify factors and solutions that increase the feeling of presence and awareness on the side of remote users. Improving the technology is still the major issue for improving the presence indicators.

The rest of the paper has the following structure: the next section presents related work, the subsequent section presents the details on the collaborative game design and the system architecture. Then, the setup and results of the explorative study are described. Finally, conclusions are presented and future work is discussed.

2 RELATED WORK
Several papers study the influence of technology on the perception of presence in augmented reality.

Juan and Joelle [10] present a comparative study on the sense of presence and anxiety for the treatment of phobia towards small animals. The authors find that the invisible marker-tracking induces a similar or higher sense of presence compared to the visible marker-tracking system.

In an anxiety focused experiment that implies the user is presented with a virtual hole in the floor that appears to drop three stories, Gandy et al. [7] find that changing the frame rates in the augmented reality visualization does not affect presence measures.

Wagner et al. [18] discuss key components of feeling present in augmented reality such as the feeling of connection between the virtual and real elements, some degree of realism and dynamic representations mapping physical environment events to those in the mixed reality scenes. The authors identify sound as the most
An instructor is located in the same room with the collocated players. This person watches the game flow and gives online indications with regard to the rules and state of the game.

In addition to consistent visual updates on the game state, the communication among the players and instructor is realized also by audio channel, using the fixed telephones from the two rooms, set on the speaker mode.

The software prototype of the AR collaborative game system is based on a centralized client-server approach that implies all AR subsystems have connections to a software server running on the computer of the instructor.

![Experimental setup for the Augmented blocks game.](image)

### 3.1 Game Design

Within a game, roles, rules and resources can be modeled [11] that can be seen as simplified representation of complex systems and problems. The goal of the AR game is to jointly build a tower by using the colored blocks available on the game board. The game represents an approximation of a complex shared task. Individual expertise is represented by the ability of each player to manipulate blocks of specific color only. Shared expertise is represented by the ability of all players to move blocks of the same color. The order of the blocks in the tower to be built is not to be randomly set. Instead, the color order of the blocks has to contain the individual color pattern of each user. This color pattern represents the individual task of the players. The individual expertise and the individual task reflect the knowledge of the players and are defined at the beginning of the game session. Table 1 shows the game configurations used in the study.

During the game, the system tracks the actions of players against consistency of rules with individual goal assignments. An on-screen message is then displayed every time a player attempts to select a block of a color other than the colors defining his/her abilities (Fig. 2).

![Table 1: Physical (left) and augmented (right) blocks game setups](image)
and their individual abilities (colors identifying the accessible blocks). The shared goal of building the tower is then achieved through a sequential process in which the players have to communicate and to agree upon the action strategy involving the next block to be moved. None of the players can build the minimal tower containing the individual color pattern without help from at least one of the other players. The rules of the game are made in such a way to support collaboration among participants. Partial information available at any time allows for nonlinear game dynamics, process of discovery and gradual development toward fulfilling the shared game task, the building of the tower.

Figure 2: Screen shot of the AR view from the player trying to select a block of a color other the colors making up his abilities.

3.2 User Interface

As shown in Fig. 3, the augmented content consists of transparent visual elements representing an information panel in the top left corner of the view, the game board, the colored blocks and the cursor. All graphical representations are rendered in 3D.

Figure 3: Augmented reality interface based on finger pointing interaction.

The participants in the AR game are notified about the current game conditions in the information panel in the upper left corner in Fig. 3. This panel shows information about the online players, the player holding the virtual cursor, the colors of the augmented blocks the player can move and the target color pattern. In case of video streaming, the system displays the identity and role of each player (“I see him” message on the screen of the remote player and “Sees me” message on the view of the collocated player).

During the game, any player can select an augmented block by holding the augmented cursor over the surface of the block for a short time period (2 seconds). A selected augmented block can easily be spotted by all players, as it is rendered in blink mode.

Once selected, a block can be translated in 3D over the game board surface by moving the finger (in case of the collocated players) or the mouse (in case of the remote player). Only single blocks and blocks lying at the top of stacks can be selected and moved.

To place a block at a specific location on the game board, the block has to be selected first, moved to the new location and then deselected. To deselect a block, the block has to be kept in the same location for a fixed time period (5 seconds).

The location of the tower is marked with the white color and is located at the middle the squared game board. At any time, the players are allowed to remove blocks from the already build tower.

When users want to concurrently move blocks, a limitation has been set to allow only the first player to try this, to hold possession of the augmented cursor.

Another special case is that of the remote player manipulating blocks through the view of one of the collocated players. The remote player gets the view of the collocated player he connected to. This can be a factor of confusion leading to focusing difficulty, when he does not move but the other player does move. The interface of the remote player projects an additional box with video from the remote player.

In addition to this, a second augmented cursor of the remote user is displayed onto the view of the collocated player. These measures are assumed to increase the self-awareness of the remote user and to reduce the confusion of simultaneously interacting with the AR game items. Fig. 4 presents a sample set of snapshots from the views of the three game participants.

Figure 4: The views of the collocated players in 3D (top) and of the remote player in 2D (bottom).

The collocated players access the AR system by free hand interaction. The system supports multiple inputs from mouse devices, AR pattern in the form of ‘magic wand’, color pattern for the tip of the finger and palm posture detection [3]. An augmented cursor (blue circle) is shown at the location where the tip of the finger is detected. Compared to the co-located users, the remote user interacts by using a regular mouse device.

3.3 Software & Technology

The open source augmented reality head mounted device Marty [20] consists of a SONY HMZ-T1 optics based virtual reality headset modified in order to support two Logitech C905 HD webcams. To take advantage of the full bandwidth at higher resolutions and video frame rates, each webcam has a separate USB connection to the computer. A special 3D printed plastic case replaces the original SONY case of the headset (Fig. 5).

Figure 5: Marty augmented reality headset [20].
The video signals of the AR headset are processed by a separate hardware that generates the final 3D content. In the AR system, the models for detection, recognition and tracking are implemented using C++ programming language, Boost::Thread library [23] for parallel computing and the Open Computer Vision library Opencv [21]. Hand detection and tracking run on the video stream of the left video camera attached to the augmented reality glasses. The graphical user interface is implemented using C++ programming language and Ogre library for 3D rendering [22].

4 EXPLORATIVE STUDY

To measure the differences in perceiving presence, work load and situational awareness in real and augmented games are assessed using a 7-points Lickert scale questionnaire coming from the NASA Task Load Index (TLX) questionnaire [8], the AR presence questionnaire of Gandy et al. [7] and questions on situational awareness following Endsley [6]. Table 2 shows the used questionnaire.

1. In the environment did you feel like an observer (rate as low) or a participant (rate as high)?
2. How natural did you feel when moving in the environment?
3. How mentally demanding was the task?
4. How natural did placing blocks seem?
5. How aware were you of events occurring in the environment around you?
6. Were you able to anticipate what would happen next in response to placing a block onto the target?
7. How well were you able to actively survey and search the environment using your eyes?
8. How physically demanding was the task?
9. How much did the setup of the game catch your attention?
10. How well were you able to actively survey and search the environment using your sense of touch?
11. How well were you able to examine the task in the environment?
12. How well could you move objects in the environment?
13. How hurried or rushed was the pace of the task?
14. How “drawn in” to the experience were you?
15. How much delay did you experience between your actions and expected outcomes?
16. How comfortable did you feel moving and interacting with the blocks by the end of the experience?
17. How successful were you in accomplishing what you were asked to do?
18. How much did the visual display quality interfere or distract you from performing assigned tasks or other activities?
19. How much did the interaction with the blocks interfere with the performance of assigned tasks or with other activities?
20. How well could you concentrate on the assigned tasks or other activities rather than on the mechanisms used to perform those tasks or activities?
21. How hard did you have to work to accomplish your level of performance?
22. How much did the setup of the game help you to foresee the actions of the other players?
23. How much did the setup of the game help you to perceive the actions of the other players?
24. How consistent did moving a block with your hand feel consistent with what you were seeing?
25. How insecure, discouraged, irritated, stressed, and annoyed were you?
26. How much did the setup of the game help you to understand the actions of the other players?

Table 2: AR questionnaire

4.1 Experimental Setup

A group of 15 users organized in 5 groups, each group having 3 players participated in the study. Each group plays the game of building a tower in two sessions, using physical blocks (Fig. 6) in one session and augmented blocks in the other session. In the latter case, two users play collocated (Fig. 7, left) and one user participates from a remote location (Fig. 7, right). The order of sessions is changed from one group to the other.

Figure 6: Experimental setup for the physical blocks game.

Before the first session, each participant has to fill in part of a questionnaire. This part includes general questions that relate to the time and day of the experiment, name, age, gender, occupation, background, the level of experience the participant has with user interfaces in augmented reality and the level of experience with games in augmented reality. After each session the participants have to answer a separate set of questions.

Figure 7: Snapshots of co-located (left) and remote (right) players, taken during the experiment on augmented blocks game.

Participants are between 22 and 42 years old. There are 3 female participants with age between 30 and 42 years old. The male participants are between 22 and 37 years old. About 53% of the subjects had no experience related to user interfaces in augmented reality while 47% had some experience. No participants were advanced augmented reality users. A percentage of 60% of the subjects had no experience related to games in augmented reality, 33% had some previous experience and 7% were well accustomed with augmented reality games.

In the illumination-controlled lab setup, the color pattern for tracking the tip of the finger proved to be the most reliable solution for real-time free-hand based interaction. Fig. 3 depicts a snapshot from the AR view of a collocated player. During the experiment the remote and collocated participants are video recorded. Additionally, user interaction events with regard to hand gestures, movements of the augmented cursor, block selection and re-positioning, are logged.

5 RESULTS

The results are based on the questionnaire on presence, work load and situational awareness as shown in Table 2. The questions in the questionnaire address different categories (Table 3). Some questions relate to the assessment of the game workload, others target interaction indicators, interface, tactile experience, moving in the environment and others the measurement of situational awareness.
All players in physical setup, 60% of the remote and 70% of the collocated indicate they are aware of the events occurring in the environment around them (Q5).

A percentage of 87% players in the physical setup and 60% of the AR players are able to anticipate what would happen next in response to placing a block onto the target (Q6).

All participants in the game based on the physical setup and 93% of the AR players are able to actively survey and search the environment using their eyes (Q7).

The percentage of 93% of the physical game players indicating they are able to examine objects in the environment is very close to the percentage of 90% collocated players and comparable to the percentage of 80% of all AR players that appreciate this indicator (Q11).

A percentage of 93% players in the physical game and only 13% of the AR participants (20% of the collocated players) indicate they do not experience any delay between their actions and the expected outcomes (Q15).

A percentage of 20% more remote game participants than collocated players mention they felt comfortable moving and interacting with the blocks by the end of the game experience (Q16).

### 5.2 Presence indicators

#### 5.2.1 Interaction

Of the participants playing the game with physical blocks, 93% indicate they feel being more participants than observers, 80% indicating a strong feeling (Q1). In augmented reality 27% of the participants feel being observers while playing the game, this indication being influenced by the 60% of the remote players. The number of users indicating a low degree of participation is comparable for the augmented reality (10% of the collocated players) to the physical setup (7% of the players).

In the augmented reality game, 40% of the remote participants indicate they did not feel natural while moving in the environment compared to only 7% of the participants playing with physical blocks (Q2).

All the players find placing physical blocks natural and only 27% of the AR players (60% of the remote participants) find this type of interaction somehow natural (Q4). A percentage of 90% of the collocated players do not find placing blocks natural, this being more than double the percentage of remote participants giving this answer.

### 5.3 Situational Awareness

A percentage of 87% of the players in the physical setup and 80% of the AR players indicate the setup of the game catches their attention (Q9). In the AR setting, 20% more collocated players
than remote players suggest the setup highly catches their attention.

According to all the participants, the physical game setup helps perceive the actions of the other players. Moreover, 93% of the players indicate the physical setup helps foresee the actions of the other players.

In augmented reality, the same percentage of collocated and remote participants (80%) report the game setup helps them perceive the actions of the other players. A higher percentage of remote players (80%) than collocated players (70%) indicate the game setup helps them foresee the other player’s actions.

A comparable percentage of players in the physical game (93%) and of AR players (87%) report the game setup helps them understand the actions of the other players. From the perspective of remote players, the AR game setup fully supports this indicator as suggested by all participants. Only 20% of the AR collocated players give low scores at this indicator.

6 CONCLUSION AND FUTURE WORK

The workload indicators suggest that the AR experience can be characterized by low mental demand, no physical demand and low pace. Fulfilling tasks in AR is difficult, with high workload, as compared to finishing tasks in AR, with low workload, stress, and irritation. With the remote participants, the mental demand is higher, the experience is more successful, but more stressful.

Though the degree of feeling as a participant in the environment is comparable in AR and physical games, the interaction in AR is neither natural nor comfortable, especially for the collocated participants. On one hand, wearing a not so light and small-sized AR headset is not natural for the collocated players. On the other hand, interacting by using the non-stationary view of other person who wears the AR headset and moves the head is not comfortable either.

Moreover, the collocated players frequently get distracted from performing the tasks due to the visual display quality. This may be because of the technical problems related to the accuracy of hand-based spatial interaction, high latency or low fidelity in generating realistic representations of the game elements. As mentioned by Billinghurst and Thomas [2], it is essential to allow users to easily point to or select small details like blocks in the augmented view.

By totally missing the feedback from the real world, typical to the sense of touch while interacting with augmented blocks, the AR players hardly benefit from any tactile experience.

In AR the players benefit from a higher level of attention, with support to perceive and understand each other’s actions. This may be mainly due to the interest and curiosity of the players in the collaborative game and AR technology.

Surprisingly, in comparison with the collaboration in real life, the AR collaborative experience has a better attention and situational awareness for the collocated users. The remote users though have a more artificial feeling interacting with the environment, with higher stress, lower performance and lower immersion in the environment. In line with these preliminary results and previous findings on remote collaboration in mediated reality [13], future research needs to identify factors and solutions that increase the feeling of presence and awareness on the side of remote users. Overcoming technology limitations may also be part of the solution to improve the other presence indicators.

REFERENCES


