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Research Article

Remote Augmented Reality Application: A Study on Cues and Behavioural Dimension

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Abstract: Remote augmented reality (AR) collaboration promotes an interactive way to present information to the user by conveying a message and instruction to the local and remote participants. Despite its advantages, it is found that due to the limited use of sensory modalities during the remote collaboration process, it can interrupt the transmission of information and interaction cues, by not conveying the right information in remote AR collaboration in which can affect focus, and responses between local and remote users. This study is intended to investigate the behavioural dimension of collaboration (collaborator's behaviour) and cues involved between local and remote user for physical task. Six participants performed as local participants where they need to build a LEGO, while another 6 participants performed as remote participants that have a complete manual instruction. Participants were given maximum 60 minutes to complete the given task. The results shown that most of the time participants used gesture and speech cues to interact with each other. There are certain signals and keywords established by both participants to have mutual understanding in achieving desired goal. Moreover, it was shown that the task completed by using handsfree produce faster response.

Keywords: ***Augmented Reality; Behavioural dimension; Communication cues; Remote collaboration***

1. Introduction

As we move towards the computerized society, advancement driven by empowering innovations such as Web of Things, artificial intelligence, AR/VR/MR and mechanical technology brings noteworthy changes, impacts and it exceedingly affected the economy, society and culture. Important data and information are able to be assembled, put away, controlled and shown in numerous procedures through the progression of computerized innovation. AR encompasses a one-of-a-kind way of showing data and information. Typically, since it able to merge the real and virtual setting. There are several and different methods in using AR such as through mobile devices, HMD and smart glasses. Currently, AR technology has been used and demonstrated to be useful in many industries segmentation such as manufacturing, marketing and advertising, forensic, e-sports, education, medical and tourism. Recently, AR technology has been used as enabling technology for collaboration activities especially in remote workspace. However, most research in collaboration and remote collaboration are focuses using VR technology.

Previously, method for remote collaboration have basically centred on including 2D visual signals or cues, such as an annotation or see-through hand motions, to the shared digital environment to help or bolster by giving direction or support on completing the physical tasks. As a consequence, it only limits the information to be search, viewed or processed by local user and remote expert. Therefore, AR is used to overcome this challenge by overlaying interactive 3D virtual cues over a view of a remote workspace. This experimental study is intended to investigate the collaborative behaviour and cues involved between local and remote user for physical task.

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Section 2 presents related works on collaboration theory, communication cues, and remote AR collaboration. Section 3 presents method used for conducting the study. Section 4 shows results of the study which gives a clue on the outcome of behavioural and cues involved in remote AR collaboration. In Section 5, the results obtained from the study conducted is discussed. Finally, in Section 6, conclusion and future works are presented.

2. Related Work

2.1. Collaboration Theory

Throughout years, many researchers have addressed few theories related to technology for collaboration work by finding more effective ways to use devices as tools to communicate and exchange information with others, whether in virtual environments (VE) or real environments (RE). For example, Computer Supported Cooperative work field of research. Currently, the most research field focuses only VE in VR and few mentioned about collaborative in AR [1][2].

Effectively support the collaboration activities is essential in order to provide an efficient way to access suitable and meaningful data, information and the right tools for communication. Researchers suggested, when developing or designing a system to support collaborative work, it is important to start learning from traditional settings by observing people working and collaborating since it includes an extensive complex data and information exchange [3].

According to Churchill and Snowdon [4], the collaborative system should support 4 key features which are: 1) shared knowledge of current events, past events, subject of communication and spaces between users.; 2) intentional awareness or sense of presence among users; 3) conversation for negotiation and communication between users; and 4) multiple representations for different point of views and tasks.

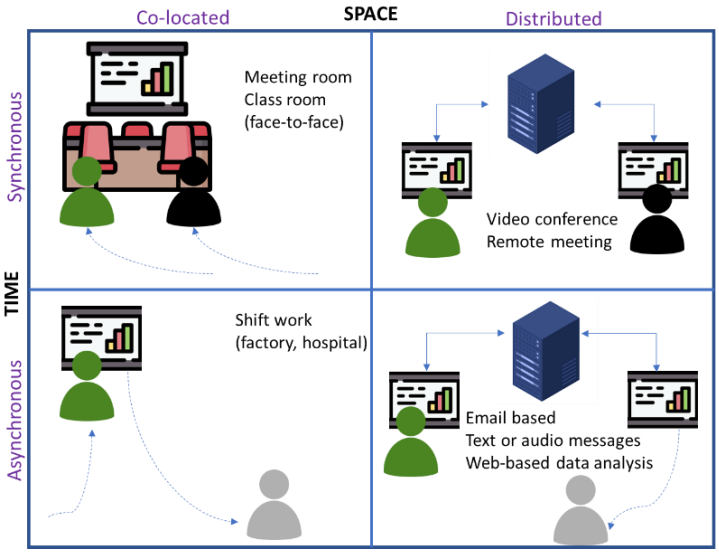

Figure 1. Relation of time and space in collaboration theory [5]

As shown in Fig. 1 above, based on action, time, interaction and location of collaborators, collaboration activities are divided into 4 categories which are synchronous co-located collaboration, synchronous distributed collaboration, asynchronous co-located collaboration and asynchronous distributed collaboration. Synchronous co-located collaboration is a face-to face collaboration where people are meeting and working together at the same time and at the same place, for example student's club meeting activities. While synchronous distributed collaboration is where people are at different locations but collaboration activities is occurring in real time using teleconferencing and they respond to the work at the same exact time. Example: meeting using ZOOM or MS Team. Meanwhile, asynchronous co-located collaboration is where people are working at the same place but the responses between them are not instantly and usually at different time such as staff at hospital that have different shifts. However, for asynchronous distributed collaboration, people collaborate at different place and at different time resulting in the response of collaboration is not immediate such as chat, email and forum. For example,

the people who are at different places can post the questions on a forum which the response to that question might take some time to be answered or replied. Example of application is WhatsApp.

2.2. Remote Collaboration

Remote communication is an area of discipline dealing with the transmission of data between two or more devices not located at the same site which differ from traditional collaboration. Remote collaboration is always a method of interaction between two or more people at different or remote locations, by interacting with each other to achieve a mutual and same desired goal. Nowadays, many teleconferencing technologies were developed to support remote collaboration which generally can provide better communication, able to keep record, offers flexibility and reduce travel time and cost.

The trend of working from home or from far places from the location of the main workplace is increasingly gaining popularity and has become new norm. To keep up with this new trend, a type of communication channel or tools needs to be developed at workplace. This is to ensure the productivity and efficiency of a team that working remotely can be achieved to meet with team's mutual goals. However, in order to achieve team's mutual goal, a team of experts face some difficulties which involve nuanced problem solving and decision-making to meet and communicate with each other physically [6]. This is due to limited availability of experts, critical timing problems or issues with accessibility to the site, and it is usually hard to bring the team together. There are some common scenarios for example in industry area: construction or machinery problems, maintenance and assembly of product, training with multipart of machinery, decision-making in manufacturing or training at sites [7]. Within these scenarios, remote collaboration is generally tedious and often ineffective due to the use of teleconferencing which supported by only video-mediated communication and verbal cues.

Though, many teleconferencing technologies such as audio-conference, video-conference and web-based conference have been developed to improve these challenges, it still has some limitations especially in providing accurate and meaningful information and data to users [8].

2.3. Augmented Reality

Augmented Reality (AR) promotes interactive and innovative method to present meaningful information and data by overlaying digital content onto the user's real view. It is interactive in 3D and real time interaction. This technology can be attained by using visual, auditory, and other sensory modalities such as gesture, vibration and olfactory.

Few components are essential in order to experience AR such as camera, sensors, processing unit, and a display which can be found in mostly in smartphones, smart glasses and headset. Camera and sensors will gather information on user surroundings or environment in order to display AR digital content. While processing unit will interpret the information gathered and will project the AR digital content to users using display.

AR can be categorized into two types based on its particular use which are marker-based AR and markerless AR. The use of target image such as 2D images to project the AR experience and position the 3D content (text, video or animation) on top of it is called marker-based AR. Example of AR application that use marker-based AR are Instagram filter, AR emoji and Snapchat. However, markerless AR does not necessary need image processing to project the AR experience. This is because, the AR digital content is exhibited through data and information gathered from the common components in mobile devices (accelerometer, GPS, compass, camera) mainly in smartphone and markerless AR is highly dependent on these components. There are 4 categories of markerless AR such as projection-based, overlay, location-based and contour-based AR. Example of markerless AR are Samsung AR and Google Maps AR.

AR technology able to merge a real world with virtual object without need to recreate the non- real environment to the user unlike virtual reality (VR) [9]. The difference between AR and VR is the experience itself, where AR make use the real physical environment while VR is totally using the digital or virtual environment. Through AR application, an interactive and engaging experience can be perceived which it can highlight the details that are not available and unseen in real physical setting.

Immersive technology, such as AR, has been used in many sectors such as medical, manufacturing, retail, edutainment and others. It is either being used as single or multi-players. Multi-players usually

involve remote collaboration in an application to provide matching and similar situation of the task scene and to visually show 3D object or information onto the real-world to the remote user who is at different location. In AR system, both remote and local users are conscious with their surroundings when using the AR application and the virtual content added to it [10] in which it suits with the goal of remote collaboration. The goal of remote collaboration is to make sure both remote and local user able to view the same scene or sources and be able to have mutual understanding by communicating and interacting in real-time to attain the same goal.

However, there are only limited number of academic research that could provide extensive and thorough knowledge and research findings, with a particular emphasis on remote AR collaboration.

2.4. Remote AR Collaboration

AR technology has been widely used and demonstrated to be beneficial in various sectors. Recently, AR technology has become technology enabler for collaboration activities especially in remote workspace. Many companies and businesses have incorporated or shift to this immersive technology to improve their services. This mainly because of characteristic of AR technology that can continuously support real and virtual elements to enhance user performance and experience, where users able interact almost naturally and spontaneously [11]. Furthermore, it can create interactive and innovative interfaces, so that user able to fully understand the content. As AR able to shift smoothly between reality and virtuality in which users are aware with their surroundings. Moreover, it able to support object manipulations in physical task and also improves the presence of spatial cues for remote collaboration which is important element in this research.

With this characteristic of AR as mentioned above, it allows user to see and have interaction with virtual object on real physical setting. Furthermore, this technology can be used to produce an interactive and interesting experience [12] by providing additional information to support decision making in remote collaboration. A collaboration between remote-expert and local worker in various application is a common scenario in remote collaboration by sharing instantaneously a real environment and AR digital content.

The primary goal of remote collaboration is to assists local workers by increasing the availability rate of a remote expert so that they can get help anywhere and at any time using appropriate technological supports and tools such as AR. For example, in manufacturing industry, a local worker may encounter technical problem on machine that requires the assistance of an expert to repair or for training and maintenance purposes. While in medical sites, support from expert surgeon who is in different location is required when a hospital has limited number of expertise to perform an operation. Not only that, remote AR collaboration able to improve the customer service organization by providing real-time assistance and solutions on product issues to consumer. Furthermore, remote AR can be applied when the assistance from forensics expert may be required by a detective who is at a remote location where the crime scene is being investigated.

Remote AR collaboration can be especially helpful, for example, when a remote expert can see the workspace of the local user and provide a meaningful and informative feedback through communication and interactive cues for physical task. This are more efficient than only relying on auditory communication, by demonstrating real-time interaction enables the users to better understand and perform the instructions faster. Other benefits of remote AR collaboration are improved flexibility and easy communication between users.

2.5. Physical Task in Remote AR Collaboration

Task that involves people to collaborate by carrying out actions on a block of object in 3D virtual world is refer to physical task [8] collaboration. There are two types of physical task which are constructional and analytical:

- Constructional Task: A task that involve working together to build a real object. For example: measure the perimeter of a block or construct or repair a physical component.
- Analytical Task: A task that include an investigation of objects in the physical environment. For example: need an expert analysis on a situation such as a crime scene.

Traditionally, physical task in remote collaboration focused on using video-sharing and auditory communication as its fundamental component which can be tedious and frequently inefficient. This is because some non-verbal cues may be missing during the transmission of information such as gesture cues. Furthermore, it also shows the low level of sense of presence or spatial presence between collaborators.

However, with the advantage of AR, it can improve on task performance and user experience as well as able to retrieve the communication cues that are loss previously in remote collaboration.

2.6. Implication of Cues in Remote AR Collaboration

Within an effective remote collaboration, communication cues are a crucial factor that need to be addressed. In order to have a mutual or common understanding in collaboration, a wide variety of communication cues are being utilized. These communication cues are widely found in three communication channel which are visual, audio and environmental. Within visual communication channel, people usually use gaze, gesture, face expression and body position. While for audio channel, most cues are being shown in speech, para-linguistic, para-verbal and others. For environmental channel, cues are shown as object manipulation, writing or drawing and object presence. These cues are essential and needed in remote collaboration. Furthermore, awareness and attention among collaborators on certain object is important when communication occurs during collaboration activities.

It is reported that, compared to co-located collaboration, to attain a better user experience and user performance is far more challenging and arduous in remote collaboration due to the lack of communication cues [13]. These cues are mostly lost during the interaction in remote AR collaboration which eventually led to the interruption of exchanging information and affect the user experience and performance [14][15]. To this date, there are only few research studies that focus on remote AR collaboration [16].

3. Method

The purpose of this study is to investigate the user's behavioural dimension of collaboration and to investigate the types of communication cues involved. Fig.2 and Fig. 3 show the LEGO CREATOR together with parts and pieces and the instruction manual that was used to build the vehicle. During the study, the video is captured by the local participants using a mini camera and then send to the remote participants who can annotate the viewed content. The annotated video is then displayed to the local participants (to convey the intentions of the remote participants) as shown in Fig. 6.

Figure 2. LEGO Creator[1]

3.1. Participants

12 volunteers participated in this study; 6 of them plays the role as remote participants and another 6 volunteers plays the role as local participants.

[1] LEGO CREATOR, https://www.lego.com/en-us/product/outback-adventures-31075

3.2. Tools, Device and Software

There are several tools, device such as LEGO Creator as shown in Fig. 3 to build a certain vehicle, the instruction manual, phone or tablet, mini camera, earphone and laptop. Software that was used to view the AR content is developed by using Unity3D.

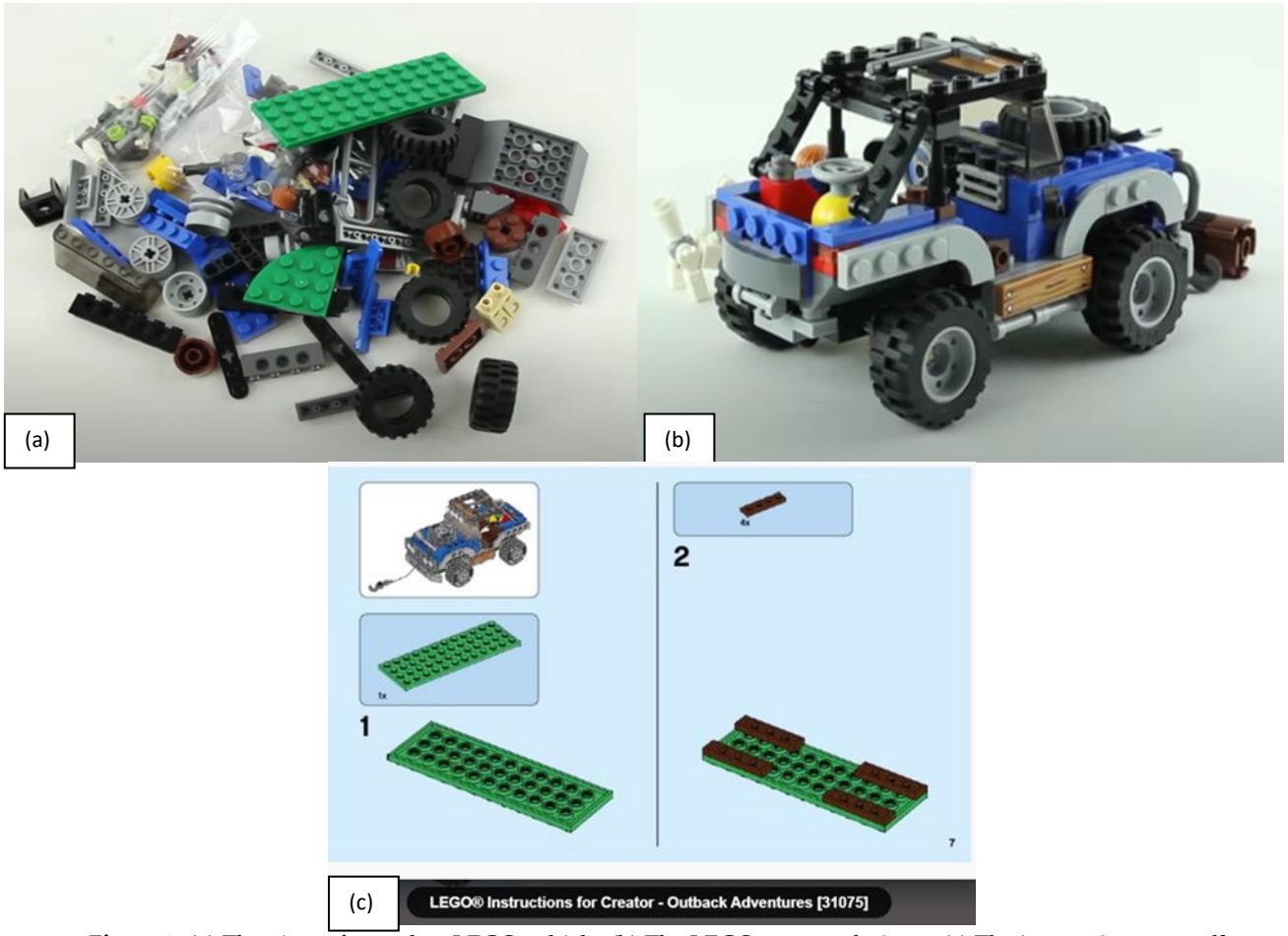

Figure 3. (a) The view of complete LEGO vehicle; (b) The LEGO parts and pieces; (c) The instruction manual[2]

3.3. Study Design

The purpose of the study design is to make sure that the scope of study is met by highlighting the roles of each main element such as: -

- Constructional physical task is only involved by building a LEGO vehicle
- Local participants had the LEGO pieces without instruction
- Remote participants had the LEGO guide images (instruction manual)
- Video must be recorded during the study.

3.4. Procedures

Several procedures need to be followed in order to conduct this study as stated below: -

- Remote and local participants were placed in different locations
- Table and chairs were provided to the participants in every location.
- The local participants were given a set of LEGO pieces.
- Remote participants were provided with a manual (2D images showing how to construct a vehicle step-by-step).
- A brief instruction is given to both participants (local and remote participants) on the procedures.

[2] LEGO CREATOR, https://www.lego.com/en-us/product/outback-adventures-31075

- Remote participants were given 15 minutes to familiarize with the LEGO vehicle and instruction manual.
- Local and remote participants is given list of tasks that they need to complete.
- Investigator will observe the behaviour of participants

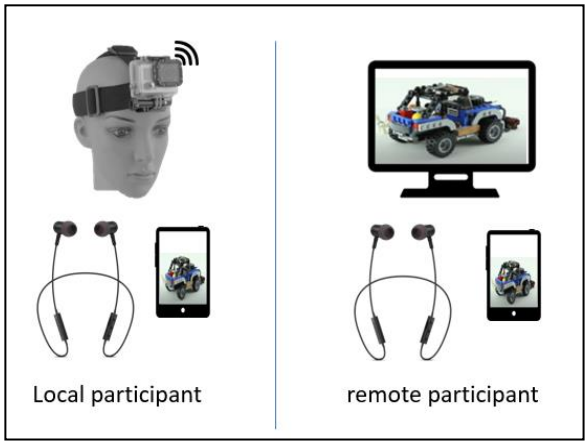

Figure 4. Handheld Setting

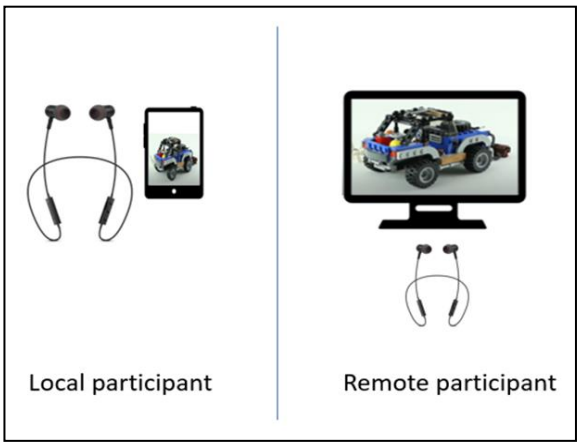

Figure 5. Hands-free Setting

3.5. Analysis

The experiment was recorded in video and direct observations were made. The behavioural dimension was analysed taking into account two different scenarios as shown in Fig. 4 and Fig. 5: -

- Building a LEGO vehicle using smartphone (handheld)
- Building a LEGO vehicle using camera attached to participant's head (hands-free)

These two scenarios were analysed in order to identify the following events from the perspectives of remote participants and local participants:

a) Proactive support (remote participants): offered their assistance without being requested
b) Reactive support (remote participants): assistance in response to a request from local
c) Question asked by local participant.

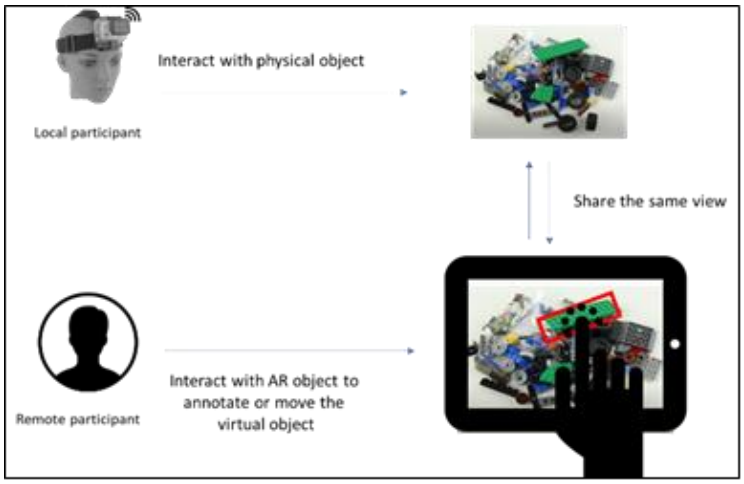

Figure 6. Interaction flow of remote AR collaboration

4. Result

There are 2 results based on 2 scenarios as mentioned in previously which are based on handheld setting and hands-free setting.

4.1. Scenario 1 (Handheld Setting)

Remote participants frequently asked about the progress of the task and received constant feedback from local participants (vice versa). This shows that there is an active engagement between participants in order to complete the task given.

During the study, it was observed that local participants left their phone on the table to connect the pieces of the LEGO vehicle. If local participants decided to demonstrate the task status or to ask for assistance, they had to position the camera to the intended target object.

Several communication cues are involved in this study, where: -

- The classification of words and gestures had to be adapted by local and remote participants to classify object parts and movements.
- Both local and remote participants have slight difficulties to understand each other in the beginning which can be seen from facial expressions.
- The collaboration process has become easier, when both participants developed common gesture cues and keywords for identification of object and movement.

4.2. Scenario 2 (Hands-free Setting)

Results showed that a certain language was established by both participants to specify the objects and movements. It is observed that a good adaptation of the camera to the head of the local participant makes collaborations more intense and active. Remote participants were more proactive in seeing the progress of the task throughout the experiment and they were able to give instruction at the same time. Additionally, local participant can focus on building the vehicle without having to move the camera whenever they need assistance from remote participant.

Moreover, the video quality could make a big difference to this kind of task as the remote participant needs to make annotations. However, as the camera is positioned to the head of the local participant, they need to stand still and not making unnecessary movements. This is because remote participants were observed to have more difficulty in seeing some of the parts positioned by local participants.

5. Discussions

Based on the result above, it was found that using handsfree setup instil focus to the local participants compare to handheld setup. 80% of participants stated that using handsfree let them to complete the work faster

Several cues were identified during the study. This helped local participants to identify which part or pieces that remote participants pointed to. Hand gesture was used to point the position of the LEGO pieces as well as showing "thumbs up" meaning they understand each other. Speech cues was involved to identify which LEGO pieces supposed to be used. In this study, both participants classify those pieces into colours, size, position and shape. For example: "Green rectangle with 6 buttons".

In the case where the remote participants (Scenario 2) cannot see the LEGO pieces, most of them have asked the local participants to move using this keyword: 'right', 'left', 'up' or 'down'.

Meanwhile in Scenario 1, local participants have more workload compare to Scenario 2. This is because in Scenario 1, local participants need to move the phone camera and at the same time building up the vehicle if they need assistance from remote participants. However, proactive support and reactive support is implemented in both Scenario 1 and Scenario 2.

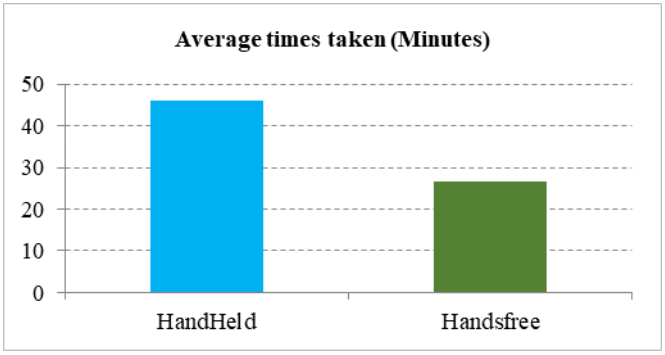

Figure 7. Average times taken to complete the task

Fig. 7 shows the average times taken for participants to complete the task. For handheld setting the average is around 46 minutes, while for handsfree setting shows average around 27 minutes to complete

the task. This shows that using handsfree setting ease the use of remote AR collaboration by 32%. Hence, it can improve the user task performance of remote AR collaboration.

6. Conclusions and Future Work

In view of the above results, in the behavioural dimension, it was shown that there is differentiation in both scenarios (hands-free and hand-held) configurations for the performance of physical construction tasks. Handsfree shows the most preferable method by participants due to ease of use (the use of hands is no longer limited) during experiment. It was found that gestures and speech cues were involved as a medium to interact and giving out certain signals. Furthermore, it is quite difficult to convey accurate information when only one mode is involved.

It has become necessary to support local workers, e.g., performing tasks, from a remote location due to the increasing workload and complexity of the task. However, by working remotely together using AR technology does have an impact on behavioural dimension and communication cues involved. Thus, effective remote collaboration may depend on the information exchange between local and remote participants.

For this research, further experimentation needs to be conducted to investigate other different cues and factors that affect interaction between participants in remote AR collaboration using different scenarios.

It is critical to ensure future work considers to improve and develop a novel remote AR collaboration that are extensive and provide effective cues for collaborators to straightforwardly perceive the collaborative activities and conditions. At the same time understanding the effects of those communication cues and presence involved during the collaboration (make collaborators feel more engaged).

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