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GAMING EXPERIENCE ON THE MOBITOP SYSTEM: A COLLOCATED AD-HOC COLLABORATION SYSTEM

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Graphical abstract

Abstract

This paper presents the study on the mobiTop system- a collocated multi-mobile system. The mobiTop system allows users to come together with their mobile devices in an ad-hoc manner to create one seamless and extended interactive display surface. The collocated multi-mobile system allows a group of people to play digital games together in an impromptu manner without having to buy an interactive tabletop equipment. This study investigates the user experience and system design of a collocated multi-mobile system when users play a collaborative game-based application using the mobiTop system. The findings show that the extended screen size of the mobiTop system enhanced the collaborative experience of the users. This study also highlights several design considerations to further improve such systems such as employing a faster network configuration, reducing the bezel effect, catering for dynamic device movements and making the object of interest more prominent and visible. With this understanding, this study present design guidelines to help designers create digital game-based multi-mobile systems for ad-hoc collaboration.

Keywords: Collocated ad-hoc collaboration, multi-mobile devices, collaboration, games

1.0 INTRODUCTION

Collocated multi-mobile system is where multiple devices are connected with each other to form a large synchronous and heterogeneous system. Lyons, Pering, Rosario, Sud, & Want [1] define that collocated multi-mobile system uses the displays of several mobile devices that are connected with each other to create one big display. The extended screen size creates an environment that allows multiple participants to interact with the system. Collocated multi-mobile system is useful in many different areas especially where a group of people meets and to share or present information in a visual and interactive manner [2]. This system is mostly used for collaborative purposes such as presentation, discussion and also for entertainment.

The mobiTop system promotes collocated and portable ways for group collaboration among participants. This system is derived from the study conducted by Lyons *et al*. on the effect of group collaboration when using the multi display composite system [1]. Multi-mobile devices system combines multiple mobile devices to create large interactive surface which enable the participants to interact and collaborate with each other. Such system could provide a cheaper and portable solution that has the capability of a multi touch digital tabletop, where multiple users can interact simultaneously during collaboration.

This study presents the *mobiTop* system- an integrated multi-mobile system that allows for a seamless multi-touch interaction between users. This study investigates the user experience when using such system. Specifically, this study investigates the user's experience when collaboratively playing a multi-player game using the mobiTop system. Unlike playing games on individual mobile device, the multi-mobile device system promotes social interaction among users more effectively. The social presence is strong when users get together to play games on collocated multi-mobile system similar with playing conventional board games [3]. Figure 1 shows mobiTop system display a composite picture.

Figure 1 mobiTop system with composite image

Existing multi-mobile system that focuses on the gaming experience include a study by Kauko & Häkkilä [3] that investigated the social presence on collocated multi-mobile system while playing games. Additionally, Huang *et al*. [4] developed a creative game application for its collocated multi-mobile system. Ohta & Tanaka [5] also developed a cricket jumping application for its collocated multi-mobile system. However, few studies have looked into investigating the user experience in the context of how the East Asian users interact with the system during a game-based application and the impact the design of the devices have on them. Thus, this preliminary study will be exploring: a) the user experience of the East Asian users when collaborating using the mobiTop system during a game-based application; and b) their experience pertaining the design of the devices.

This study will next discuss about the existing work in this particular field to ground this paper further. Following this will discuss the mobiTop system and its design before detailing out the user study. Then this study highlights the prominent findings and conclude it with a design guideline.

The findings demonstrate that the mobiTop systems enhanced the user's experience when playing the game-based application in a collaborative setting environment. This study also highlights several design considerations when designing for such systems such as making the object of interest bigger and more prominent for ease of interactivity and visibility, reducing the bezel effect as well as catering for dynamic devices movement to support the organic flow of impromptu collaboration.

2.0 RELATED WORKS

Lyons *et al*. [1] proposed the idea of a collocated multi-mobile system and presented multi-display composition by connecting multiple displays using wireless network and developed a photo sharing application for the user study. Users gave a positive feedback for the system due to its larger screen when compared to the screen of a single system as well as the ability to collaborate with a group of user and experienced higher activity awareness. The user study also identified some interactive issues for its multi-display composition system. From the study, users suggested that the bezel around the device might be a drawback for its multi-display composition system. However, users did not find this very intrusive as more information is displayed due to its large screen estate and therefore outweigh the issue. Using the mobiTop system, the study will investigate the effect of the bezel system during a collocated and competitive game-based application. Lyons *et al*. [1] also highlighted that the multi-display composition system is not optimized for multi-user touch input which could potentially hinder collaboration. The mobiTop system promotes multi-touch input so that more users can interact and play the game simultaneously. This will also be another aspect of this study.

Additionally, Ohta & Tanaka [5] developed several applications to demonstrate the natural and intuitiveness of a pinch gesture to expand the screen estate. For example, the jumping cricket is a game that enables an object such as a cricket to jump across from one device to another after the screen was expanded using pinch gesture. Another application called the dynamic canvas allowed the expansion of a photo allowing for each device to have its own composite image. Lastly, the *TuneBlock* game enables users to compose and play music [5]. Users could compose different music using the extended display. However, they did not perform throughout user interaction on the application for its collocated multi-mobile system. For the mobiTop system developed a competitive *Ping Pong* Ball game application to investigate the multi-user interaction.

Tong & George [6] developed a Mario-style game application for its collocated multi-mobile system. The game world can be extended onto multiple devices by placing each device beside the running system. The magnetic switch on each side of the device identifies the relative position of the device and creates a composite world as a result. The system also can be connected and extended toward other devices such as tablet or smartphones by using web based architecture that require an external server. Following this ideology of an extended screen size,

mobiTop system will connect multiple devices to expand the interactive area to enhance the user experience. The expansion of the screen creates more space for the user to interact with the game.

Huang *et al*. [4] developed *MagMobile* to stitch the display or create a collocated multi-mobile system by using magnetic sensor. *MagMobile* had several game applications such as collaborative snake game and collaborative tower defense game to demonstrate how the easiness in detaching and stitching the display by moving the devices around. Both applications use the magnet and magnetic sensor to join devices at different position to achieve the goal of the game. The snake game requires player to join the devices so that the snake can get the goal across the devices. The tower defense requires player to defend the gate from enemy by arrange the devices to create difficult path for the enemy. The game application for mobiTop system makes use of multi-touch interaction instead of device detach and stitch interaction in *MagMobile*. Therefore, the mobiTop system did not require any external sensor but instead use available sensor in mobile devices for such interaction.

Schmitz & Li [7] designed a system that utilizes mobile devices with ad hoc network to create multi-displays with touch. The system presented is based on server-client architecture similar to the mobiTop system. The system runs on most platforms and can be ported to more devices. The system is sufficient in rendering capabilities, touch enable devices and wireless network supported. For wireless network, it was recommended using Wi-Fi network instead of Bluetooth network as it is able to offer lower latency and able to support more devices than the Bluetooth network. Data transfer for user interaction use UDP protocol for minimal latency and data transfer for data and calibration uses TCP protocol for reliability. The game application for mobiTop system required fast network and data transfer for higher game performance in real time. Therefore, Wi-Fi network and optimized data transfer was implemented into mobiTop system to achieve better gaming experience on collocated multi-mobile system.

Kauko & Häkkilä [3] developed a tennis ball game application to study social interaction on a collocated multi-mobile system. The difference between mobiTop ping ball application and their system is that mobiTop system did not implement spatial relationship between displays. This is because mobiTop system wanted a natural form of interaction between players rather than 'forcing' them to behave in a particular way.

3.0 SYSTEM DESIGN

An application for the multi-mobile device system using the Android operating system was developed. The mobiTop system connects multiple mobile devices using the Wi-Fi. The data transfer between devices is coordinated using the server-client architecture. One of the devices is act as a host to handle data from and to the client. The clients transfer the data, such as touch input and object, for the server to process. Figure 2 shows client-server architecture for mobiTop system.

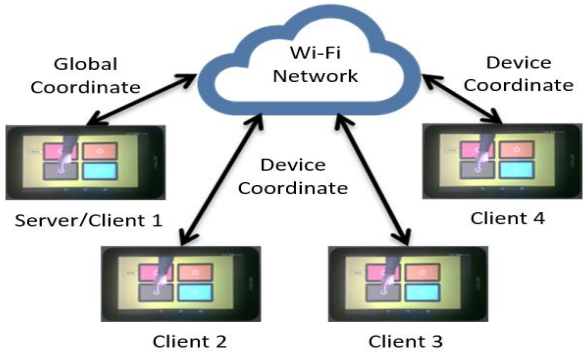

Figure 2 Client-server architecture for mobiTop system

The game application developed for the mobiTop system to investigate the collocated collaboration using multi-mobile device is a simple Ping Ball game. Ping Pong is one of the popular table-based sports game in the South East Asia. The game was design to for a two on two competitive settings. The game has a bat on each device. Players can move around the bat on each device using a touch-and-drag gesture. The bat however can only move within the boundary of a device. Therefore, it is unable to move outside the boundary of the device and join on another device. The reason for this configuration is to limit the complexity of the system allowing for the system to run the application efficiently and quickly. However, this could potentially affect the result but the importance of the user experience outweighs such decision.

Additionally, the ball movement is not limited to a particular device boundary but it can freely move to any of the devices within the mobiTop system. The bat is then used to prevent the ball from reaching the goal that located at the left and right side of the devices. If one of the players fails to catch the ball and reach the goal on either side of the device, a point will be given to the scoring team. The game has a maximum of two round and in each round, the game will determine the winner when one side gathers a maximum of seven points. Each round has different configuration for the Ping Ball game where there is an increased complexity in each round. Round 1 has a ball move at a normal speed. Round two has two ball movements at a normal speed. The game will determine the winner when one side wins more round than other side. Figure 3 shows the Ping Ball Game Application setup for the mobiTop system.

Figure 3 Ping Ball Game Application

4.0 EVALUATION

4.1 Participants

Thirty-two full-time undergraduate university students from different courses participated in this study. The participants consisted of 13 males and 19 females (aged between 19 and 23 years old). All of them speak English as their second language.

4.2 System

For the evaluation, the mobiTop multi mobile device system was designed by one of the author for the purpose of the study. The system was installed on four 7" Asus tablets (18.9cm L x 11.4cm W). The system has an interface to connect and calibrate multiple mobile devices. Participants are required to arrange the tablets in a 2x2 grid pattern. Participants are required to set the system and choose which of the tablets will serve either as a host or a client. A tutorial will be displayed on the tablets to guide the participants on the steps required to connect the mobile devices. To connect and calibrate the devices in 2x2 grid pattern, participants would use a swipe gesture in clockwise direction from device 1 to device 4. Finally, the system will display the result of the screen composition by displaying a composite photo on the multiple mobile devices. Figure 4 shows how to do a swipe gesture in clockwise direction from device 1 to device 4.

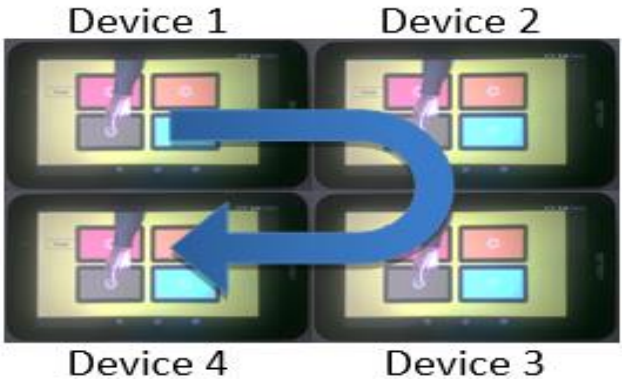

Figure 4 Swipe gesture in clockwise direction

To investigate the user experience when using a multi-mobile system, the Ping Ball Game Application was installed on the mobiTop system. Participants are required to press the start button and the application will show an empty field with a bat on each device. The ball will start to move in diagonal directions when all the players start taking control on the bat. The scores were displayed on the left and right corner of each device. After a round is finished, a menu will appear and tell the participants who won the last round. The menu also asks participants whether they would like to continue the game for the next round. Prior to the study, we created a low fidelity and a high fidelity prototype and tested for user feedbacks which were used to improve the next iteration. The user study was conducted in the laboratory of the Faculty of Computer Science & Information Technology at University Putra Malaysia. Two researchers were involved in the study setup. One experimenter interacted with the participants during the briefing and at the ending of the tasks, while the other experimenter handled the mobiTop systems and video recording.

The study apparatus and materials were set up in the middle of the study location. The same table that was used in the both evaluation tasks for the participant study. All sessions were recorded for analysis purpose. Three video cameras were used to record the evaluation sessions. All activities in the room were captured by two digital video cameras in two different angles; and a close-up webcam which was mounted on the ceiling to record the activities surrounding the tablet in order to get a clear view of the tablet display as shown in Figure 5 and Figure 6 respectively.

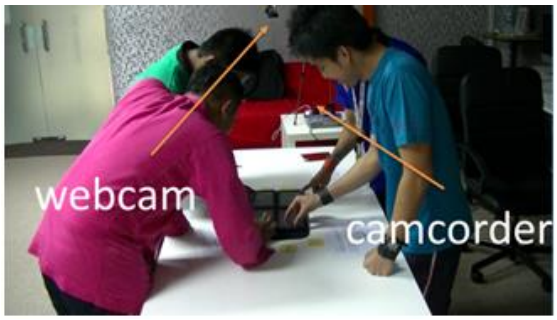

Figure 5 Evaluation setting

Figure 6 A close-up view of the tablets captured by a webcam

At the beginning of the study session, all participants were required to sign a consent form. The main experimenter explained the study information and procedure to each group and they were allowed to ask questions on any issues regarding the study. Each participant was equipped with a pair of colored paper wristbands for easy recognition during analysis stage. The participants were then invited to perform the both evaluation tasks using the Co-located ad-hoc system.

4.3 Procedure

Prior to the evaluation study, a simple training task was conducted as a warm-up session (for both the tasks) to familiarize themselves with the features and functions of the system for at least 5 minutes. The participants had a hands-on experience playing the game on the mobiTop system. During the study, the participants played the game for ten minutes.

During the evaluation study, participants were required to complete two tasks. For the first task, participants are required to arrange in 2x2 grid pattern, connect and calibrate four devices using the co-located ad-hoc system. This is to investigate the user experience when connecting the mobiTop system. A stopwatch is used to measure the time taken by the participants to perform this task. Upon completing the first task, a group-based face-to-face interview was conducted and moderated by the experimenter. All participants were asked to share their experiences towards the first task. After that, each participant was required to complete a set of questionnaire; information included the participant's demographic background and the participant's current practice of connectivity and calibration preferences. The questionnaire used a 5-point Likert score.

For the second task, participants were invited to play the Ping-Pong game-based application using the mobiTop system for two rounds and for each round, they need to score 7 points in order to win and end a game. During the first round, they need to play with one ball and with two balls for the second round (Figure 7 and 8). Figure 9 shows the result for each round.

Figure 7 Game setting for round 1 (with only one ball)

Figure 8 Game setting for round 2 (with two balls)

Figure 9 Screenshot of *End of game*

At the end of this second task, a group-based interview will be conducted by the main experimenter. The main experimenter asked about the participants' experiences, preferences and suggestions. After that, participants are required to complete another set of questionnaire. The information in the questionnaire included the and usability of multi-touch interactivity on functionality co-located ad-hoc system. Similar to the previous questionnaire, the questionnaire used a 5-point Likert score.

5.0 RESULT AND DISCUSSION

The data was gathered and analyzed through observations, video recordings, questionnaires and interviews to understand the user experience when using the mobiTop system. The study showed that sixteen participants tended to use their mobile devices to play games either on a daily basis or more than once a week (Figure 10). Three participants played games on their mobile devices once a week whilst thirteen participants played games on their mobile devices either once a month or rarely. Additionally, 59% of the participants had used their mobile devices to play games indicating a sense of familiarity with the task activity.

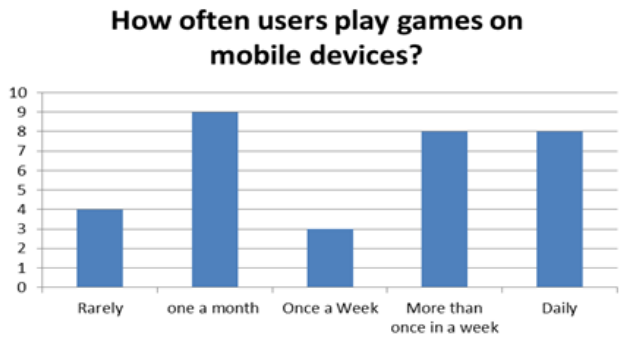

Figure 10 Users frequency of playing games on mobile devices

5.1 User Experience

From the questionnaire, thirty-one participants agreed that it is very easy to perform the game activity on the mobiTop system with mean score of 3.875 (standard deviation = 0.83) and only one participant that did not agree. Thirty-one participants said that they enjoyed playing games on the mobiTop system with 16 participants feels very enjoyable and 15 participants feels enjoyable with mean score of 4.47 and standard deviation of 0.57. Thirty participants (94%) agreed that the extended screen size improved their gaming experience. However, two participants were participants unable to tell the differences of an improved gaming experience between the extended screen size versus a single tablet. Thirteen participants highly agreed and fourteen participants (total of 84%) agreed that the mobiTop system is able to enhance their gaming experience when compared to playing the game using a single mobile device. Eight participants highly recommend and twenty-one participants would recommend using the mobiTop system to their friends to enhance their user experience when playing a game-based application (mean = 4.22, SD = 0.55).

This study demonstrated that users found the extended screen size enhanced their user experience during the game-based application on the mobiTop system. Users agreed that the mobiTop system was easy to use and have enjoyed playing the game using the system. Finally, 84% of the users would recommend their friends to use the mobiTop system when playing a collaborative game-based application.

This result suggests that users prefer playing games together on collocated multi mobile system. This is likely due to the larger interactive surface created by combining multiple mobile devices together as compared to the smaller screen size when users use their individual mobile devices. The display of a single device is typically too small for effective collaboration [8]. Study from [9] shows that increased screen size could improve mood, enjoyment and social responses. With the ability to cater for collaboration in an impromptu manner combined with the affordability factor (mobile devices are becoming less expensive and more affordable to the mass market), various social groups (such as families, friends and colleagues) can engage in a leisurely activity using the mobiTop system. Previous study also shows that users will be more presence and immerse while playing game on large screen [9]. It offers both the social and competitive aspects to the society and potentially brings a new level of experience for users. They are able to share their experience, excitement and engagement with each other through the mobiTop system. Multiple users connected together through a single system thus allowing them to socially interact with each other and express themselves in an on-demand and affordable manner.

5.2 System Design

5.2.1 Ball Size and Color

In terms of system improvement, during the interview sessions, participants suggested that the ball in the game application should be bigger and used bright color due to the ball is too small and too dark for participant to track in the dark background. Below is an excerpt from the Group 2 interview session that discussed about the color and size of the ball.

[Group 2]
USER 3: "*Add more color!*"
USER 2: "*Use bigger ball instead!*"

From the observation, some participants found that it is hard to keep track of the ball. The example below shows the participants in Group 5 lost a point due to the inability to track the current position of the ball.

[Group 5]
USER 1: "*Oi!*" [User 1 missed the ball]
"*Eh, what happened? I can't see the ball clearly!*"
USER 2: "*We are all blind!*"

When there are two balls in round two, the participants found it a little bit harder to track both balls. Below is a scenario where participants in Group 5 played round two of the game.

[Group 5]
USER 2: "*Ahhhh!*" [User 2 tried to catch to one of the balls but failed]
"*I can't see! When I only focus one ball then suddenly another ball came!*"

Figure 11 and 12 shows group 5 gameplay on round 2 where one of the participants failed to notice the incoming ball as he/she focused on another ball.

Figure 11 User with yellow band failed to notice the ball

Figure 12 User with red band failed to notice the ball

5.2.2 Performance

Participants highlighted that they experienced a lag and slower system response. One study publish by Schwarz, Klionsky, Harrison, Dietz, & Wilson [10] highlighted that it's system that utilizes a Pixel system for its mobile phone devices also faced similar performance issue. This is due to the network latency and limitations of each device. These factors may affect a smooth user experience when using a collocated multi-mobile system such as the mobiTop system. Using the Wi-Fi direct could potentially help to reduce the network latency as it provides a device-to-device transfer speeds of up to 250Mbps [11]. The following was a conversation in Group 5 demonstrates the performance issue of the system.

[Group 5]
USER 2: *"The game looks like it has some kind of lag, the ball shows some kind of lag too!"*

The server host in one the device was causing this problem due slow computing power of the device. One study suggest by Wang & Dey [12] is that cloud gaming might able to solve the problem by reduce the computation required on mobile device but instead rely heavily on the processing power of cloud server.

5.2.3 Bigger Screen Size

Some participant suggested expanding the screen size for the mobiTop system by connecting more mobile devices (the mobiTop system currently connects four mobile devices) or using a larger screen size of the mobile device. Below was the suggestion to increase the size of the system by the participants in Group 8 during the interview session.

[Group 8]
USER 2: *"I would like to suggest expanding the screen size for the system."*
USER 1: *"For example, allow the system to connect more mobile devices in order to play."*

5.2.4 Bezel Effect

Some group has comment that the bezel effect (the think border surrounding the tablets) made it difficult for the participants to predict the direction and momentum of that was coming from other connected tablets. Figure 13 shows the area where users view has been block due to the bezel of the device. Participants in Group 1 highlighted this issue below:

[Group 1]
USER 3: *"Sometimes we lose a point because of the middle (bezel) as I cannot see the ball coming, I don't know where I (am) going to defend it!"*

Figure 13 User point the bezel of the screen

A study from Bi, Bae, & Balakrishnan [13] found that interacting with objects was faster with no bezel compared to a tiled screen. This is because user tends to view the display using grid to grid strategy. Therefore, tiled screen are more prone to error while perform some task that will hinder users performance. This can be solve by introduce spatial relationship

between display. *OneSpace* develop a technique by treating the bezel as a space to reflect the physical distance between displays [14]. When a ball goes across the bezel, the ball will travel the space between the bezel so that on the next display it will show up on at the expected location. Another way is to provide a trail for the ball so that user can identify the ball trajectory.

5.2.5 Device Movement

It is found that participants tend to move their devices from its original position. The mobiTop system is configured such that the mobile devices remained static during interaction. When that happens, the participants quickly arranged the devices back to its original position and reminded each other others to hold tight their devices respectively to prevent it happen again. The scenario in Group 5 below depicts the behavior.

[Group 5]
USER 2: *"Hold the tablet!"* [User 2 tried to hold the tablet from getting out of place]
USER 1: *"It's still continuing!"*
USER 2: *"That needs to connect (back)! Hold it tight!"* [User 2 asked others to hold down the tablet]
USER 2: *"Hold it, .hold it, hold it!"* [User 4's tablet was out of place and user 2 tried to arrange back the tablet to the original position]

Figure 14 shows user 3 from group 7 accidentally moving devices away from the group while trying to block the ball from reach the goal.

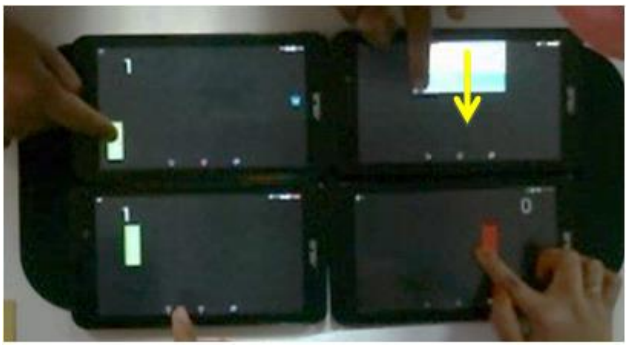

Figure 14 User accidentally moved the device away from others

This study shows that users tend to move the tablets around very often, therefore it is best to be able to track the devices in real-time. *HuddleLamp* formed an ad-hoc collocated system by using table lamp with an integrated camera that could track position and orientation of mobile device in real-time [15]. The system aligns itself automatically when the device was moving from its original position. The game application could use this technique so that user would not have to worry about misalignment of the view for smoother gaming experience.

5.2.6 Accidental Trigger

From observation, the participants sometimes accidentally pull down notification or press home button due to excitement. This could disrupt their gameplay and it already happens a few times. The disruption only happens for those participants that accidentally trigger menu. Others participants can continue on playing the game while he/she trying to get back to the game. Figure shows a participant accidentally pull down the notification and home button while defending its goal. Figure 15 and 16 shows participants' gameplay has been interrupted by accidentally pressing home button and dragging notification center.

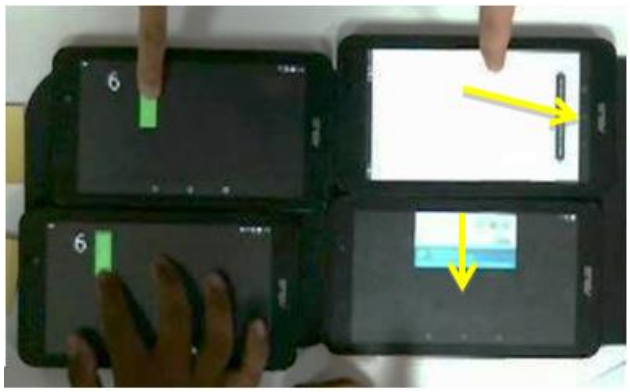

Figure 15 User accidentally pressed the home button and dragged the notification center while playing Ping Ball Game

Figure 16 User accidentally dragged down the notification center while playing Ping Ball Game

The Android operating system always shows navigation and status bar at the bottom and top of the screen respectively [16]. For collocated multi-mobile system, it is recommended to hide the bar to prevent accidental trigger. Hiding the bar can also help reduce the space consume and expand the

size of interaction with the application to create a coherent and fluid gaming experiences without interruptions.

5.3 Design Implications

Based on this study, we propose the following design guidelines to enhance the user experience when designing for a collocated ad-hoc collaborative system for game-based applications:

- **Objects of interests** - make the object of interest bigger and more prominent for easy visibility and interactivity.
- **Smoother performance** - employs a connectivity system that promotes a seamless, smoother and up-to-the-minute performance and reduces the lag.
- **Bigger screen size** - allows users the ability to connect more devices to increase the screen size during collaboration.
- **Reduce the bezel effect** - employ a configuration that would reduce the bezel effect or choose devices that have minimal bezel effect.
- **Device movement** - allow for a dynamic device movement to naturally support the fluid collaboration.
- **Hiding navigation bar** - prevent accidental trigger that could cause interruption on while playing the game and as well as maximising the screen space for game-related items.

The guideline could help designer or developer to provide seamless, enjoyable and uninterrupted experience while doing interactive activity such as gaming on collocated multi mobile system. With this design guideline, user will less likely to notice any differences between playing games on collocated multi mobile system mobile device or tabletop system. Users will also able to enjoy playing games by utilizing the expandable display using the system. Lastly, users will also be able to enjoy the smooth and uninterrupted gameplay on collocated multi mobile system.

4.0 CONCLUSION

This study found that using the mobiTop system for collocated ad-hoc collaboration tends to enhance the user experience during a fast pace game-based application. Users found the extended screen size and multi-touch capabilities to be beneficial during their interactions. The game based application for collocated multi mobile system provide a beneficial social tool for sharing a collaborative, impromptu and affordable experience and interactions between users. This study also highlighted the need to consider several design configurations in designing such systems such as making the object of interests bigger and more prominent for easy visibility and interaction, reducing the bezel effect and allowing for dynamic device movement to support the natural flow of impromptu configuration. Additionally, these design guidelines also highlight the importance of hiding the navigation bar whilst users are engaged with the gaming experience to minimize interruption and maximize the screen space for game-related items. We foresee that users from various social groups such as families, students, friends and co-workers can come together in an impromptu manner and engage in a collaborative social activity that provide both leisure and competition using this mobiTop system. In future, we aim to explore the dynamic collaboration between users and the mobiTop systems further.

Acknowledgement

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