A Comparative Assessment of User Interfaces for Choreography Design

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***Abstract*—Choreography design is a vital creative art that benefits vastly from digital applications. In this study, we investigate the effects of different interaction techniques on user experience for a choreography generator interface. We develop an augmented reality choreography generator and compare it with 1) a personal computer based choreography generator and 2) a mobile application for choreography generation. We evaluate user performance and user experience on the interfaces in terms of task completion times, as well as subjective criteria, such as mental stress, physical stress, and pleasure experienced. Our research contributes to the study of how different interaction methods of the same application affect user experience. The paper also contributes to human-computer interaction in education and training. The results verify the effectiveness of augmented reality in developing training and design applications.**

Keywords–choreography; augmented reality; user experience; natural user interfaces.

I. Introduction

Choreography is a creative process that has evolved over years. With the advent of technology, different ways that embraced digital tools for choreographing emerged. Thus, allowing choreographers to benefit a lot from this evolution. It is imperative to develop interfaces that are robust and suite well for hand-held devices and computers. Furthermore, to enhance user experience in choreographing tools it is important to design human friendly user interfaces.

One emerging field of Natural User Interfaces (NUI) shows much promise shows much promise in the Human Computer Interaction(HCI)field. The approach put more emphasis on developing interfaces that allow users to perform tasks in a natural way, including touch based techniques, gestures and voice; it runs away from the traditional approach of using keyboard and mouse [1]. In this study we develop interfaces that utilize the traditional interactive approach and also interfaces that seek aspects of NUI. NUIs have a pivotal role to play in HCI in education and training.

Augmented Reality (AR) presents an interesting approach to interface development. AR coupled with touch screen presents aspects of NUI, which potentially improves user experience. AR combines the real world and the virtual worlds, it provides interaction with 3 dimensional objects superimposed onto a real world [2]. AR provides a simultaneous way for users to interact with the virtual and real world. With the surge in mobile devices, mobile AR is quickly gaining momentum [3]. This growth in mobile AR applications has been facilitated by the increasing processing power of modern day mobile devices [4]. The ability to process intensive applications has seen a swift shift from the bulky hardware that has symbolized AR since the 20th century. AR promises to be a major player in interface design in the 21st century. Whenever 3D objects appear superimposed onto the real world, a novel experience is created that adds pleasure and creates amazement and curiosity to the user [5]. This has seen AR being embraced by the mobile gaming industry. The year 2016 saw a major shift for AR in the gaming industry with the launch of "Pokemon Go" that has revolutionized how people viewed AR. New York Times suggests that Pokemon go represents the moment AR breaks through the current position to something bigger [6]. As the trend continues, it is imperative to embrace AR in interface development. Technological advances have allowed cheaper ways to develop AR applications.

Over the years different digital platforms have been developed for choreography generation. 3D animation is a preferred choice for dance learning [5]. Furthermore, choreographers have been fascinated by the use of digital tools when perfoming their tasks. The use of these digital tools encourages choreographers to observe the creative compositional process as new through confines alongside new possibilities [7]. In this study, we complement existing choreographing tools by adding AR. Several researchers have suggested that AR can aid reinforce motivation of students and trainees through improving their educational realism [8]. AR applications in mobile platforms provide a lot of promise with respect to training and planning [9].

In this study, we design, implement and compare the mobile AR interface with 1) the Personal Computer (PC) based choreography generator and 2) the mobile application for choreography generation. Our aim is to investigate the effects of different interactive techniques of the same application on user experience. We also investigate how AR affects user experience on training tools. The results of the experiments are important in understanding the impacts of different interaction techniques on user experience, as well as understanding the effects of AR on training applications. In this study, we provide an important contribution presenting a choreography application bridging the gap in the creative technological field. This study also contributes in evaluating aspects of NUI with respect to user experience.

The rest of the paper is structured in this way; Section 2 discusses related work. Section 3, 4 and 5 discuss the PC based, the mobile application and the AR based interfaces respectively. In Section 6, we discuss the experiments that we carried out and share the results obtained. Finally, in Section 7 we discuss the results, challenges and future work.

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II. Related work

As the digitization of choreographing continues, different approaches have been explored to fully embrace technology for this creative process. However, the lack of standards with regards to development of choreograph applications slows down the advances of the development process of these applications. Therefore, as attempts to digitize choreography appear many open questions in relation to the support tools and consensus on the standards exist [7]. Standardizing choreography applications remains a major challenge. This has seen different choreographing tools being developed. Lack of standards allows creativity thereby encouraging more developers to come up with different idea. However, at the same time this leads to development of applications that lack a proper structure.

As early as the 1960s digital tools were introduced for choreography generation. The first choreographing computer system was developed in 1967. It was influenced by the need to create dance annotations without the need of a physical space or the physical dancers [10]. The system developed made use of a two dimensional interface, which utilized stick figure representation of dancers displayed on the computer screen. The choreographers crafted dance annotations using different buttons and controls to control the stick figure representations. The system played an important role in crafting a way for choreographing in the digital space. It was initially developed for ballet dancing, although with time it included other choreographs. However, the major weakness of such a system is dependence on 2D which hinders the natural feel of the interface. Furthermore, early systems suffered from limited input techniques and low processing power of computers. However, the modern century has seen an increase in processing power and the availability of different input techniques.

As digital tools evolved augmented reality has been incoperated in different applications. AR has gained a lot of use in teaching, training and visualization for many different institutions over the last decade [9]. Choreography has also embraced AR and virtual reality in recent years. An interactive mixed reality system for stage management and choreography is mentioned in [11]. The system developed is a hybrid choreography system that uses both virtual reality and augmented reality to achieve the desired goals. The system facilitates planning for stage shows and events. It makes use of head mounted devices to allow the choreographer to design choreographs for 3D generated characters. Furthermore, 3D pops can be used in stage set up to visualize how the real stage will look like. These 3D props include different stage set up items like drums and guitars. Choreographers can define different choreographs and play them on the miniature stage. Interior designers can also use this mixed reality stage. However, the major downside of this approach is the dependence on bulky and expensive hardware. Furthermore, it requires a lot of space for setting up the miniature stage, making it difficult for mobile users. However, this cumbersome approach to AR has been improved by recent advances in mobile hand-held devices like smart phones [12].

Another digital approach to dance learning that is based on a Web3D environment is described in [13]. This interactive system realizes dance animations for training and education. Using the application a choreographer can compose various dance annotations. The Web3D environment is effective for interactive dance steps observation, slow movement of fast steps and different angles of view. The choreographer is presented with a rich interface that enables the creation of choreographs with a good zooming level. The system enables the dancer to learn the annotations defined by the choreographer from different angles and speed. This 3D animation environment provides an easy way for dancers and choreographers to perform their work without the need of a physical platform. However, the interface is effective on desktop browsers. In this approach portability is a challenge.

Much work has been conducted to compare different interactive techniques. A study mentioned in [1] investigates the usability of the mouse-based and touch based interactive approaches in manipulating objects in a 3D virtual environment. In the study, they measure subjective aspects such as fatigue, workload, and preference. The researchers used docking tasks on participants to accomplish the investigation. The experiments were conducted in a well controlled environment, which allowed the users to continuously give feedback. The results were important in showing that the two approaches provide relatively similar levels of precision, however time of interaction differs. The subjective results also showed which of the interactive techniques users preferred. The study conducted contributed to the study of interactive techniques and usability of applications. However, as per our knowledge there is no work comparing the different interactive techniques on user experience for choreographing applications which also takes AR into consideration. Therefore, our study focuses mainly on user experience on a choreographing tool. Furthermore, we focus on AR for training and education. We seek to develop a clear understanding on the effects of mobile AR on user experience.

III. PC based interface

We first developed a desktop application for choreography generation. We engaged various stakeholders in the arts field to obtain the necessary functionality of a choreography application. This interactive process played a big role in crafting the control for the characters in the choreographing scene. In the application, we limit choreography animation to movement only, for the sake of simplicity.

The interface is a 3D choreographing environment that a choreographer uses to define different annotations. The presented stage is rich in props and presents a well modeled stage that resembles real stages for theaters. The choreographer is presented with controls to add dancers and props into the stage. The props that can be added include trees and boxes. Figure 1 shows the PC based interface with dancers and props added. The choreography generator interface can be customized to suit well for different set ups ,this enables flexibility to choreographers. In this way users can define their stages in different ways depending on the type of choreographing they are working on. Furthermore, individual character profile for the dancer can be created when adding a character, the profile contains attributes such as name, age, gender and height. This functionality allows the choreographer to define 3D virtual characters with attributes that makes it easier for the real performing artists to follow in order to understand their roles in the choreography.

The stage can be viewed from different angles, allowing the choreographer and the dancer to view the defined annotations from various views. The user can zoom into and out of the

Figure 1. A screen shot from the PC based interface showing props added.

scene using a mouse, and also rotate the scene to view it from different angles. The interface provides high levels of zooming that permits both the choreographer and the dancers to view the defined annotations clearly.

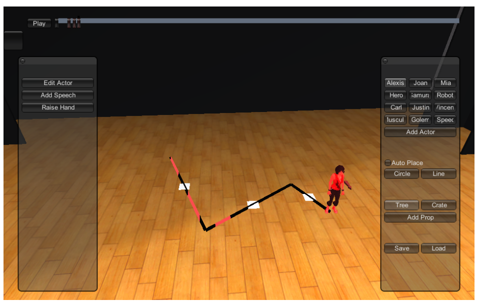

Figure 2. PC based interface: draw path.

To add a dancer into the scene the user utilizes the “add dancer” button, then selects the character from the presented grid. Once the dancer is added into the scene the choreographer can then define the path that the dancer must follow. The “draw path” button is used to set the scene into a mode for defining the path. The user uses the mouse to drag the character along the path to follow. A line trail is used to show the user the path they are defining as shown in Figure 2. After defining the choreography the “play” button is used to play the defined choreography. While the scene is playing the choreographer can use a slider to control the speed of the characters.

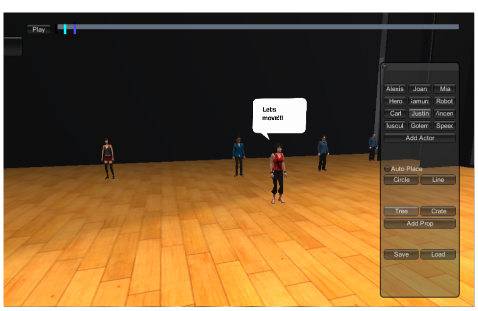

Figure 3. PC based interface: text bubble.

Other animations include a bubble to keep track of any text that a performing artist utters in the scene, and also the ability to raise hands as a sign for different signals. The choreographer can set different signals that dancers use in the scene, including voice signals which come in the form of note bubbles on the interface. The bubble carries a message that a character must utter as shown in Figure 3. This is analogous to a lead dancer hailing out instructions during the dance or an actor telling his lines.

IV. Mobile Application Interface

The PC based choreography generator functions as the foundation for the mobile application for choreography generation and the AR application. Mobile touch screens such as those of phones and tablets remove reliance on the keyboard and mouse for interaction, and present the touch based interaction technique. The touch based approach present a new dimension of controlling the characters and interacting with the interface. This interface is designed to function on hand-held devices of different screen sizes.

Figure 4. Mobile application interface: draw path.

The application retains the same functionality and graphics as the PC based application, but relies on the finger to define different controls. The user can select the actors to add into the scene by touching a specific button from the character grid presented in the interface. Once the character has been added the finger is used to draw the path the character follows. The user uses his/her finger to drag the character towards a path to follow. A line trailer utility is developed to set the trail behind the path to show the user the path being defined as shown in Figure 4. Drawing the path using the finger allows a natural way of performing this task. This enables an easy way for the user to achieve the required result, in addition it facilitates defining paths that are difficult to achieve using the mouse.

To play the scene the “play” button is used. Whilst playing the choreography the choreographer can view the scene from different angles and zooming levels, by utilizing the touch screen. To zoom in or out the interface allows the simultaneous use of two fingers to open up or close down the interface. Rotating the scene is achieved by dragging the view towards the required viewing angle using just one finger. The mobile application also allows the user to add different props to decorate the scene. The underlying visual graphics for the PC based interface and the mobile application interface are generally the same with a little difference owing to the nature of mobile devices’ screens.

V. AR Based Interface

Mobile AR presents an interesting approach to interface development. AR changes the users’ real view by superimposing computer generated graphics using a smart-phone screen or a headset. AR is important in choreographing as it takes away the need for physical resources to set up a choreographing environment. Using AR a virtual stage can be created anywhere and virtual 3D characters can be added.

The AR based interface presents the same functionality as the two previous interfaces. However, the graphical interface of the AR based application differs significantly due to the nature of AR. The AR application is a mobile based AR tool that utilizes marker based detection. The application uses marker-based augmented reality approach. The marker is used as the stage set up required to initiate the interface. Marker based AR uses a camera and a visual marker to determine the center, orientation and range of its spherical coordinate system [3]. The marker used for this application is shown in Figure 5.

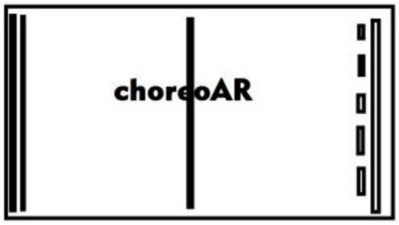

Figure 5. Template designed for the AR marker.

Using AR, different real world tangible objects can be added on top of the marker apart from the computer generated imagery. This aspect gives the choreographer ability to use different real world tangible objects. Therefore, using AR the stage is not a fixed environment but rather it allows the choreographer to creatively define different environments for choreographing. AR's inherent nature provides a unique opportunity to create authentic extraordinary environments that make use of both digital and physical material [14]. In Figure 6 two physical objects are utilized as props and an image as a background scenery. In mobile or PC based interfaces only computer generated imagery can be used in the background for stage setup.

Figure 6. A screen shot from the AR interface, which shows interactive buttons, physical objects as props and an image as background scenery.

The user utilizes his/her mobile device's camera to view the marker and initiate the interface. To interact with the interface the user also utilizes the touch screen of the mobile device. Once the marker is detected the user is presented with the application's interface on the mobile device's screen. The interface presented has controls for adding a dancer, drawing the path, adding props to decorate scene, controlling speed of the characters and resetting the scene. To add the characters into the scene the "add button" is utilized. The user can then position the dancers anywhere on top of the marker. To define the choreography the user drags the 3D character along the path to follow; this is achieved using the finger. The line trailer utility of unity is also utilized to draw a trailer behind the path being defined, so that the choreographer has a visual aspect of the path being defined. Figure 7 shows a simple path defined for a single character.

Figure 7. AR based interface: draw path.

Figure 8. A screen shot from the AR interface, which shows characters and a prop added.

A play button to play the defined choreography is presented to the user as shown in Figure 7. Whilst playing the defined choreography, the user can control the speed of the characters, view the choreography from different angles and zoom in or out. To achieve different zooming levels the user moves the mobile device closer or further from the marker, whilst keeping the marker at a fixed position in the screen. This same functionality can also be achieved by moving the marker closer to the device's camera, whilst keeping mobile device on a fixed position. In order to view the scene from different angles the user can move the camera around the marker. The scene can also be reset to correct any errors that arise. This functionality enables the choreographer to explore the interface further without fear of making errors. Figure 8 shows the implementation of the AR interface with a tree and four dancer characters added into the scene.

VI. EXPERIMENTS

Experiments were conducted to evaluate the performance of users on the three developed interfaces, the PC based version, the mobile application for choreography generation and the AR based version. We investigated four of Nielsen's factors of usability: satisfaction, effectiveness, ease of learning and efficiency [15]. We obtained satisfaction levels from the post user questionnaire form. The effectiveness is shown by how the test subjects completed the given tasks. The user's feedback on how easy it is to learn the system gives an indication of the time needed to learn the different interfaces. The time scores determines the efficiency of the interface.

A. *Software and Hardware*

To develop the three interfaces we used Unity3D software, a cross-platform game engine used to develop video games for computers, consoles, mobile devices and websites [16]. Unity is a powerful platform for developing 3D based graphical applications with rich interfaces. The PC based interface is available as a standalone desktop application or as a web based application, but works only on browsers that support Unity3D plugin. The user interacts with the interface using a keyboard and a mouse.

The mobile application for choreography generation is designed for hand-held devices. For the experiments we published the application for Android devices. The users use the touch screen to interact with the interface. The AR application makes use of an additional plugin for Unity3D named Vuforia. Vuforia facilitates for the creation of robust AR applications on the Unity3D platform. It uses computer vision technology to recognize and track planar images and simple 3D objects in real-time [17]. Vuforia and Unity3D have a seamless combination that enables the development of rich interfaces.

To test the PC application the participants accessed it as a web application from the Mozilla Firefox web browser, and also as a standalone desktop application. To test the mobile AR application and the mobile application we used an LG G4 stylus and a Samsung S5. These devices have good cameras that are very effective for AR applications.

B. Participants

We used a total of 15 unpaid test subjects for the experiments. From the 15, 9 were males and 6 were females. Their ages ranged between 19 and 28, with a mean age of 24. We selected the participants based on their ability to use computers. The experiments were carried out primarily to evaluate the usability of the applications therefore the use of non-professional test subjects, this is a preliminary study. With respect to expertise in AR, four participants had experience with AR applications whilst the others stated that they had no significant previous experience.

C. Tasks

For this comparative study, we chose these simple tasks that are easier to handle for users since all of them are first time users of a choreographing application. The participants were expected to complete these tasks on the three interfaces. The participants had to add a dancer to the left and to the right of scene. After adding the dancer, the user then adds a prop into the scene, the prop being the tree or the box for decoration. After adding the prop the user then draws a simple path for the dancer to follow. Finally, the user is expected to play the defined choreography. In addition to this task, users were required to zoom in and out, and also increase speed of characters in the scene. This was to allow users to explore the interfaces further.

The four tasks that the users were expected to perform:

- Task 1) Add dancer to the left and right of the scene
- Task 2) Add prop to the left and right of the scene
- Task 3) Draw a simple path from the back to the front
- Task 4) Play the choreography (free play time)

D. Procedure

The participants performed the four tasks in sequence on each of the three interfaces. The participants were each given a brief description of the task to be performed. During the experiments, our participants used the interfaces in a random order to avoid task adaptation and to obtain fair scores for the three interfaces. We encouraged the users to think aloud during the process and we recorded their feedback at each stage.

We recorded the time the users took to complete each tasks to obtain the objective test results. We only recorded completion time for the first three tasks, whilst the last task of playing the scene had a free time so as to allow the users to explore the system more.

At the end of the experiment the users were presented with post test questionnaire that assisted in obtaining subjective analysis of the experiments. The users gave feedback on satisfaction, the pleasure they experienced, time to learn the interface, their frustration levels and they also gave feedback on their preferred interface. Difficult measures of using the interfaces in the type of mental stress and physical stress scores were also attained. Furthermore, we required our participants to express their preferred interface from the three given interfaces. These results gave us a fair comparison of the interfaces to have a conclusive analysis.

The user experience test conducted on the interfaces investigated the following issues:

- Users' awareness and experience with AR technology
- Users' preference on touch based or pointer based interactive technique
- Users' reaction to the different zooming approaches
- How the users interact with the two interfaces.
- Time taken to complete tasks

To measure the different aspects of user experience we used a scale 1 to 10. Satisfaction, pleasure, physical stress and mental stress level were attained from this scale. We also expected users to give a feedback on the effects of the different interactive approaches on viewing the choreography from different angles, and also the effects of the different zooming interactive techniques.

E. Results

The results of the experiments are shown the Tables 1-6. Table 1 gives mean time scores, Table 2 gives mean mental stress scores, Table 3 gives mean physical stress scores, Table 4 gives mean satisfactions scores, Table 5 gives mean pleasure scores and Table 6 gives mean frustration scores. Best scores are highlighted in bold.

TABLE I. TIME RESULTS[IN SECONDS]

	PC based	Mobile application	AR interface
Task 1	9.3±1.2	8.3±1.0	**7.5±1.2**
Task 2	**8.9±1.2**	9.0±2.5	9.1±1.3
Task 3	12.4±2.10	7.2±1.2	**6.5±0.8**
Task 4	free time	free time	free time
Average	7.7±1.1	6.1±1.2	**5.4±0.8**

The results in Table 1 indicate that completing the tasks was generally faster on the touch based interactive approaches of the AR and the mobile application interface as compared to the mouse approach of the PC based interface. The total average time for completing the first three tasks in sequence is 30.6 seconds for the PC based interface, 24.5 seconds for the mobile application interface and 23.1 seconds for the AR based interface. The total average scores show that AR

TABLE II. MENTAL STRESS RESULTS [IN LIKERT SCALE 1-10]

	PC based	Mobile application	AR interface
Task 1	3.1±0.9	3.0±0.7	**2.9±0.9**
Task 2	1.5±0.8	**1.4±1.0**	1.7±1.1
Task 3	6.7±1.00	2.9±1.2	**1.3±0.7**
Task 4	1.5±1.1	2.0±1.0	**1.3±1.2**
Average	3.2±0.9	2.3±1.0	**1.8±0.9**

TABLE III. PHYSICAL STRESS RESULTS [IN LIKERT SCALE]

	PC based	Mobile application	AR interface
Task 1	**1.5±1.3**	2.0±0.7	4.3±1.0
Task 2	**1.6±1.2**	2.8±0.4	4.2±1.3
Task 3	2.9±0.9	1.7±3.6	**1.35±0.7**
Task 4	**1.6±1.6**	4.8±0.7	6.6±1.7
Average	**1.9±1.2**	2.8±1.4	4.1±1.1

TABLE IV. SATISFACTION RESULTS [IN LIKERT SCALE 1-10]

	PC based	Mobile application	AR interface
Task 1	**7.0±1.1**	6.5±1.2	6.8±0.8
Task 2	7.9±0.9	7.3±1.3	**8.0±0.5**
Task 3	6.7±2.1	7.64±0.2	**8.2±0.8**
Task 4	7.2±0.5	7.0±0.9	**8.6±1.0**
Average	7.2±1.2	7.1±0.8	**7.8±0.8**

TABLE V. PLEASURE RESULTS [IN LIKERT SCALE 1-10]

	PC based	Mobile application	AR interface
Task 1	7.0±1.1	6.7±1.6	**7.4±1.0**
Task 2	7.6±1.0	7.6±1.2	**8.0±1.1**
Task 3	6.7±1.2	8.2±1.3	**8.6±0.9**
Task 4	6.6±0.7	7.0±1.1	**8.9±0.6**
Average	6.9±0.9	7.4±1.5	**8.2±0.9**

TABLE VI. FRUSTRATION RESULTS [IN LIKERT SCALE]

	PC based	Mobile application	AR interface
Task 1	1.90±0.8	**1.4±0.9**	2.3±0.9
Task 2	**1.4±1.30**	1.8±1.1	1.8±0.9
Task 3	3.1±0.8	2.8±0.9	**1.0±0.8**
Task 4	3.0±0.9	4.10±0.8	**1.8±0.9**
Average	2.4±0.9	2.5±0.8	**1.7±0.9**

produces faster task completion rates compared to PC based interface and the mobile application interface. Especially *Task 3* drawing path shows significant difference on the mean time values. Drawing path on the mobile based application and the AR interface is performed drastically faster than on the PC based. The AR has 6.5 seconds , 7.2 seconds for the mobile application and 12.4 seconds for the PC based interface. Furthermore, we note from the standard deviation scores that the divergence of AR results is rather small, showing that the task was performed almost similar by all users. Drawing the path on the touch based interfaces using the finger was simpler and faster as compared to using the mouse to define the path. The time scores generally show that the touch based approach is more efficient than the mouse based approach as they produce faster task completion rates. Furthermore, although time was not measured for *Task 4* it was observed that zooming in and out or changing the viewing angles was faster in the AR based interface. This further highlighted the efficiency of AR as it gives users a quicker way of achieving different viewing positions.

The levels of mental stress on all the three interfaces are generally low owed to the simplicity of the tasks and the interfaces, as shown in Table 2. However, we note a significant difference on the result for the PC based interface when drawing the path. This was a result of the approach that required more time to grasp. The mental stress scores for the PC based is 6.7, whilst it is 2.9 for the mobile application interface and 1.3 for the AR interface. This shows that the users experienced a lot of stress mentally in this task. Furthermore, the standard deviation score of 1.0 shows that almost all the users agree on the high mental effort needed to perform *Task 3* on the PC based interface. On the AR interface users experienced the least mental stress on three of the four tasks.

Physical stress is significantly high on the AR interface. The AR interface has an average physical stress of 5.6 as compared to 3.1 and 1.8 of the mobile application and PC based interface respectively. *Task 4* "playing the scene" shows the highest level of physical stress experienced by the users on the AR interface. Having a physical stress score of 6.60 as compared to 1.60 and 2.75 of the PC based interface and mobile application interface respectively. This highlights one big disadvantage of mobile AR on user experience as it requires more physical effort over time. However, for *Task 3* we observe that AR has the lowest physical stress. This result highlights that users needed less physical effort when drawing the path using the finger as compared to using the mouse. The high levels of physical stress on the AR interface are due to the movement of hands, as the user moves the device closer and further from the marker to achieve different angles and zooming levels. This effect is also the cause for the physical stress scores on the mobile application as the fingers need to constantly interact with the interface for any activity. Thus, the touch based interfaces require users to use more physical effort to perform the tasks. From Table 3, best scores are achieved most on the PC based interface highlighting that the mouse as an interaction device requires low physical effort. The main source of physical stress on the PC based interface is the movement of the mouse through small movements of the hand while the arm lies in rest-up position. This explains the low levels obtained in this regard.

Users expressed high levels of satisfaction from completing their tasks on all the interfaces. These results are attributed to the simplicity of the interfaces themselves. The standard deviation scores that are generally less than 1.0 also indicate that users experienced almost similar effects. As shown in Table 4 users expressed more satisfaction on the AR interface as compared to the two other interfaces. For *Task* 4 the satisfaction scores are 7.2 for the PC based interface, 7.0 for the mobile application interface and 8.6 for the AR based interface. These high scores are attributed to the fact that users managed to complete all their tasks to a satisfactory level. Users expressed satisfaction in the quicker and easier way they managed to move around the scene using the AR interface.

Table 5 shows the scores recorded for the pleasure experienced by users when performing the tasks. The results show significant excitement when using the AR interface. The main excitement is brought by the curiosity that the interface introduces as stated by [8]. On all the tasks the highest pleasure is recorded on the AR interfaces with scores of 7.4, 8.0, 8.6 and

8.9, for *Task 1* up to *Task 4* respectively. Of particular interest are the results for *Task 4* where the users were allowed a free time to explore the interfaces. The pleasure results for the PC based interface, the mobile application interface and the AR interface are 6.6, 7.0 and 8.9 respectively. These results show a significant difference; on the AR interface users experienced the greatest pleasure. The ability to zoom in and out of the scene by only moving the mobile device closer or further from the marker, brought about such a compelling effect to the users when using the AR interface. This approach of changing viewing position gave users an easier way to move around the scene. This ability also reduces the time to achieve the required zooming position or angle as compared to using the touch screen to zoom in or using the mouse to zoom into the scene. Therefore on the overall the AR interface is more effective than the other two interfaces. The results also indicate that users experienced more excitement on the mobile application than on the PC based interface.

The mobile based interface produced high level of errors when the user was zooming in and out of the scene, thus more frustration as shown in Table 6. This was largely due to the user rotating the scene instead of zooming. A number of errors were also experienced on the PC based interface, but this was less than the ones on the mobile based. This result is attributed to the level of control a pointer device has on the scene largely due to the small point of contact with interface as compared to the finger's surface. However, we note that with the AR based interface this error does not exist as the AR interface allows a more natural way of zooming which is analogous to moving closer to an object to view it clearly. The frustration scores for *Task 4* demonstrate the effects of the errors on the interface as the users were frustrated on interfaces with many errors. The score for *Task 4* for the PC based interface, the mobile application and the AR interface is 3.00, 4.10 and 1.81 respectively. This shows that users were less frustrated on the AR interface whilst playing the scene. This is largely due to the easiness of changing viewing angles and zooming levels. However, we note that when adding the characters the AR presents the highest frustration scores (2.3 compared to 2.1 and 1.43 of the PC based interface and mobile application interface respectively). This result is caused by the tilting effect of the mobile device whilst the user is positioning the characters. Therefore, this makes it difficult for the user to correctly position the characters in the scene in the way they wanted. On the contrary, in the PC based interface and the mobile application this difficulty does not exist. Table 6 also highlights that frustration levels differed on the tasks the users were performing on the different interfaces. The AR interface gave the least frustration levels on the last two tasks whilst the PC based interface gave the least on *Task 2* and for *Task 1* the mobile application interface gave best result. The main source of frustration for the AR interface is the tilting of the device whilst performing tasks that are more effectively done with a static device, such as adding the character on the scene.

The simplicity of the interfaces is further shown by the "easy to learn" results we obtained from the users, which have scores of 8.4 for the AR based application, 8.01 for the mobile application interface and 8.10 for the PC based interface. The AR interface has fewer visual buttons than the other two interfaces this makes it easier to learn as shown by the results. Generally, the interfaces provided the same basic functions and controls that explains why the scores for the easiness to learn are very close to each other. It is of high importance to develop interfaces that are easy to grasp for the users, especially for applications that are used in training and education. This was also demonstrated by the willingness of the participants to explore the interfaces further. This also helps the users retain over time.

After completing the experiments, we also asked which interface for choreography generation the users prefer best after having performed tasks on all the three interfaces. Seven preferred the AR interface, four preferred mobile application and four preferred the PC based interface. These results show that the AR based interface was the preferred option by the users. From the users that already had prior experience with AR only one of the users did not choose the AR based application as a preferred interface for choreography generation.

VII. Discussion

The experiments were carried out to complete the same task on three different interfaces using different interactive techniques: 1) the PC based application that uses pointer based interaction approach utilizing a mouse and keyboard, 2) the mobile application interface and 3) the AR application that used touch based interaction approach. The results obtained from the experiments contributes to the study of how different interaction techniques affect user experience and also the effects of augmented reality on user experience.

The touch based approaches produced faster task completion times compared to the mouse based approach. The touch based interactive approach of the AR interface and the mobile application showed faster times using the finger to draw path demonstrating the power of interfaces that provide a natural way of interaction to the users [1]. Using the finger to define choreographs presented a natural approach to define movement as compared to using the mouse, this explains the significant time differences. The AR interface gives the best overall task completion rate compared to that of the PC based and mobile application interfaces. However, the mobile application and the AR interface show a small difference of 1.4 seconds since both approaches use the touch based interactive approach. Furthermore, the ability to zoom in and out of the scene by only moving the hand-held device closer to the scene gave users a quicker way to complete the task. This further demonstrates the effectiveness of having interfaces that facilitates a natural way to complete the tasks. Thus, interfaces which facilitate a natural way to complete tasks possess a great advantage in as far as user experience is concerned.

The results showed that when adding the dancer and the props into the scene the rate of errors was high in the AR interface as compared to the other two interfaces. This result is influenced by the changing position of the interface as the phone tilts or is held in an unstable manner and also the underlying design of the interfaces. Maintaining a mobile device in a stable position during interaction is a big challenge for all mobile AR applications. This is attributed to the natural hand tremor [18]. This effectively undermines AR's effectiveness for mobile devices in applications that require accurate positioning. Nonetheless, depending on the application these errors can be tolerated. However, AR interface had no errors associated with zooming or rotating the scene since this was achieved by only moving closer or around the scene. The

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mobile application had more errors in this regard compared to the PC based application owing to the larger surface area of the finger as compared to the mouse pointer. The mouse facilitates an easier zooming approach compared to using the finger. The mouse utilizes the scroll wheel to change the levels by scrolling it towards the required direction. In addition, changing the viewing angles by dragging the scene using the mouse pointer produces faster and more accurate results, compared to using the finger on the touch screen of the mobile device. This effect is influenced by the small contact area of the mouse pointer which gives the user more control to perform the required task. The touch based approach is efficient, however care has to be given when dealing with interfaces that have many controls in the same line. This gave many errors on the mobile based application where a user was zooming but instead found himself/herself rotating the scene. This is a drawback for the touch approach. However, rarely experienced on the PC based approach due to the small area of contact on the mouse pointer as compared to the larger surface area of the finger.

It very important to develop interfaces that are easy to learn. The simplicity of the graphical user interface goes a long way in achieving faster “time to learn” scores as demonstrated by the results from the experiments. Time to learn eventually affects the usability of the interface, especially with regards to training tools. Interfaces that are simple to understand also help boost the users’ retention rate. In our experiments, the interfaces were easy to learn, this made users more interested in exploring different functionality of the interfaces. We also noted that AR interface produced the best “time to learn” score. This also led to the interface being the preferred choice of the users, as they felt more relaxed while using the interface.

The results of the experiments also show that AR has an important part to play in crafting training tools as stated in [9]. It gives a compelling effect to the users and excitement through the curiosity it creates. Furthermore, AR allows the addition of physical objects into the scene in addition to the computer generated objects. For training applications this helps explore many objects to illustrate concepts without the need of completely changing the graphical interface. Therefore, AR allows flexibility in interface design. The user preference results demonstrate that AR has a great promise, this reenforces the findings in [14]. This demonstrates that AR is effective in teaching and training.

The AR interface affords users the ability to interact with the characters by only moving the phone around the marker. The ability to move closer to the dancers on the scene and easily shift the viewing angle provided pleasure and excitement to the users. This is similar to moving closer to an object or further from the object, which is a natural approach to changing positions. This approach gave users an easier and quicker way to move around the scene. However, mobile AR for hand-held devices presents high levels of physical stress on the hands of the user and also a high error rate when interacting with the touch screen as the mobile device tilts and shifts positions on the hand of the user. The interface requires a lot of physical effort from the user’s hand to achieve the desired results, this in turn leads to the high levels of physical stress. Another contributing factor to physical stress in mobile AR is the screen size of the device as limited screen size tend to restrict the covered field of view as stated in [19], thereby forcing the user to continuous adjust viewing positions.

Therefore, wearable glasses or goggles can prove more effective for AR in training applications. For example, using wearable glasses like Google’s cardboard the user does not need to continuously use the hand to position the mobile device correctly, but rather by positioning the eyes in the required position. This is an approach we leave as future work, it will give an understanding on the effects of wearable devices on AR and training tools. Furthermore, we intend to extend the interactive approach for the AR interface by allowing the choreographer to use virtual buttons on the marker and draw on the marker. In this approach the mobile phone screen becomes a merely viewing screen but no longer the means of interaction. To achieve more of the natural interface approach voice commands will be important in the future work. For the time being, voice is used as a means to enter text into speech bubbles using the Google speech API. Therefore, future work will complement the current interfaces by having voice commands to add and control characters especially on the AR interface. This future work study focuses more on the natural user interface aspect by having an application that combines virtual buttons and voice commands to control characters in a real environment superimposed with 3D graphics. It is also imperative to extend the interfaces to include a virtual reality interface and compare user experience too.

VIII. Conclusion and Future work

In the study, we designed and implemented three interfaces for choreography generation a PC based interface, a mobile application interface and an AR based interface from which we compared the performance of users in terms of user experience. The interfaces allow a choreographer to define choreographs and makes the choreographer in charge of the actors just like in the real world. The results indicated that using touch based approaches the users obtained faster task completion rates as compared to using a mouse on the PC based interface. Users were more comfortable completing tasks using natural approaches, for example defining choreographs using their finger on the touch based interface. The result demonstrates the need to develop natural user interfaces to improve user experience. Excitement and pleasure obtained was highest on the AR interface, followed by the mobile application interface and lowest on the PC based interface.

The results of the experiment showed that AR has a big role to play in the development of training and educational applications. Researchers can build upon this to further investigate AR coupled with natural user interface aspects like voice and gestures. Another aspect to be implemented in the future includes virtual buttons and virtual drawing of paths where the user only interacts with the marker and not the mobile device screen. In this approach the mobile device screen becomes just a screen to view the real world but the user only interacts with the marker. We plan to add more forms of movement and special animation for choreography generation and test the interfaces on experts working in the arts domain.

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