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Investigating User Experience Using Gesture-based and Immersive-based Interfaces on Animation Learners

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Declaration of Authorship

I, Ezwan Mohd Mokhtar, hereby declare that this thesis and the work presented in it is entirely my own. Where I have consulted the work of others, this is always clearly stated.

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Date:

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Abstract

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Creating animation is a very exciting activity. However, the long and laborious process can be extremely challenging. Keyframe animation is a complex technique that takes a long time to complete, as the procedure involves changing the poses of characters through modifying the time and space of an action, called frame-by-frame animation. This involves the laborious, repetitive process of constantly reviewing results of the animation in order to make sure the movement-timing is accurate.

A new approach to animation is required in order to provide a more intuitive animating experience. With the evolution of interaction design and the Natural User Interface (NUI) becoming widespread in recent years, a NUI-based animation system is expected to allow better usability and efficiency that would benefit animation.

This thesis investigates the effectiveness of gesture-based and immersive-based interfaces as part of animation systems. A practice-based element of this research is a prototype of the hand gesture interface, which was created based on experiences from reflective practices. An experimental design is employed to investigate the usability and efficiency of gesture-based and immersive-based interfaces in comparison to the conventional GUI/WIMP interface application.

The findings showed that gesture-based and immersive-based interfaces are able to attract animators in terms of the efficiency of the system. However, there was no difference in their preference for usability with the two interfaces. Most of our participants are pleasant with NUI interfaces and new technologies used in the animation process, but for detailed work and taking control of the application, the conventional GUI/WIMP is preferable. Despite the awkwardness of devising gesture-based and immersive-based interfaces for animation, the concept of the system showed potential for a faster animation process, an enjoyable learning system, and stimulating interest in a kinaesthetic learning experience.

Publications, Conference Presentations, and Demo of the Work

Mohd Mokhtar, Ezwan., Azman Ong, M. Hanafi., Gillies, Marco. 2022. *Gestural animation is quicker than keyframing and produces "better" results, but that doesn't mean animators like it* [Manuscript submitted for publication in Computer Animation & Virtual Worlds Journal (Manuscript ID: CAVW-22-0099)]. Goldsmiths, University of London, London, United Kingdom.

Mohd Mokhtar, Ezwan. 2013. 'Puppetry-inspired Animation: A Midair Hand Gestures Manipulation for 3D Character Animation'. In: *The 27th International British Computer Society Human Computer Interaction Conference: The Internet of Things*. Brunel University, Uxbridge, United Kingdom. [Conference presentation (Doctoral Consortium)]. http://research.gold.ac.uk/id/eprint/8881/

Mohd Mokhtar, Ezwan and Gillies, Marco. 2013. 'How I Animate: A Hand Gesture-Centric Technique'. In: *EVA London 2013: Electronic Visualisation and the Arts* (pp.56). London, United Kingdom. [Conference presentation]. http://research.gold.ac.uk/id/eprint/8881/ https://www.scienceopen.com/hosted-document?doi=10.14236/ewic/EVA2013.14

Mohd Mokhtar, Ezwan. Sept, 2013. Character animation on Leap Motion [Research project demonstration]. In: *Goldsmiths Tech Expo 2013*, Goldsmiths, University of London, London, United Kingdom.

Mohd Mokhtar, Ezwan and Gillies, Marco. May, 2013. Movement in 3D computer [character] animation: Issues of animat[e]ing techniques [Conference presentation]. In: *Goldsmiths Graduate Symposium*, Goldsmiths, University of London, London, United Kingdom.

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Practice-based Supplementary

This thesis is supplemented with a practice-based component, which can be viewed at, https://vimeo.com/234845996

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1 Chapter 1

Introduction

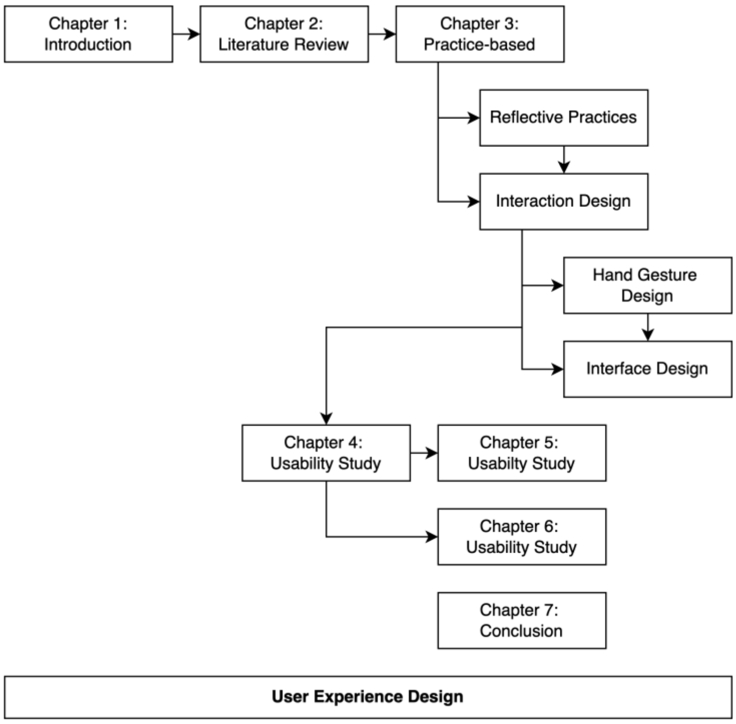
Animating 3D character animation is an exciting endeavour to experience but the time-consuming and painstaking process makes the activitiy tedious. In traditional animation techniques, there are various ways to animate character animation from drawn animation, stop-motion, keyframe[1] animation to the motion capture system. These methods require a substantial amount of production time, understanding of their technical procedures, and expertise in the field.

This practice-based research seeks to investigate new technologies available exploring user experience through an unconventional system that promotes natural interaction and an enjoyable method for creating animation. Exploiting movement in animation by projecting our body movements directly onto the virtual object can be a new animating experience in real time. The experience not only encourages interactivity but could also reduce the production time required for the animation process in comparison to the keyframe animation technique. For the practice-based element, a gesture-based interface system that uses hand gesture is proposed as a means of gestural animation in a real time setting to animate a 3D character.

The foundation of this research is about exploring a user experience in handling computer animation applications in the context of its processes. The position of this research is not just based literatures, but also on personal experience as an academic who involved in teaching and learning of animation. The issue is similar that animation is time-consuming and tedious process, but seeking possibilities exploring potential of new technologies and interfaces that would accommodate new technique. This practice-based research methods include what have described in Chapter 3 in which the first part is very much involved self-reflecting upon teaching keyframe animation and attempt to

[1] Keyframe or Key Frame in animation is a set of images that were positioned at a different time on a timeline. Each frame contains different action poses that indicate the beginning and end of the action.

understand acting technique in order to create animation. Acquiring a an understanding of movement is crucial. We analyse the concept of interaction between animator and 3D character from the traditional marionette puppeteering manipulation technique where the controller plays its role as the interface. These practices have emerged this research into the second part in which bringing technologies into the study, and subsequently designing the interface. The study involves experimenting with devices, participatory design, and interface developments. This research is interested in investigating hand gesture interface design that enable user to directly control 3D character without involving the keyframing process, a similar concept to the marionette manipulations technique. From the development of the second part, the next phase is the evaluation of which the proposed system is to be tested with users for usability investigation. The usability study is include in Chapter 4 and Chapter 5. This research is attempt to take the study in slightly different perspective. In taking this research in a different perspective, we approach user experience into an immersive environment where users animate a 3D character in virtual reality. This study is featured in Chapter 6. These investigations are in comparison to the conventional keyframe animation used in the GUI/WIMP-based applications.



1.1 Problem Statement

While this research was originally motivated by the idea of imparting *believability* by creating animation through the notion of *acting by the animator* and imbuing the 12 Principles of Animation, the task of creating animation remained time-consuming and lacked interaction with inanimate objects. These factors prompted this research to look into a possible system from the Human-Computer Interaction (HCI) perspective. Therefore, the investigation of this research is based on the following statements:

1.1.1 Acting, and expressing movement and timing in animation

These elements have become the key aspects of animation and have constantly been emphasised by professional animators and practitioners in the industry for many years. They highlight how the animator should embrace the importance of acting (Thomas and Johnston, 1981: 473; Hooks, 2000: 5) and this is still practiced today. I agree that the aspect of acting helps the animator to develop a character's emotions and expressions through its body movements. For an animator, each movement of the body needs to be performed independently, checked and reconfigured while animating a character. This process is due to the fact that movement in animation is simply an illusion, but needs to be created from the very beginning. For this reason, the animator plays a crucial role in 'lending' their sense of motion in order to make the inanimate object move.

Giving 'life' to inanimate objects by creating animation can be a very fascinating activity to be involved in. But the complexity of animating and moving a character using keyframing requires complex and detailed observation through the construction from fragments, to make the appropriate sequence of images. With the key issue of making the inanimate character move, comes the issue of determining the appropriate timing. Creating movement is the key element underpinning every animation but it is meaningless without considering the importance of timing. Precise timing provides believable movement and expression, which communicates meaning. Creating timing for animation is another aspect that has always been a key concern among animators. Knowing how important timing is, Walt Disney includes timing as one of the basic 12 Principles of Animation. Appropriate animation timing provides an entirely convincing animation.

Dealing with movement and timing frame-by-frame is laborious. A ‘frame’ is an object that is physically visible, whereas movement and timing are the substance of the illusion that lies within the frames, but are invisible in terms of physical form. To create animation using keyframes in any 3D animation software packages, the animator must set one key frame to another to indicate a different pose and record it on a timeline. On the other hand, creating the appropriate timing for change (transition) depends on the spacing in between the frames. The process of arranging and moving the keyframes to a more appropriate location on the time line goes on and on, and the procedure has to be repeated until the desirable movement is achieved. To establish whether the accuracy of the movement and timing created have been appropriately recorded on the timeline, the animation sequence has to be played back. The procedure for keyframing is repeated until the process of animation is complete. Keyframe animation does not provide feedback directly from the virtual character so that results can be seen in real time. In this way, the animator can feel ‘detached’ from the 3D character, without any interaction.

1.1.2 Time-consuming and laborious process of animation

From repetitively observing actions to creating animation, producing animation is a painstaking process that commonly takes a long time to complete regardless of the technique used. The process is due to the challenges of creating the ‘illusion’ of a sequence of images to give life to the animation. From drawn animation, stop-motion to computer animation, the techniques require an immense amount of time and teamwork to produce a 30 seconds of animation. In computer animation, keyframe animation is one of the various animation techniques that have a complex workflow to deal with the numerous processes of animating.

As an alternative to the traditional animation technique, animators can take an unconventional approach by using motion capture systems to map animation onto animation characters. The system allows the recording of full-body movements in real time; however, motion capture is unable to provide the cartoony-style of animation which keyframing can. Moreover, handling a motion capture system is expensive and requires a highly skilled operator to maintain and manage the input data. In this research, I propose a system that enables animation to be created in real time by directly transferring body movement and timing onto 3D characters.

1.1.3 Creating animation by exerting movement using gesture controls

In this practice-based research, I designed and investigated an inexpensive system to enable animation to be created by using hand gestures in real time and subsequently transfer and record the movement onto a 3D character. The system was inspired by the technique of handling traditional marionettes, where the puppeteer's hand gestures play the important role of manipulating the rods and strings that control the puppet. The system provides a direct interaction method of manipulation between the user and 3D character, and encourages the movement created to originate from the animator's kinaesthetic sense. I believe humans are animated living creatures that possess various bodily senses, including a sense of movement. Our body is intelligent in the sense that it understands the trajectories of movement according to our circumstances.

1.2 Motivation

As part of the basic need of every animator, interaction of a software application plays a vital role to determine the efficiency and effectiveness of the process of creating animation. It is a great challenge for animators to cope with the time-consuming and painstaking process of frame-by-frame technique while animating 3D character animation. To interact with the virtual character, the role of an interface is to act as the intermediary to the animator.

The complexity of the interface design of animation software is one of the problems. Animators are aware of the difficulties of coping with many functions and tools available in the software application. It is because acquiring the technicalities of the software is an aspect that would consume a lot of time to master the skills, while the intricacy of a character's body mechanics is also another aspect that animators must take into consideration. Consequently, animators would hunt for alternative applications that would make them work productively.

Interaction in GUI interfaces are obviously practical interfaces that are capable to offer many solutions to different tasks. However, a GUI-based interface direct manipulation system is likely tedious in its procedure, especially when comes to animation. The WIMP (Windows, Icons, Menus, Pointers) elements of interaction appear to affect the effectiveness of the animation process and take a longer time to execute an animation. This means, that the 'many activities' involving opening windows, clicking icons, scrolling/searching for menus, and moving pointers around the interface using a mouse would distract the production process. Furthermore, these interaction processes exclude the number of errors that animators made handling the application. This led to a mundane and frustrating process.

The emergence of the user interface in today's digital technologies appears to provide various improvements in terms of manipulation style and the way users interact with applications. New interfaces such as NUI-based interface is anticipated as the alternative solution to address the efficiency and effectiveness problems for animating character animation. Spontaneity in the interface is indispensable to ensure intuitive interaction that blurred the lines between the animator and the animated character. The sensory element that NUI interfaces provide by capturing and engaging real-time interactions could change the animation learner's manipulation process. In other words, the NUI interface could minimise the number of times clicking buttons, opening windows, and moving pointers across the software application.

The purpose of NUI-based interface in this research is not intended to replace the conventional interfaces have to offer in animation. Rather, this research is interested to repurpose the animation skills and interaction with character animation in a more physical and natural environment. Repurposing the skills in this sense is about utilising user's body actions as a tool to directly manipulate the limbs and joints of the virtual character in real time. The closest motivation to this concept is through the classic marionette and the puppeteer manipulation process. This research is attempt to investigate a similar process by using bodily interaction techniques in order to reduce time consuming and tedious process of animation. Therefore, the user experience and interaction design are the central focus of this research project.

1.3 Research Questions and Hypotheses

The aim of this research is to investigate the user experience interacting with 3D character using natural interfaces in the domain of computer animation. The problem statement and motivation that drive the main research questions and hypotheses:

On Effectiveness of Animation Process: Effectiveness evaluates the practicality and usefulness of the NUI and GUI/WIMP interfaces in providing more value to the animation process in order to produce a satisfying outcome.

RQ: Could NUI-based interfaces provide an effective process of animation than GUI/WIMP interfaces that improve animators' performance?

H: NUI interfaces could provide an effective process of animation than GUI/WIMP interfaces that improve animators' performance.

On Efficiency of Animation Process: Efficiency investigates the potential of NUI and GUI/WIMP interfaces in order to help animator to produce intended task in least time and effort while creating good animation.

RQ: Would NUI-based interfaces be a better solution than GUI/WIMP interfaces in helping animators to work efficiently?

H: NUI interfaces is a better solution than GUI/WIMP interfaces in helping animators to work efficiently.

On User Experience: It is essential to explore how new technologies give an impact to animators in seeking for interfaces capabilities for the new development in animation.

RQ: Would animators be influenced by the emerging technologies in determining appropriate interfaces in order to enhance their experience?

H: Emerging technologies can influence animators in determining appropriate interfaces in order to enhance their experience.

It is believed that natural user interfaces in some way could improve usability in creating animation compared to the conventional GUI/WIMP interface. To address the assumption more specifically, we formulated hypotheses for each chapter to explain the different levels of usability issues in Chapter 4 and Chapter 5.

It is important to consider several terms that are used throughout this research: *hand gesture animation* refers to gesture-based interface using direct control of hand gestures without involving full-body gestural interaction, while VR animation refers to immersive-based interface that explores virtual reality environment. The word *creating animation and animating* indicates the process of animation involving user, 3D character, and the interface. The term 'user' and 'animator' are used interchangeably refers to the target group of this research who are among beginners. The term keyframe animation and windows-based animation are used synonymously describing GUI/WIMP interface.

1.4 Contribution of Knowledge

i) Development of Gesture-based Animation

Since the early years of animation, creating animation can be developed using various different techniques. The approaches to animation such as 2D animation, stop-motion, 3D computer animation have traditionally being used in making inanimate objects move. With the advancement of technology, NUI interfaces have become the trend and applied in various ways. Many researchers have endeavoured to develop techniques using the NUI approach that can improve the interaction between the user and virtual object, such as in Oshita et al., 2013, Heloir and Nunnari, 2013, Held et al., 2012, Chen et al., 2012, Leite and Orvalho, 2011, and Shiratori and Hodgins, 2008. I believe hand gesture animation could provide animators with a different way of experiencing animation. Based on the feedback from the interviews, most users found hand gesture an exciting technique to use in animation. They agreed that the method was not only simple and easy, but also helped them to spend less time creating animation.

ii) Beyond GUI/WIMP Interface of Keyframe Animation System

Our body is intelligent in that it has a set of innate senses that allowing us to interact with our surroundings. Our kinaesthetic sense is our sense of bodily awareness - of position, the effect of movement on muscles and joints that helps us to coordinate all the movements in our body. With the notion of direct interaction, hand gesture animation could support another, more interesting way of creating animation kinaesthetically. The technique allows learners to develop their sense of movement by intuitively manipulating a 3D character through using the movements of their own bodies through gestures control. In today's animation, hand gesture control could also be a way to fully utilise and take advantage of our body perceptions. What the animator feels and experiences could be directly expressed onto the 3D character. In this study, some participants became aware of feeling connected to the character and attentive to the effect of their movements on the character. Although the participants felt more responsive and directly involved using this technique, the technical limitations of the current state of the interface prevented the process of animation becoming totally effective, and created confusion because of unfamiliarity with its functions. This can be solved by identifying the problems raised by the participants and addressing those issues appropriately in order to enhance the kinaesthetic experience of creating animation.

1.5 Thesis Outline

This thesis is divided into seven chapters, each of which is described in the structure and chapters outline below:

Chapter 2: Literature Review

This chapter discusses previous work related to the development of this research. The literature reviewed is that considering the meaning of animation, grasping animation skills, and how the animator and acting can play an important role in producing animation. The key component for creating movement in animation, i.e. timing, is emphasised, as it is also one of the fundamental elements of Disney's 12 Principles of Animation. The literature then reviews the Natural User Interfaces (NUI) and discusses how interactive interface systems were introduced as animation techniques through GUI and NUI approaches in order to provide an overview of the techniques of animation.

Chapter 3: Interface Design and Prototyping Hand Gesture Animation

This chapter highlights the methods and practices that steered me to design a novel system of animation. The method encompasses long-term personal experience learning animation and how keyframe animation works, exploring body movement through acting, and investigating how motion-sensing devices could benefit the process of animating. This section also presents a special conversation with a puppeteer and the handling marionette manipulations that became the turning point in conceptualising gesture-based animation.

Chapter 4: A Usability Study for Gesture-based Interface

This chapter presents a study of the proposed interface design with participants. The user experiment conducted was to verify the functionality of the system. I evaluated the design by providing the prototype of the system alongside the keyframe animation technique. The study includes the effectiveness of the interface, and efficiency to see if the system was able to reduce the animating completion time.

Chapter 5: Quality of Animation Using Hand Gesture Interface

This chapter determines whether hand gesture animation provides the best result using this system for the animation work created. This chapter is an extension of the usability study that further demonstrates how far the hand gesture interaction technique is an appropriate one for animation in comparison to the keyframe technique.

Chapter 6: A Usability Study for Immersive-based Interface

This chapter investigates whether immersive-based animation provides the best result for animation. This chapter is an extension of the usability study that further demonstrates how far animation is used in VR environment in comparison to the keyframe technique.

Chapter 7: Conclusion

This chapter draws the threads of the research together, where the research questions and hypotheses are revisited to uncover the answers from the results. This chapter also concludes by looking into possible contributions and future work to further enhance the proposed NUI-based system in the field of computer animation.

2 Chapter 2

Literature Review

2.1 Overview

This chapter explores the important concepts involved in this research by reviewing the fundamental issues in creating animation and the relevant systems that commonly used to create animation. The literature review then moves on to the developments in the Natural User Interface (NUI) and its technological applications in various fields. Lastly, it reviews various NUI interfaces used in animation.

2.2 Frame-by-Frame: A Fundamental of Animation

There is no animation if there is no movement in any part of an object. Movement is the essential element to grasp in order to create animation. The word animation itself originates from the Latin word *animare*, which means ‘to give life to’ (Wells, P., 1998: 10). In fact, one of the widely acknowledged definitions is from the legendary independent animator in the 50’s, Norman McLaren. He explained,

> ‘Animation is not the art of drawing that moves but the art of movements that are drawn; What happens between each frame is much more important that what exists in each frame; Animation is therefore the art of manipulating the invisible interstices that lie between the frames’ (Furniss, 2007: 5).

McLaren strongly emphasizes the underlying aesthetic of animation, although he also describes the physical activity of a typical animation process. Similarly, Charles Solomon stresses that in animation ‘the illusion of motion is created, rather than recorded’ (quoted in Furniss, 2007: 5).

From the perspective of animation production, some practitioners highlight the technicality of how animation is made, which results in movement appearing to happen.

The technical view is also seen in Wells' definition that 'animation in practice is a film made by hand, frame-by-frame, providing an illusion of movement which has not been directly recorded in the conventional photographic sense' (Wells, 1998: 10).

Keyframe animation, principally, borrows the concept of film frame, whereby a sequence of photographic images (frames) are put together to produce the appearance of moving pictures. Animation uses a similar concept in its process. Frame-based animation can trace its origins in traditional drawn animation. The process is when a set of drawings– each of which represents a frame - are placed in a sequence. The function of timing appears only upon playing back the sequence of drawings. In terms of movement, timing is the manipulation of space between the action poses in the drawings. This means creating timing using the frame-based technique requires animators to know how to exploit 'the number and spacing' (Whitaker, H., and Halas, J., 1981: 46) in between the poses making up the action of a character.

As a general rule-of-thumb, for most frame-based animators, the common measurement of timing is through the understanding of how frames are constructed in one second of time. This is based on film rates of counting time, that is, 24 frames per second.

While stressing how crucial key frames are, whether in traditional or computer animation, Jones and Oliff point out that common problems for animators in computer animation when animating key frames is that the resultant 3D characters look 'spliney' [floating], 'mechanical', and have 'watery motion' (2007: 133). According to them, this is due to the fact that animators do not have full control of the tools featured in the software, and can't decide where best to place the key frames. They demonstrated the importance of using Graph Editor, so animators can engage in and achieve a snappy, cartoon-style of timing.

2.3 Animation and the Illusion of Movement

The basis to every animation is how movement works; however, moving creatures or beings in real time, in the physical world are unique and different to the movements of characters in the virtual world. The two worlds are differentiated by the existence of time; it is important to realize time is part of the physical world, whereas, time in animation is created by the animator through sequences of images. Thus, it is the animator's responsibility to take control of creating good timing for any given movement through animation. Without the correct placing of timing, movement can become meaningless, regardless of how much the viewer is aware of the object or character's motivation. Further, in creating movement, the importance of timing is also strongly emphasized in Disney's 12 Principles of Animation (see Figure 2.2, below) as necessary factors for good animation. According to Thomas and Johnston, 'neither acting nor attitude could be portrayed without paying very close attention to [t]iming.' (1981: 64). In *Timing for Animation*, Whitaker and Halas further point out that 'I[i]n nature, things do not just *move*', but timing 'gives *meaning* to movement' (*italics* in the original, 1981: 12).

As movement is the principal component of any animation process, some practitioners have explored how acting technique can contribute to the development of character animation. Walt Disney introduced this approach to his animators in the 1920's after his animation studio expanded to cater for mass production. Achieving 'believability' has always be the key aim for Disney animation (Thomas, F., and Johnston, O., 1981). With believability in mind, and having explored movement through acting over several years, Walt Disney and his animators devised a set of guidelines they called the 12 Principles of Animation (see Figure 2.1). It is a tool to help young animators produce good character animation. It is not merely about making the characters move, but the additional effort given to every detail of constructing movement so that it looks convincing.

The Disney's 12 Principles of Animation

1. **Squash and Stretch** – *Defining the rigidity and mass of an object by distorting its shape during an action;*
2. **Anticipation** – *The preparation for an action;*
3. **Staging** – *Presenting an idea so that it is unmistakably clear;*
4. **Straight Ahead Action and Pose-to-Pose Action** – *The two contrasting approaches to the creation of movement;*
5. **Follow Through and Overlapping Action** – *The termination of an action and establishing its relationship to the next action;*
6. **Slow In and Out** – *The spacing in between frames to achieve subtlety of timing and movement;*
7. **Arcs** – *The visual path of action for natural movement;*
8. **Secondary Action** – *The action of an object resulting from another action;*
9. **Timing** – *Spacing actions to define the weight and size of objects and the personality of characters;*

10. **Exaggeration** – *Accentuating the essence of an idea via the design and the action;*
11. **Appeal** – *Creating a design or an action that the audience enjoys watching;*
12. **Strong Drawing** – (not stated and emphasised in Lasseter, 1987).

Note: The explanations in *italics* are those of Lasseter (1987: 36)

Figure 2.1: Disney's 12 Principles of Animation

Disney's animation principles have become accepted by animators around the world up to today as an important instrument in animating characters. Although the principles were invented to fit classical drawn animation, they have been applied to various techniques, including 3D computer animation. Lasseter in his Siggraph article *Principles of Traditional Animation Applied to 3D Computer Animation*, examines the application of each of the principles to one of his earliest experimental 3D characters called Luxo Jr. (Lasseter, 1987). Animators, be they experts or novice learners, continue to explore and apply the animation principles in their animations striving to produce animation "something-like" Disney's characters. In recent years, when making animation became easier through the use of many different animation software packages such as Blender (Hess, R., 2011), 3DS Max (Lapidus, R., 2011), and Maya (Montgomery, L., 2012), practitioners to produced how-to-use handbooks demonstrating through step-by-step guidance how animation principles worked, together with the tools applications in the software.

2.4 Assimilating Animation

Some debates concerning the practice of learning animation centre round whether it should be taught within a formal education framework or self-taught to develop the talent and skills demanded by the animation industry. In the SIGGRAPH 2004 panel session, *3D Animation: Difficult or Impossible to Teach and Learn?* (2004), the discussion broadly revolved around teaching and learning computer animation. Industry practitioners like Jim Jagger, a Senior Animator working in the games industry, would look for more aesthetic values such as possessing skills related to timing, weight, acting and performance, in balance with technical aspects and skills. Of a similar opinion, Craig Slagel gave an acting lesson to his animators to improve their understanding of human facial expressions and movement for animator production. An educator like Jim McCambell is likely to claim computer animation needs to involve collaborative work across disciplines in higher learning institutions in order to stimulate creativity and reduce the time spent in teaching and learning only basic skills. Such a program exposes animation students to diverse disciplines to develop multi-skills and not confined to one area of expertise.

Ebert and Bailey demonstrated how their pedagogical model of computer animation is so successful by introducing two important elements: *interdisciplinary work* and *collaborative education* (Ebert and Bailey, 2000: 83). The model combines teamwork between teachers and students in the visual arts and the computer science departments. They believe the skill sets that the teachers and learners acquire in their respective disciplines can be imparted effectively through this dynamic collaboration. The structure of the model is rather generic as it involves all aspects of the technical inputs to the animation process, ranging from basic programming, rendering, composition, kinematics, dynamics, to animation basics that include timing and keyframing (ibid., 2000: 84). Taking another new interdisciplinary approach, Orr and Nord (2005) proposed music should be added to the computer animation teaching framework. In their model, a music course is included with computer animation course in which they anticipate to raise the level of productivity among the students. Involving students from both disciplines, means they can exchange work developed in their respective fields, and as a result, they found this collaboration has a positive effect on the quality and creativity of the students' work. Beside of dealing with the technicalities of production, students were able to improve their aural and visual aesthetic values.

Although McCracken (2006) highlighted the issues of the development of 3D computer animation in education and the marketability of the graduates, he also emphasised the big issue of the influence of technology on computer animation. At some point, according to McCracken, animation students today become very software oriented and they struggle to master the many technical features of 3D software within a limited timeframe during their courses, this can leave aside the importance of creative values. As a result, they spend too much time learning 3D software while the process of animation itself is very time consuming. An interesting aspect that McCracken pointed out was learning 3D animation has traditionally focused on demonstrating ideas in the form of '2D expression' (ibid.: 6) of visual arts. A 3D animation is a different art form involving 3 dimensional space, so that the object has mass and length rather than just appearing flat on a flat plane. Consequently, mentioned, learning 3D animation must be treated differently; strong emphasis should be placed on sculpturing an object in its physical form.

These approaches to learning computer animation are quite broad, taking facets from exposure to various areas and disciplines, while learning animation itself can be within two separate areas: 3D modelling and animation. In fact, animation has been long since been established as an academic discipline of study, with animation education per se unable to split into specialisation within different aspects of the field.

Learning animation by any means is about creating movement in any form of inanimate object. The ideal way to learn animation is not just by grasping the theory but more importantly, learning to apply it in practice. Looking at teaching animation as teaching the art of movement, Joel and Echevarria proposed a 'kinaesthetic exercise' (Joel and Echevarria, 2005) to their animation students. During this exercise, the students experimented by half of them repeatedly dropped a chosen object while the others observed by sketching out the bounciness, flipping, and distortion of the falling object (ibid., 2005). The use of an object like this is common practice among animators to examine its behaviour. From the kinaesthetic learning perspective, the learners explore by doing and observing the spontaneous action.

Some experienced practitioners encourage animators to have an understanding of the basic laws of physics as foundation principles, in order to provide a good sense of timing in creating animation. Moreover, the study of every moving object relates to the study of its dynamic properties. Webster (2005), and Whitaker and Halas (1981) suggest that animators follow Newton's Laws of Motion and take steps to apply them when creating animation. They stress the importance of inertia, acceleration, and action and reaction as at the essence of animation timing, and the animator must be able to understand their meanings. Similarly, Garcia points out that 'as a character animator, a basic understanding of mechanics and bio-mechanics is helpful' (2012: 1). He further proposed a set of principles, which he called the 'Principles of Animation Physics[2]' (*ibid*.: 1). Garcia's portrayal of such a system is similar to devising a 'physical script' in order to encourage animators to plan movement in advance, during the pre-production process, in a similar way to how Disney's Animation Principles are used.

[2] The Principles of Animation Physics proposed by Garcia consists of 1) Timing, Spacing, Scale; 2) Law of Inertia; 3) Momentum and Force; 4) Centre of Gravity; 5) Weight Gain and Loss; 6) Action-Reaction.

With some understanding of basic physics, animation timing can be perceived as the physical appearance of the animated character or object. As Lasseter observes, timing is ‘the speed of an action [that] defines how well the idea behind the action will read to an audience [as]…[i]t reflects the weight and size of an object, and can even carry emotional meaning.’ (1987: 37).

2.3 Animation, and Animator

Traditionally, since the golden age of Disney’s animation, animators in the field of animation art have explored how acting and performance can enhance the understanding of body movements. They believed that by getting animators involved in acting, they would be able to develop a physiological sense of every movement through the body in an action, including the character’s emotions, which could stimulate the imaginative mind. Looking from an actor’s performance point of view, Hooks (2003) suggests that it is important for animators to experience similar processes to stage actors, particularly for developing a character’s behavior, thinking, and interaction. He, however, adds that what makes acting for an animator different is ‘… she then must keep re-creating that same moment over and over again, […] while she captures it on the page or computer screen’ (Hooks, E., 2003: 5). Similarly, Kundert-Gibbs (2009) support the view that acting is essential for animators, claiming that ‘as an animator, you are basically doing the job of an actor– just very slowly’(Kundert-Gibbs, J., and Kundert-Gibbs, K., 2009: xiii). In *Action! Acting Lessons for CG Animators*, they provide an overview of how some renowned acting techniques such as the Stanislavski System, Commedia dell’Arte, and Laban, to name a few, can operate in animation. These explorative approaches to performing acting movements can then be represented in the characters in 3D by mapping real actions.

In a more specific approach, Bishko investigates the acting method through Laban Movement Analysis (LMA). She applied the components of LMA[3] specifically to character animation, hoping that it could assist animators in analyzing and producing ‘cartoon style’ movements in the frame-by-frame technique (Bishko, L., 2007). She asserted that bringing LMA into animation, ‘teaches us about the richness and

[3] Laban Movement Analysis (LMA) was introduced by Rudolf Laban. It is one of the acting methods extensively used for analyzing body movements. The approach is rather technical built upon: 1) 4 Basic Efforts of Space, Time, Weight, and Flow; and 2) 8 Effort Drives of Pressing, Punching, Wringing, Slashing, Gliding, Dabbing, Flicking, Floating.

complexity of communication through movement' (*ibid*.: 34). In addition, De Beer examined movement in character animation from the kinesics' (De Beer, A., 2009) point of view. He claimed not only is movement 'associated with the body, appreciably differentiated from movement as performance or as gesture, but also how movement itself can contribute to communication or meaning making' (*ibid*., 2009: 44).

2.5 From Traditional Method to Interactive Style of Animation

Animation is valued by its ability to create the art of movement as well as the process of using many different techniques. I have discussed how important the notion of movement-timing and learning is in animation. However, these perceptions are unable to bridge the gap between imagining and executing animation without the involvement and application of techniques. Furthermore, animation generally, in any form, relies heavily on how a technique is used as an instrument for manipulating the creation of animation.

In this section, I consider look from a technical point of view, how tools are used to bring the imagination to life. This section s traces back from a historical perspective, how animation evolved through various techniques in the traditional way until the era of computer animation.

2.6 Desktop-based Interactive Animation

In solving movement issues in 3D animation, some recent research into computer graphics has tended to consider various interface approaches to animate a 3D character. These systems are likely to cultivate more interactivity and responses using the evolving technologies that enable the representations of movement and timing to be based on the performance of the user in real time.

In 2012, Walther-Franks developed a drag-based system of transferring motion into 3D called *Dragimation* (Walther-Franks et al., 2012). This technique allows the user to leverage motion timing naturally through the actions being transferred from the fingers holding the pen onto a pen tablet, i.e Wacom Cintiq UX, as a tool for 'performing the timing' (ibid., 2012: 105) onto a trajectory curve (see Figure 2.2).

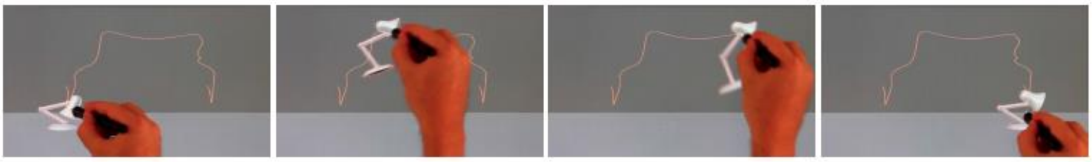


Figure 2.2: Walther-Frank's Dragimation technique

Similarly, Terra and Metoyer used a sketch-based as an alternative to the conventional keyframe settings (Terra and Metoyer, 2004, 2007). The technique requires the user to sketch a path, and 'keyframes are then distributed in time according to the acted motion' (Terra and Metoyer, 2007: 90) from the sketched path. On the other hand, the input value of speed of the hand is transferred while creating the path, and this will influence the movement timing transferred to the object (see Figure 2.3).

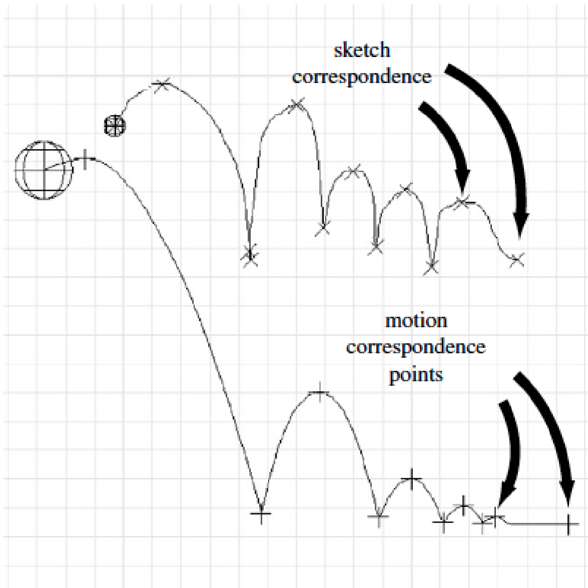


Figure 2.3: Terra and Metoyer's sketch-based performing timing technique

Likewise, Thorne developed *Motion Doodles*, a sketch-based technique to aid creating motion for 2D and 3D characters (Thorne et al., 2004). The user creates motion by directly sketching trajectory curves using gesture controls from their hand motion input data. The motion timing of the character will depend on the user's hand pressure while creating the paths.

While the drag and sketch based techniques emphasise recording real-time motion timing on to a trajectory path, Igarashi et al. (2005) developed a technique called *Spatial Keyframing*. In this process, the keyframes are controlled by changing the position of the preset control cursor to a desired point around the coordinate axes in 3D while creating poses for the character. The clutter of the frame-by-frame technique is replaced by changing the space in between the keyframes. Although it is not clearly explained how timing is generated, it is believed to be captured from real-time, based on how the user manipulates the control cursor.

In 2003, Popović et al. presented a 'motion sketch' (2003) from the user's hand gestures in real time projected onto a rigid-body simulation object technique in order to leverage motion timing. Prior to Popović, Laszlo et al. (2000) proposed an interface that enabled the user to interactively control the character using their intuition and experience of motion control directly applied onto the character. The motion controls are mapped from a moving mouse onto the selected joints of the character, which allows the user to use their hand gestures to create behaviour such as walking, jumping, shuffling and flipping. Popović and Laszlo's goal for manipulating character motion is similar to my goal of performing motion through hand gestures. However, their characters are based on physically simulated objects, which obey physical laws. Additionally, a conventional input device, such as a mouse, is used to delineate motion in their experiments.

In the late 90's, Sampath introduced a plugin created in Maya called NUKE (Sampath, 1999), which allows the manipulation of timing without using the time slider. Timing is automatically transferred and recorded on the timeline once the user has provided a certain amount of pressure with their hand while moving the mouse.

Nonetheless, through these interfaces, the input generally relies on the concept of "Windows/Icon/Menus/Pointer" (WIMP) interface devices, such as a mouse, keyboard and pen tablet, which the user's needs to hold in their hand. In addition, this affects the interaction between the physical world and the object in the virtual world, as users' hand movements are limited to working on a flat surface.

2.7 Animation and Natural User Interface

As technology evolves, computer interfaces change the way users interact with computers. Our activities with computers are becoming more embodied - through direct contact, press button etc. - than they used to be, and this provides natural control between the user and computer. Graphical User Interface (GUI) has dominated the way people interact with computers for decades, and NUI or Natural User Interface has increasingly been taking its place in recent years. It is the current emerging technology that has become trendy for many applications for different purposes, ranging from everyday activities to more advanced levels of interest. As the name implies, NUI exploits intuitive bodily interaction (Gillies and Kleinsmith, 2014: 2) by the user to interact with the computer systems rather than using graphical symbols and devices in WIMP-based (windows, icons, menus, pointing) interfaces as the intermediary form of interaction. In other words, NUI allows users to interact naturally with objects in the virtual world using their body parts as the source of communication. The notion of NUI interaction is to allow users to experience a 'real world' sense (Wigdor & Wixon, 2011: 9) of 'seamlessness' (ibid.: 43) with objects as though they were in the physical world. As Roger points out, "the naturalness [of NUI] refers to the way they exploit the everyday skills we have learned, such as talking, writing, gesturing, walking, and picking up objects" (Rogers et al., 2011: 215). Users don't need specialist training to use an interface. For instance, gesturing in NUI allows users to directly open, navigate and close applications instead of moving a cursor, pointing to an icon to select it, and clicking to open an application. This process requires an input device, such as computer mouse, in order to interact.

NUI interfaces have been applied in various fields, such as entertainment, architectural visualisation, engineering, education, and healthcare. While there are numerous types of interaction style, the emphasis here is on gesture-based and tangible interaction. Gesture-based interaction includes multi-touch, full-body, and mid-air hand gesture interaction styles.

The automotive industry has seen advancements in the driving experience. Pfeiffer developed a multi-touch steering wheel to provide better navigational interaction with entertainment while driving, compared to the conventional buttons (Pfeiffer et al., 2010). Innovations in microbiology can be traced in Liu's development of *MoClo Planner*, an interactive multi-touch interface to help scientists design complex biological structures (Liu et al., 2012). In music, Goh developed *MuSeeCol*, a system that allows two users to collaboratively create music (Goh et al., 2016). The system was designed in such a way that music is created with two people face each other interacting via a see-through panel of glass, and together composes music based on percussion and melody. The art of Japanese paper folding - *origami* - has evolved to another level that allows users to interact in virtual form. Chang developed a multi-touch origami simulator (Chang et al., 2009) that enables users to imitate similar hand gestures for folding techniques to traditional origami. Interestingly, in image manipulation techniques, Pfeuffer et al. produced a gaze-touch system, incorporating the element of gaze into a multi-touch interface. The application allows multi-touch and gaze to interact simultaneously on the same surface (Pfeuffer et al., 2014).

Much of the full-body interaction encourages users to actively interact using the entire body. Gerling developed a full-body interactive game for inactive older people to encourage them to move and be active (Gerling et al., 2012). The experiments were conducted among elderly people with different physical limitations in a nursing home care system. Using Microsoft Kinect allows users to plant flowers and interact with a virtual garden. The full-body control from Kinect also provides freedom of interactivity and reduces the tension of holding a handheld device. The users found the game satisfying as they played the games, moving their bodies' actively. In a study for special needs children, Mora-Guiard created *Lands of Fog*, a full-body games system to nurture children with autism and help them to cope with social interaction difficulties (Mora-Guiard et al., 2016). The game encourages children with autism to explore 'mysterious elements' (Ibid.) hidden in the space filled with fog. While playing, the children showed significant improvement in their behaviour and adaptability to new environments by displaying more friendly and cooperative attitudes. Another study stimulates creativity and explorative learning among young children. Paul introduced *Word Out*, a learning game that allows users to spell out and constructing words using body gestures (Paul et al., 2015). The game is not only entertaining but also promotes active mind-body activities in early development naturally, without the children having to engage with any handheld devices. Misumi's Game Action Motion Interactive Controller (GAMIC) (Misumi et al., 2011) allows users to control animation timing in real-time using full-body gesturing on Kinect and Wiimote. Full-body interaction is also well acknowledged as useful in music. Bernhardt and Robinson created an interface that enables music to be controlled through bodily expressions (Bernhardt and Robinson, 2008). The significant of the interface is that the emotional state of the user determines combinations of music produced. In another music-based interaction system, Fiebrink developed The Wekinator, a system that allows users to compose a live music through gesture controls (Fiebrink et al., 2010).

There are also gesture interactions in the medical field to aid the handling of health equipment efficiently. Kang (Kang et al., 2003) and Zeng (Zeng et al., 2012) developed a hand gesture assisted wheelchair to help disabled users steer with less effort. In the automotive industry, in contrast to the direct touch interface, May developed a mid-air hand gesture interface for navigating infotainment while driving (May et al., 2014). Nestorov investigated the uses of touchless interactions in medical imaging that could benefit surgeons and radiologists (Nestorov et al., 2016).

Many researchers have studied different NUI applications in various fields. Understanding the potential of gesture interaction can improve the conventional workflow system. An increasing number of researchers into computer animation aim to improve user/character interactivity while animating.

2.8 Gesture-based Animation

Earlier in this chapter, I discussed how movement-timing is crucial for creating animation. The technique of animation should evolve together with the technologies that could provide different dimension for the craft. I argue that the process of creating animation could involve interaction beyond using icons and a mouse alone. The animation technique of manipulation can be directly controlled and embodied through the user's bodily experience. It focuses on creating movement-timing based on the user's intuitive perception of real time. The purpose of such direct interaction is to eliminate the tediousness and laborious process of keyframe animation.

Much of the research into character animation began by looking at direct manipulation in a different way, by involving motion-sensing devices such as Microsoft Xbox Kinect and Nintendo Wiimote, which were used widely in the video games industry. Utilising both these devices in 3D character animation have their purposes; to reduce the high maintenance cost of the motion capture system as well as seek a more user-friendly interface for non-experts in the system. Leite and Orvalho proposed an inexpensive animating system using Xbox Kinect to overcome the common difficulties of keyframe animation of 2D and 3D characters. They called it 'digital puppetry' (Leite and Orvalho, 2011), and referred to the 'virtual marionette' (Leite, 2012) when they experimented with a 2D and 3D character interacting with human body movements in real time as a source of direct control over the character's body's performance. Although this technique is effectively 'affordable', 'intuitive', and 'user-friendly' (ibid.: 2011) for both novice users and animators, the constraints of the "digital marionette puppetry” as they claim to mimicking puppets, are that the digital puppets have to replicate realistic human body movements, while a “marionette” itself has its own style for expressing its movements, control and stylisation. Meanwhile, Held et al. (2012) developed a technique that enables users to animate using 3D objects in their physical forms, such as toys and puppets, while Kinect is used to capture the process (Figure 2.4). The puppetry-like handholding of the objects allows the motion and timing of the object to be captured directly when the user performs the actions. Although the technique is applicable to character animation, the constraints limit the inflexibility of the object. Nonetheless, this technique uses kinaesthetic responses from the user.

Figure 2.4: A handhold toy-like puppetry interface by Held and colleagues

An interesting technique for creating character animation using Kinect can also be found in Chen’s work (Chen et al., 2012). He developed the ‘KinÊtre’ system (Figure 2.5), which enables non-human objects to take control of anthropomorphic manipulation spontaneously performed by the user. While Kinect captures the physicality of the object, the user’s body skeleton is also rigged and tracked directly to the object in real time.

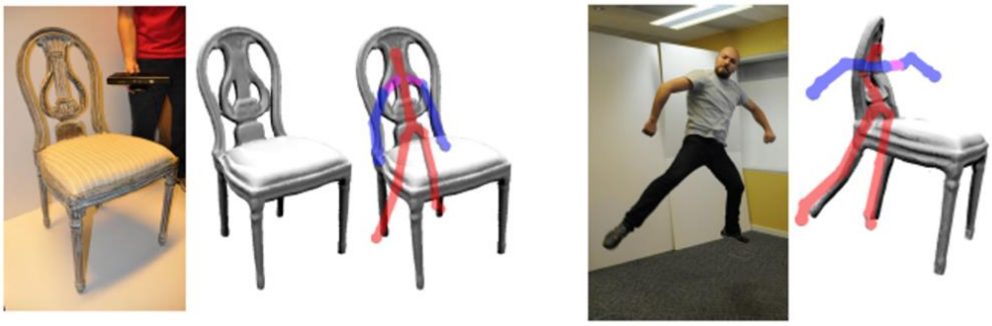


Figure 2.5: Chen’s KinÊtre system anthropomorphising objects

While Kinect has made its place among researchers exploring its application in computer [character] animation, an accelerometer-based device such as Wiimote is also attracting the interest of researchers investigating its potential. Using Wiimote as the controller, Shiratori and Hodgins (2008) developed a technique allowing motion to be leveraged from the user's body gestures by holding the device in their hands or attached to any part of their body in order to interact with the locomotion of a 3D character based on the laws of physics (Figure 2.6). The character reacts in real time according to how the user manoeuvres the device by transferring it from one part of the body to another and rotating their wrists, arms and legs at different speeds (ibid., 2008: 123:6). However, as it is a physics-based simulated character, the movements are pre-generated before the animation.

Figure 2.6: Shiratori's Wiimote technique of controlling a simulated character

Another technique that uses a motion-sensing device, which is becoming widespread and worth discussing, is Leap Motion. The unique thing about this device is that it allows users to directly control information in the computer by using their bare hands and fingers without the need to grab and hold onto any device or put on any wearable computer devices. By placing the simple device in front of the user, the hands then play their role in mid-air space, above the device. As the device tracks hands movement and gestures in real time, it is unrestricted and can be used on any form of surface, giving maximum freedom and flexibility to the controlling system. This device was released in 2013 and has attracted many developers and researchers- including myself- to explore its potential for application in computer [character] animation. In the same year, a software developer[4] developed a Leap Motion plugin[5] for Autodesk Maya (version 2014). The plugin, though somewhat basic, not only enables the Maya user to move the object in 3D but also to model and shape objects as naturally as they are manipulated in the real world. As mentioned, the standard process of animating characters using 3D animation software is rather complicated, Maya-Leap Motion plugin allows the user to control the 3D character spontaneously, like digital puppetry. As a basic plugin, its functions are still limited; the 3D animation of the character cannot be recorded anywhere in the software. The controls are restricted to thumb and index finger gestures. Inspired by the traditional marionette puppetry controller, Oshita et al. (2013) proposed a manipulation technique using hand and finger gestures to animate virtual characters (Figure 2.7).

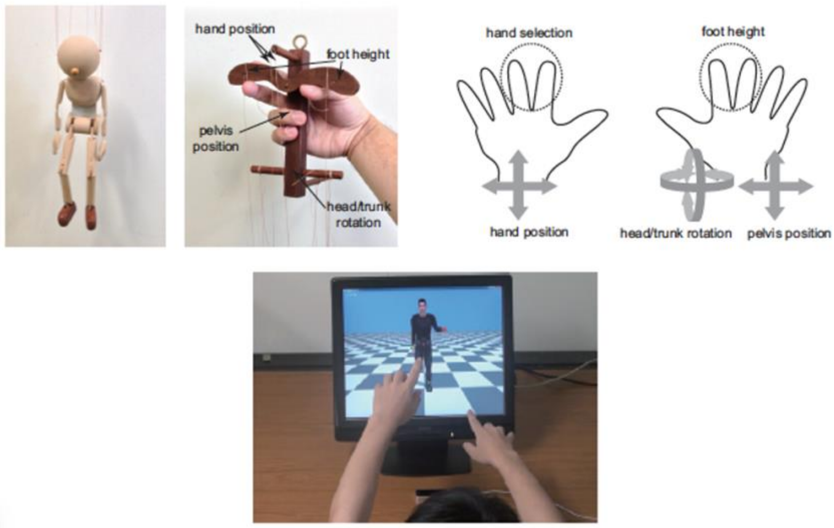


Figure 2.7: Oshita's system of marionette puppetry-inspired hand manipulation

Heloir and Nunnari developed an intuitive interface specifically for hearing-impaired people to create animation. Combining Leap Motion and Kinect, they aimed to provide such people with 'new concepts, invent new signs and populate dictionaries [of] …Sign Language linguistics' (Heloir and Nunnari, 2013). Although this interface is designed for a target group, utilising sign language gestures can also be beneficial in the public domain as it encourages people to use signs and would be able to improve

[4] Stephane Bersot. Source: http://www.stephanebersot.com

[5] The information about the plugin created by Stephane Bersot can be found and downloaded from the Autodesk website. Source: http://area.autodesk.com/MayaLeapPlugin

communication with the hearing-impaired community. This interface has a similar purpose to my research when it comes to resolving the complexity of the animation process, by allowing 'space-time constraint edit and interactive performance capture recording' (ibid.) intuitively.

2.9 Summary

This chapter argued that animation is not only a technique for making inanimate object move, but is also empowering for creating a better interactive system. Combining the domain of animation and interactivity can be seen as a system that progressively transforms isolated processes into more intuitive problem-solving techniques. This chapter established the conceptual bases of animation and interactivity, which will assist the next chapter to demonstrate the concept in practice, which later on leads to the design of an NUI-based interface for animation.

3 Chapter 3

Reflective Practices, Interaction Design, and Prototyping Hand Gesture Animation

3.1 Overview

This chapter presents the practices and methods applied in this research. It is divided into two parts in which the first part is based on a self-reflective study using keyframe animation and the understanding of acting technique to create animation. In order to acquire a sense of movement between the self and a 3D character, the concept of interaction from the marionette manipulation technique was used. The second part is the exploration with technologies and interaction design part, which involved the study of devices, participatory design, and interface developments. From the development of the second part, next phase is the evaluation of which the proposed system is tested with users for usability investigation in Chapter 4 and Chapter 5.

3.2 PART 1: REFLECTIVE PRACTICES

In seeking to represent bodily movements in real time for character animation, the techniques and tests that I carried out along the way had a big impact on this research project. Moreover, the main issue of this research was based on my previous experience as a learner of animation and a teacher of animation to novice learners. Some experience from several years ago made a distinct contribution to getting the development of this research started. I describe the practices that were carried out in this research as ‘reflective practice’ (Gray and Malins, 2004: 22).

3.2.1 Keyframe

Some experienced animators claim that drawn animation is the best method to understand how frames work in animation. They assert that the drawn animation technique should be fundamental to animation, especially for novice learners, before taking steps into other types of animation technique. This is because drawn animation allows learners to observe actions and poses through a sequence of drawings. Through drawn animation, actions are broken down into key stages by making drawings of them, and then of the steps in-between the key stages.

The understanding of *frame* in animation derives from what was learned about frame rates from video production. Thus the concept of 24-frames-per-second film rate has become a general rule-of-thumb for animators at the start of any animation process. In addition, setting keyframe norm as 24 frames-per second it is much easier to grasp the concept that *the more frames, the slower the movement* and *fewer frames make the movement faster*. This concept enables the animator to anticipate how to place and give enough space in between the keyframes to provide the right movement-timing for 3D characters.

3.2.2 Keyframing Process

Keyframing is a time-consuming process. It is difficult to determine how many frames are required to create a particular movement in 3D. A typical keyframe animation can be explained through the simple diagram below (Figure 3.1). The process can be quite complex with several repetitive actions in the process, especially when selecting parts of the subject's body to be animated and assigning keyframes on the timeline.

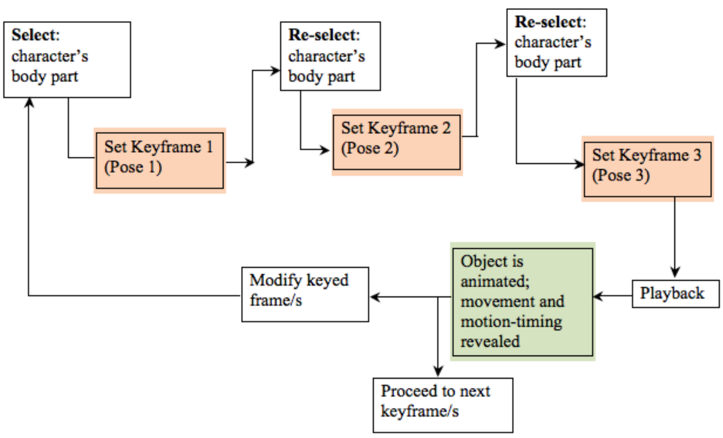


Figure 3.1: A typical process of keyframe animation

I refer to Figure 3.2, below, to describe the process in an actual setting in Maya. The character is fully rigged complete with IK handles and positioned in a T-pose. The particular part that the animator wants to move is selected. In the example in Figure 3.2, the aim is to move the character's left hand up and down to tap his chest. At this point, by selecting the IK handle on the character's wrist at frame 1 on the timeline, the first keyframe for the first pose of the hand (Figure 3.2 (a)) is selected. The IK handle is now moved vertically by dragging the Move tool on Y-axis, to move to frame 4 and assign another keyframe (Figure 3.2 (b)).

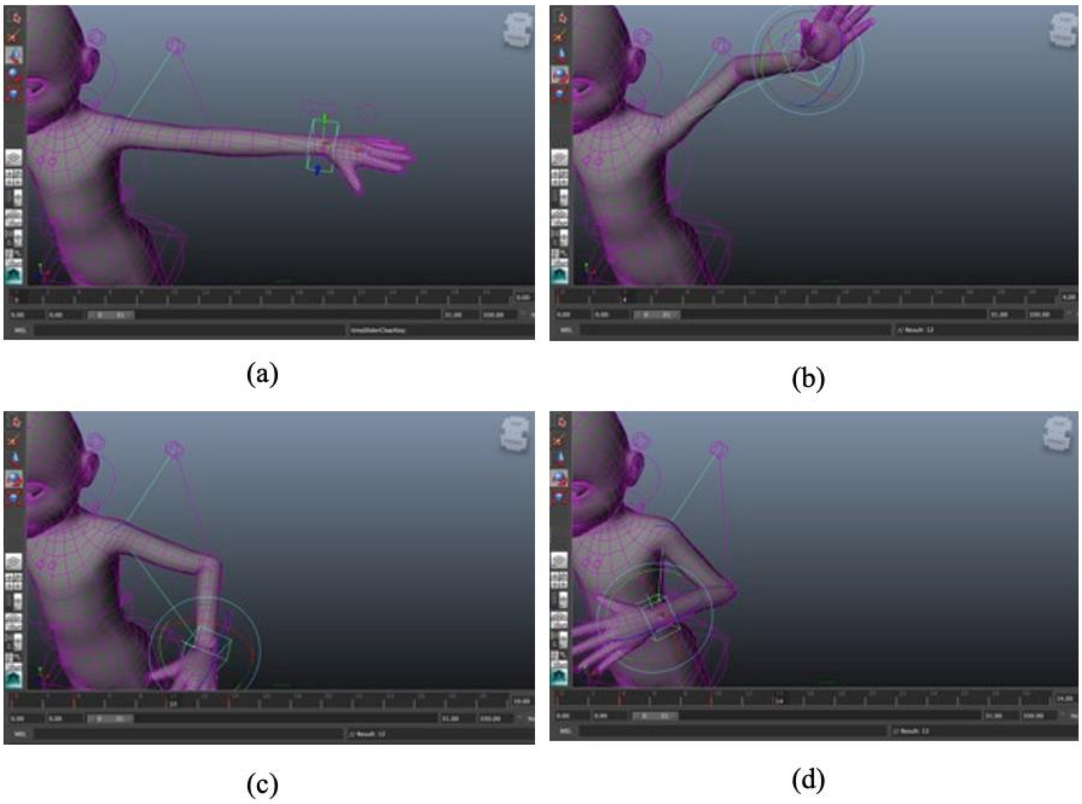


Figure 3.2: Assigning keyframes to each of the movement made

Then, at frame 10, the IK handle is dragged downwards and assigned another keyframe (Figure 3.2 (c)). To place another keyframe at frame 14, the IK handle is moved again on the X-axis towards the character's chest (Figure 3.2 (d)). In 3D animation, when keyframes are assigned at a specified position, the inbetweens are automatically interpolated by the computer. If it is necessary to see the outcome of the keyed frames, the animator can playback and see the result of the animation and can carry on with the animation process if satisfied with the position of the keyframes and provided the timing of the movement is appropriate. If not, the animator returns to the incorrectly keyed frame and amends it accordingly. The process goes on in loops to review and amend the keyframes as necessary.

3.2.3 Character Animation

It is common to see animated characters with complete limbs and features that imitate human or animal behaviour. Nevertheless, I am of the opinion that the perception of "character" is not limited to two or four legged creatures but can be applied to any kind of object, including those that do not possess limbs on a body. It is important to know that animation allows the illusion of life or illogical life that is unachievable in the real life to be created. For example, the animator can provide "life" to the most basic primitive shapes such as cylinders shape, a box or a sphere without having to add additional limbs or facial features to it. The audience can understand a character by how it communicates through body gestures or movements that impersonate human behaviour and characteristics. Character animation is also about giving behaviour to an object, which reflects its mental and emotion states. Through my observation, one classic example of learning how to give *character* is through animating a bouncing ball[6].

[6] This bouncing ball exercise was done in May 2010 during a 5-day course & workshop, *Train-the-Trainer Programme: Principles of Animation*, organised by Red Turtle Animation Studios Sdn Bhd, at the Malaysia Animation and Creative Content Centre (MAC3), Multimedia Development Corporation (MDeC), Cyberjaya, Malaysia. The Train-the-Trainer series of workshops were coached by professional animators in the industry for the academics who teach animation in higher learning institutions across Malaysia. It is aimed to improve the academia-industry linkage.

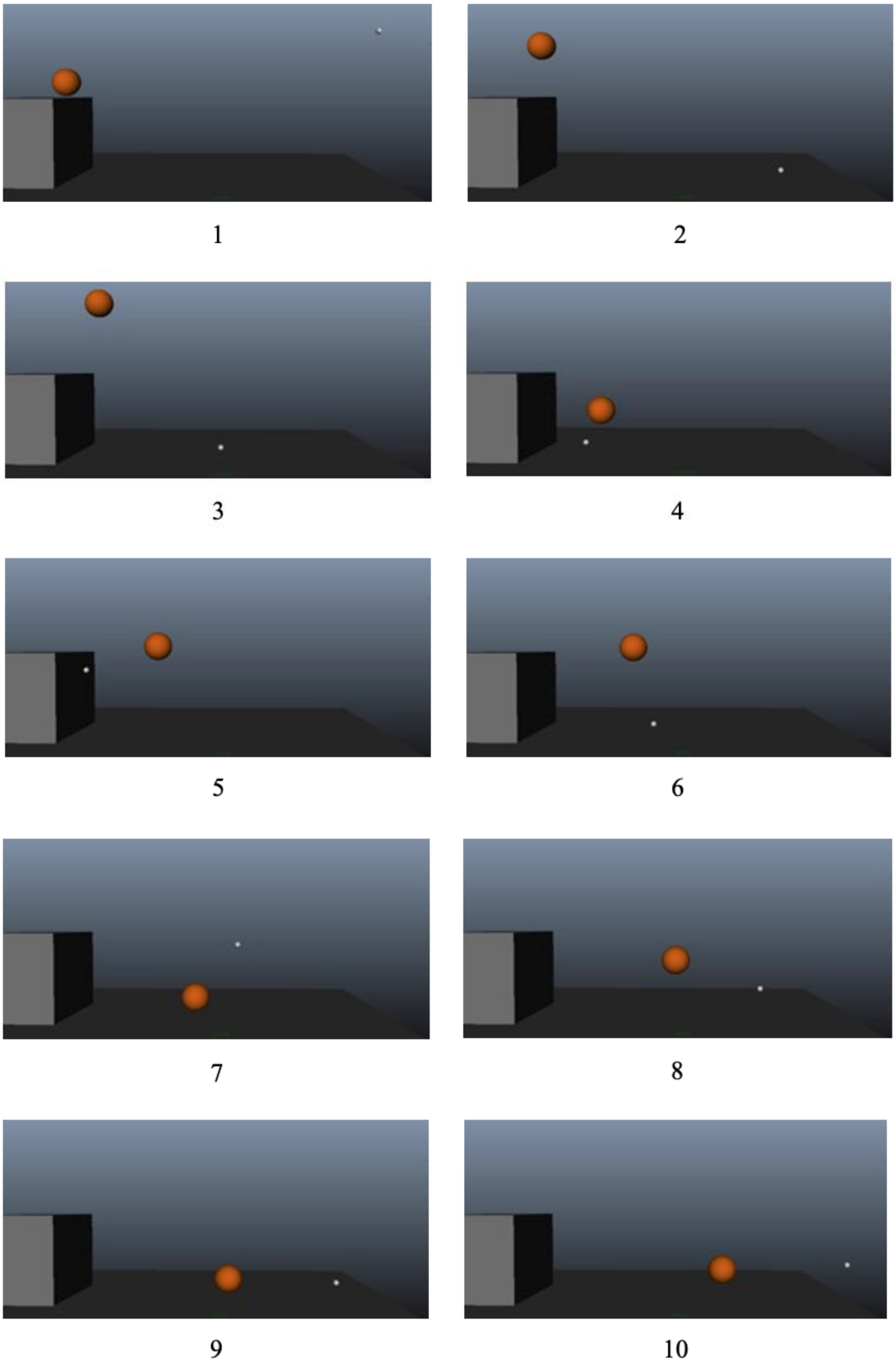


Figure 3.3: Bouncing ball exercise between a basketball and a ping-pong ball

Animating a bouncing ball (see Figure 3.3) is a fundamental exercise for understanding how to create animation, and has been traditionally practiced by most animators for many years. However, animating a bouncing ball is more than merely making it move up and down and add bounciness to it. Animating a bouncing ball describes the basic physics of gravity, timing, weight, liveliness, and the elasticity of a ball. Different types of ball produce different sets of behaviour depending on their form, size and weight. For example, if we were asked to play with a ping-pong ball, a rubber ball (tennis ball or basketball), and a bowling ball, we would need to observe the basic elements of physics such as trajectory, acceleration and deceleration, velocity, energy, and the force applied to the ball. This includes noticing how each type of ball bounces, rotates in the air, rolls and reacts when it hits the ground, how much height the ball can reach, its steepness gradient and how much the energy decreases as its bounciness gradually declines until it comes to a complete stop. The behaviour of the ball is also affected by how much force is put into the ball when throwing it. Real-life experience and observations are then used in the process of animating a bouncing ball in 3D. In 3D, the practical experience has to be separate into a linear (2 dimensional) sequence. Due to the different attributes of weight, size and material between a basketball and a ping-pong ball, in animation, it is necessary to distinguish how to arrange the speed, trajectory, and timing to replicate the original characteristic of each type of ball and make them believable.

Similar ideation to the bouncing ball exercise is applied when animating two or four-legged characters. Although animating a ball and an object with limbs is seen as a whole, one-piece object of animation, animating objects with limbs involves dealing with the different kinds of joints that connect the limbs to the body (Figure 3.4)[7].

[7] This character animation was modeled in June 2010 during a 10-day course & workshop, *Train-the-Trainer Programme: 3D Character Modelling for Animation Production*, organised by Animonsta Sdn Bhd, at the Malaysia Animation and Creative Content Centre (MAC3), Multimedia Development Corporation (MDeC), Cyberjaya, Malaysia. The Train-the-Trainer series of workshops were coached by professional animators in the industry for the academics who teach animation in higher learning institutions across Malaysia. It is aimed to improve the academia-industry linkage.

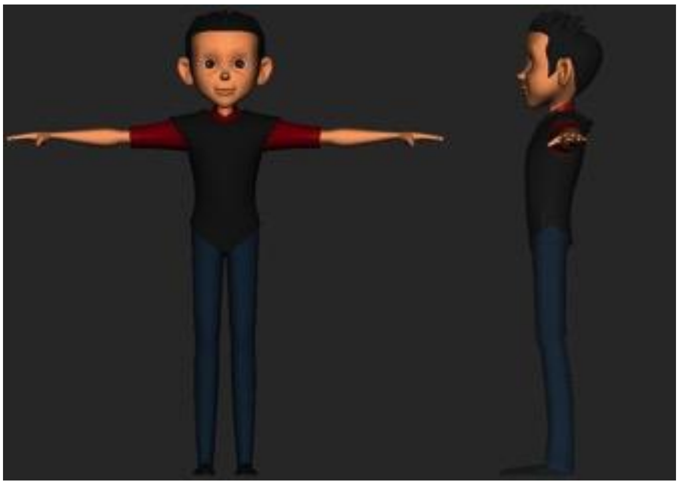


Figure 3.4: A full-figure character animation

Animating a full-figure character is hard work and time consuming due to the many different joints and body parts, each of which may play its role in the animation. When many adjoining body parts are involved, the tendency is for animation to look mechanical. This is high often to the unidentified position of the selected part of the body to be in action, and vague decisions about where to insert the keyframe. As a result, the movements appear unrealistic when the movements of the character were played back on the timeline. The movements seemed to float and it is rather disturbing when the actions of a character are not bound by the laws of physics. In the *Train the Trainer* workshop (2010), the participants were unable to compute how to achieve a cartoon-like *snappy* effective. The next section investigates the principles of animation, which aid the animation process and the details of how to go about creating an animation.

3.2.4 The Disney's Principles of Animation[8]

The Disney animation principles have become the main guidelines for learning how to overcome animation problems, especially getting the correct timing to overcome floating movements and to present *believable* movements, as always emphasised by experienced animators. *Believable* in this sense does not mean looking realistic as in the real life. Rather, the expression believable, used since the Walt Disney era, means

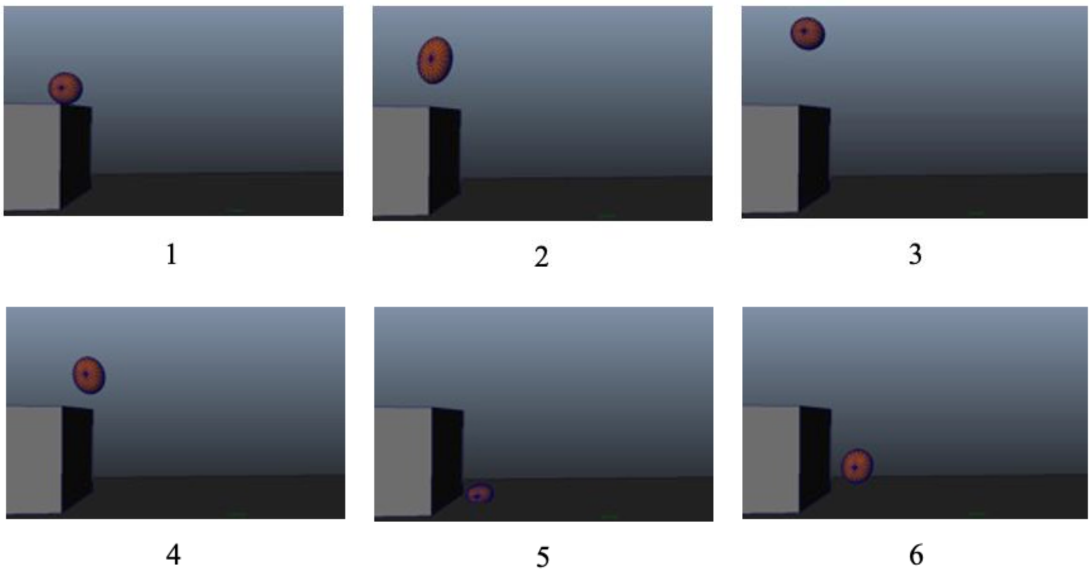
[8] The 12 Principles of Animation consist of 1) Squash and Stretch, 2) Timing, 3) Anticipation, 4) Staging, 5) Follow Through and Overlapping Action, 6) Straight Ahead Action and Pose-to-Pose Action, 7) Slow In and Out, 8) Arcs, 9) Exaggeration, 10) Secondary Action, 11) Secondary Action, 12) Solid Drawing. The principles are not necessarily in any particular order.

to avoid creating meaningless character behaviour while expressing an action. As explained in the literature review, these highly regarded principles were put together after years of observation and analysing movements and actions to achieve convincing and dynamic animated characters. These observations and analyses have become the core principles and guidelines for animators to learn traditional 2D animation, but later were applied to other forms of animation, including computer animation.

The first steps in learning animation involve exploring and applying the animation principles to the animation task. The principles most emphasised are squash and stretch, timing and exaggeration:

1) Squash and Stretch

Lasseter (1987) considered squash and stretch as the most important principles in animation. Squash and stretch are used to enhance the elasticity, flexibility and to add natural appearance and to the animated object so that it will not appear too rigid. The muscles on the human or animal body are the best reference for understanding how squash and stretch work. Walt Disney brought the squash stretch principles into animation after observing how the human body moves.



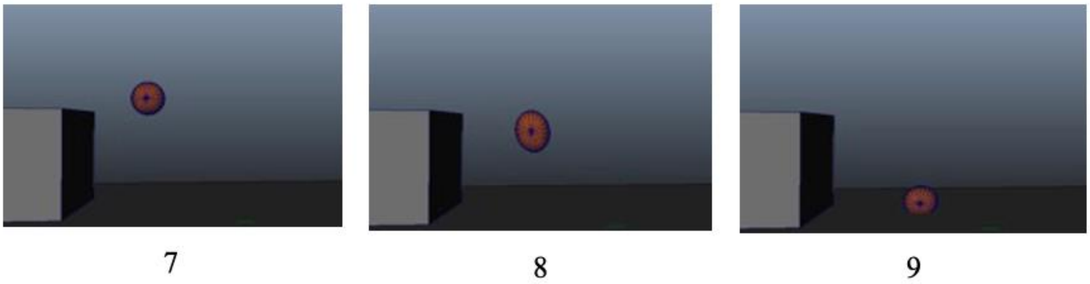


Figure 3.5: Squash and Stretch applied to a ball

The above example (Figure 3.5) shows freeze frames of the movements of a rubber ball as it bounces. When the ball accelerates on its bounce upward, the animator stretches the ball as soon as it lifts off the ground (2). As the ball reaches its highest peak, it starts to squash and the amount of stretch is reduced until it goes back to its original shape (3). On its way down again, the ball stretches (4) and is squashed as it hits the ground (5). The process continues (5-8), as the ball's momentum is reduced until it comes to a complete stop. The process is rather time-consuming, as keyframes have to be assigned each time the ball moves to indicate squash and stretch. Carrying out this exercise provides a basic understanding of how gravity works, which is important to make sense of the animation. A similar process applies when squash and stretch principles are applied to two or four-legged characters' adjoining body parts.

Creating squash and stretch, however, still needs to keep to the appropriate timing, so that the frames are distributed appropriately to avoid the movement looking stiff.

2) Timing

Although squash and stretch are emphasized as highly significant principles, I argue that timing should be given priority in animation, above any other principle. Timing applies to almost all animation, even while creating using the squash and stretch, or ease-in and ease-out principles. When animating objects it is necessary to make sure that the spacing between the frames is not equal. If it is, the movement can appear quite mechanical and monotonous. The example below shows an attempt to animate a bouncing ball (Figure 3.6). The first frame at 0 is the first keyframe. Then, as the ball moves up, the next keyframe is frame 8, leaving 8 gaps for in-betweens. After frame 8, the next keyframe is at frame 16, with the ball on the ground, leaving several gaps for inbetweens. The movement timing in this scenario suggests slower movement as the ball accelerates upwards against gravity and a slightly faster one as it falls downwards. As the ball gradually loses momentum, the keyframes need to be much closer to each other, leaving fewer in-betweens. As a result, the movement-timing gives faster and narrower gaps in the bounciness.

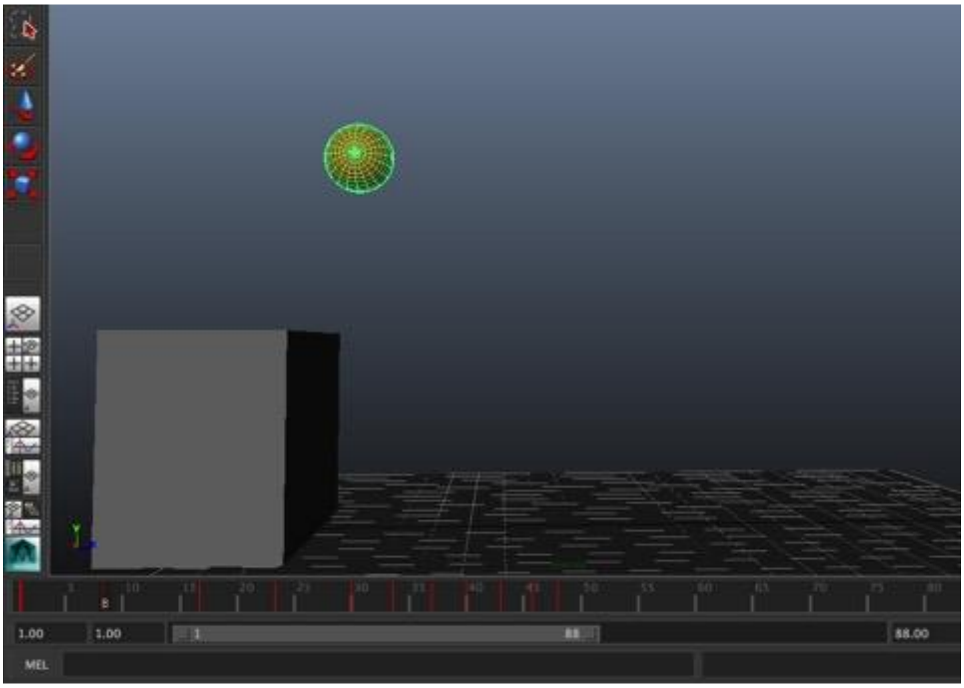


Figure 3.6: Timing created on a timeline in 3D software

The above understanding of movement-timing is based on the basic concept of timing (Williams, 2009). From the perspective of a traditional 2D drawn animation, he pointed out that timing is about how space is distributed between the frames (Figure 3.7). In his example, he visualised how a spinning coin would move from one end to the other end of a table. He broke up the motion of the coin into outline drawings to depict the speed of the coin. As the coin began to accelerate at the start, the spacing is a lot closer, to suggest quick movement. The coin slows down when it reaches the middle point of its path and the spacing is shown by each becoming slightly farther apart from the one before. However, the space between the frames gradually becomes less and faster as the coin decelerates and moves towards a complete stop. In this case, the spacing between the frames increasingly becomes closer.

Figure 3.7: Richard William's concept on timing and spacing

Timing in animation is commonly portrayed in two different contexts; 1) from a technical point of view, timing is part of creating time, which entirely depends on how space is organised through the separation of frames on the timeline, and 2) from an aesthetic perspective, timing is a way of communicating a particular movement through the actions of the character. I argue that movement-timing should be seen as a single, coherent embodied element.

3.2.5 Evaluation

Keyframe animation is a technique which offers full control over every movement and the freedom to manipulate the animated object beyond what real life can offer while still creating the illusion of animated life. Keyframe animation is also a unique type of art for creating movement that appears to be formed from series of images that were put together.

However, the keyframe animation process is very complex to deal with. Movement and time[ing] are its core functions, achieved through assigning keyframes. However, this process can be rather messy and repetitive, as the results cannot immediately be seen. The animator needs to repeatedly go back and forth to adjust the keyframes and play back the animation to get the desired movement-timing. Keyframe animation somehow has separated the animator from the 3D character's movements. To reconnect the animator and the character, some have suggested that body movement exercises can help the animator get the *feel* of the character's movements and timing.

According to some, the key to understanding how to produce character animation is to possess a *sense of performance* in oneself. As discussed in the literature review, many experienced animators encourage young animators to acquire acting skills in order to produce good character animation. They claim that a sense of performance must be achieved through proper acting coaching so that body movement can be understood and more believable character animation created.

This notion brings me to further investigate the relationships between keyframe animation, timing, body movements, acting techniques and what constitute the formation of a *sense of performance*. This is the starting point, where I began to make a leap forward by bringing this idea into this practice-based PhD research. I started with the initial idea of exploring the aspects of acting performance, which use body movements and also analysing the actions, and voices, which build a convincing animated character and its role. I also aimed to map the functionality of animation principles as part of the acting component. The study concerns not only physical action and movement but also how the internal development of feelings, thinking, and mood affect the how the body moves.

3.3 'Acting for Animator': A Method for Understanding Body Movement

Some animation experts claim animation should be grounded in the ability to tell stories. It is certainly true that animation is a medium of narrative that enables one to express what the characters think and feel about something. Nonetheless, stories can be told in many ways, one of which is through body movement. Many experienced animators who are directly involved in the process of making animation, emphasise the importance of grasping an understanding of body movement. Animators dealing with animating cartoon and/or virtual characters need to understand the motivations that drive the actions of the animated characters. Furthermore, body movement is believed to be the consequence of our inner feelings and thinking, which leads to something that we put into action, based on how we respond to everyday activities. Fundamentally, the job of an animator is often associated with how real actors imitate someone else for use in their acting. This supports the claim made by Wells that '[an] animator must essentially use the techniques employed by the actor to project the specificities of character through the mechanistic process of the animation itself' (Wells, 1998: 104).

Seeing the acting process as the connection between the animator and the actor, Kundert-Gibbs (2009) asserts that, 'as an animator, you are basically doing the job of an actor – just very slowly. You are creating a living, breathing character that tells a story, shares an experience, and moves an audience'.

Since Disney began to produce character-oriented animation, acting has continuously been part of the practice, as every action must come with emotion. The animators are taught a range of expressive emotions which communicate not just laughter and sympathy, happiness and sadness but also an extensive range of feelings such as hate, jealousy, fear and love (Thomas & Johnston, 1981).

Due to this concern, some animation practitioners have formalised the need for animators to learn acting skills in order to understand the inner and physical expressions which reveal what a character is about.

3.3.1 Experiencing Moving Bodies as Method

This research, originally, was motivated by the idea mentioned above, of how acting should guide animators and how animators can be perceived as actors in creating their animated characters, especially in dealing with keyframe animation. The prominent theatre director and actor, Constantin Stanislavski, proposed a set of essential skills for training actors in his first book *An Actor Prepares*. Some believe that similar training should apply to animators. To investigate the role of acting in relation to keyframe animation, I took part in what it can be termed *the animator prepares* training, alluding to from Stanislavski's idea. I explored body movement through several acting-related practices as part of my seeking answers for this research; among these were:

1) The *Action Theater*™ Course

The Action Theater Course ran from October–December 2011, a 10-week acting course with Kate Hilder- a certified practitioner and advanced teacher for Action Theatre in London.

The Action Theater session was very focused on training stage performers as most of the attendees came from stage acting and dance backgrounds. Kate Hilder, the course leader, also used some of the training lessons from Ruth Zaporah's book, *Action Theater: The Improvisation of Presence*. The fundamentals behind Action Theatre focus on three understandings associated with the body. These are: 'energy and tension', feeling and imagination', and 'ourselves […] inside out' (Zaporah, 1995: 29). However, it is interesting that in Action Theater, the word *character* (Ibid: 29) is not the central focus of the training. The objective is to give the performer the freedom to create their presence in the space and time. The movement drills performed each week were based on different themes. I shall not describe all the thematic drills but select a few which are relevant to my study.

i) Form

To illustrate this, we worked in pairs following our partners actions, but we each performed at a different pace and rhythm. Body movement and gestures alone were used in this exercise, with no use of voice. One person took the role of leader and his/her partner was the Follower. The Leader would walk, run, at different speeds, and every now and then would accelerate, decelerate and stop moving to hold different poses. The Follower did the same thing, copying the Leader’s actions. We took note of what the other was doing and tried to be aware of his/her inner thoughts that had been put into action. In another exercise, the Leader and Follower would interrupt each other and move at different speeds.

This exercise describes the collaborative elements of form, which, in Action Theater, are made up of ‘time, space, shape and dynamics’ (Zaporah, 1995: 6). The exercise is practised early in the course to introduce the basic components of movement to illustrate how to become responsive to the timing and spacing created during movement to produce (as actors or animators) lifelike forms of action.

ii) Voice and Action

This exercise combined voice and action with movement. The exercise had two stages: group work and pair work. The pairs were made up of a Sounder/Speaker and a Mover. The Sounder made sounds or told stories using different pitches and tones. The Mover performed actions and moved around the space by interpreting the voice or sounds. This gave the participants the freedom, first in groups, then in pairs, to create and explore the various lines and shapes the body can make in space.

The exercise illustrated the importance of sounds to the movement of the body and how we react to the different volumes and tones of sounds. The story or sounds created by the Sounder's voice affected the way Mover reacted. In a way, the Movers tried to encapsulate the sound within their body movement experience to create appropriate actions. Everyone became aware of every limb that moved, with the dynamics of the voice or sound in space.

iii) Imagination

The body and mind interact. They cannot be separated or made to work individually. In class, we further explored our body movements by using more imagination and being inventive in our actions. In one exercise, we were required to observe the natural phenomena that surround us. As we imagined falling leaves, rock, mud, lightning, and wind, we acted out each phenomenon by providing actions to indicate its attributes. The manifestation of its shape, weight and timing were explored by moving in space. We endeavoured to embody the strength and pressure of each by communicating with the internal idea of it and externally, pretending being to be the object ourselves. We used our body-mind relationships to be aware of every part of the body, allowing it to explore how lightly a leaf travels in the air, how heavy a rock rolling on the ground is, and how one would be dragged down by thick mud.

iv) Composition

We combined the actions together as a whole, either with just our own physical movements or with a partner to form a more complete meaning. It is difficult to convey meaning when a single element works on its own. In one of the exercises, we explored body imitation or what Action Theatre calls 'mirroring'. We work in pairs, a Leader and a Follower. The Leader simply created a movement, expression or an attitude out of his/her own imagination, and the Follower imitated the actions of the Leader. The imitation requires observing and identifying each body movement made by the Leader and its timing to create an identical form. What the Follower sees the Leader performing is what s/he will copy in his/her own form. In this way, the Follower endeavours to experience a similar energy to that of his/her partner. Leader and Follower unite together to make a whole performance, by learning to act and react, anticipate, and embrace their actions.

2) Series of Acting for Animator Workshops

Series of *Acting for Animators Workshops* with Sarah Perry[9] of Shape in Motion:

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[9] Sarah Perry professionally trained as an actor in1998 and opened *Shape in Motion* in 2010. Besides her various movement coaching services, she also became enthusiastic about the visual effects industry in 2008, and has been training acting and movement for animators in London. Source: www.shapesinmotion.com

- *Acting & Movement for Animators Workshop*, MovingArtBase Studio, London, 16 October 2011;
- *Acting through Improvisation for Animators Workshop*, MovingArtBase London, 27 November 2011;
- *Facial Expressions and Mouth Movements Workshop*, MovingArtBase London, 8 January 2012.

I attended three workshops in the series *Acting for Animators Workshops*. However, I shall discuss the *Acting and Movement for Animators* and the *Acting through Improvisation for Animators* in this section as they relate to my study. Two different approaches were introduced in the workshops. The first was the Laban Movement Analysis (LMA), while the second focused on applying Improvisation techniques to acting.

i) Laban Movement Analysis

The exposure to LMA during this workshop was intensive, but it was impossible to cover all aspects of LMA. To acquire a complete understanding of Laban would require formal training in the technique. LMA involves many technical aspects of the process, which needs years of consistently learning the skills. Thus, the instructor, Sarah, selected some important areas of LMA best suited to animators. The area of focus was limited to LMA's Basic Efforts in a one-day workshop. Most of the participants in this workshop were experienced animators, with their own expertise in dealing with various techniques such as motion capture, keyframing and stop motion animation. However, we all had similar objectives in attending this workshop, that is, to explore body movements and how we could apply the knowledge gained in our work.

During the session, we were asked to move around and use the space to explore various movements at different speeds. We created our moves in space, alternating between quick movements and then gradually slowing down the speed. Simultaneously, we had to be aware of our own body movements and those of the bodies that passed through our shared space. We bent over, stretched, rolled on the floor, sauntered, and walked briskly, for example, by contracting muscles in every part of the body at different times, and created shapes through the movements. Sometimes the group participants scattered, and were far apart from the others, while at another point they moved closer, combining the movements into a single form. Each one of us had a unique way of moving their body based on their personal observation. In the LMA, such movements are called a Kinesphere experience; a self-awareness of 'the distance around the body that the limbs can reach […]' (Adrian, 2008: 9). The Kinesphere experience explains the space in which the body is moving. It works in tandem with Laban's Basic Efforts, which consist of Space, Time, Weight and Flow (Figure 3.8).

Laban's Basic Effort Factors

Efforts	**Elements**
Space	- Direct and Indirect (Flexible)
Time	- Sudden and Sustained (Slow)
Weight	- Strong and Light
Flow	- Bound and Free

Laban's Eight Effort Drives

Drives	**Elements combination**
Pressing	- strong, sustained, direct
Punching	- strong, sudden, direct
Wringing	- strong, sustained, indirect
Slashing	- strong, sudden, indirect
Gliding	- light, sustained, direct
Dabbing	- light, sudden, direct
Flicking	- light, sudden, indirect
Floating	- light, sustained, indirect

This note is extracted from the Acting & Movement for Animators Workshop handouts, 16 October 2011

Figure 3.8: Laban's Basic Efforts and Effort Drives

We came to understand that the movements we made are very much made manifest by the four effort factors that drive a character to move. Movement is accompanied by the effort elements (see Figure 3.9). What causes the efforts to result in physical movement originates in our emotions, how our feelings change at a particular moment to produce action. Physical movements will not tell a story if they are not driven by feelings. Laban listed eight basic Effort Drives (see Figure 3.9) that characterize actions. Take *pressing* for example; the elements combination is *strong, sustain,* and *direct*. A person needs to exert strong pressure with his/her hands down onto an object using strong force on it. While pressing, the actor belongs directly to the positive space where the object and s/he are located. Depending on the weight of the object, the timing needed to press the object is somewhat sustained in order to develop the right momentum. However, the situation depends on the impact of the environment, the form of the object, and a person's physical strength.

ii) Improvisation

In another *Acting for Animators* workshop session, we were introduced to a different approach to acting called Improvisation. Improvisation (also known as Improv) allows more flexibility and naturalness in its technique. As the name implies, we were encouraged to make changes to our movements, vocal range, expression and emotion as we moved, and explored beyond rules or guidelines. Improv allows stillness and silence. In one of the exercises, we performed actions without being affected by our voice or sounds. However, in a different exercise, we extensively use various tones of voice and added some external sound effects to explore how speech affects actions.

Improv eliminates the thinking process, insofar as one simply performs actions and allows them to develop into a new action structure. Without any proper planning in mind, we learned to think of a character and act promptly according to the character's state of mind in that situation. For example, in one exercise, we were asked to use a chair to improvise our actions with the chair as a subject. We learned to anticipate an action by observing every dimension of the chair and perform a spontaneous act. Improv reflects the events that occur in everyday life. We found the Improv technique much more straightforward and not very formal to learn. The approach resembles our normal actions that we carry out as everyday activities but slightly exaggerated, allowing some inventiveness among the participants by exploring his/her creative imagination through their own body movements. Nonetheless, the notion of excluding the thinking process in Improv, contrasts with the process of animating, as a keyframe animator needs to think and anticipate not just the character's position but also the action timing.

3.3.2 Evaluation

While performing these movement activities, I attempted to return to do animation by animating a 3D character. This was the aim of transferring the movement that I explored and assigning it to a 3D character. While enjoying discovering movement through acting, I however, feel that the long process of animation remains the same. I have to repeatedly do/redo the action poses, go back to create poses for the 3D character and assign keyframes to create timings. This time-consuming process does not get any better when applying keyframes. I must admit that acting exercises was able to cultivate a *sense of character* by copying the action made, but combining acting and keyframe animation, can contribute to making it an even greater time-consuming process, because there is a big gap between reality and virtual world, which are determined by the technology.

Acting preparation for animators is a transformational tool, which has been accepted by many animation experts for its function in character development and analysing body movement and action. Animators are bodily engaged with particular character's behaviour during their acting training; however, there is no direct connection to inanimate objects in the virtual environment when it comes to assigning body movements to fit a character’s behaviour. A character’s action envisaged by the animator is detached from the virtual inanimate object. In terms of the notion of time, the ‘discrete unit of time’ (Wells, 2011: 17) of frame-by-frame animation is unable to place animator and virtual character together in the same space; instead, the animator analyses action and movement repetitively and laboriously. In this sense, the approach to animation should be perceived differently, with a kind of mediation device that can interact directly with the virtual character. This idea has led this research to a further action plan by taking a leap into thinking about intervening tools to aid the learning of animation.

3.4 Traditional Marionette Manipulation Technique: A Concept

What drove this research to approach marionette puppetry was through the preliminary exploration of acting movement. I realised all movements are embodied within myself, nonetheless, continuously doing keyframing and to perform movements, I feel somehow detached from the 3D character. I need an intermediary to provide a kinaesthetic sense that can be manipulated directly. Marionette puppetry came into the picture to explore the directness of the manipulation process. The way I perceive marionette puppetry is as representing a direct manipulation technique of the past. The basic elements of transformation such as translation and rotation happen immediately within the same physical space.

3.4.1 Handling Marionettes

I interviewed Stanley Middleton (Figure 3.9), a young professional marionette puppeteer at the Puppet Barge[10] in Little Venice, London in February, 2013. I got to know Stanley personally through recommendation from a member of the teaching staff in the Puppetry degree programme at the Central School of Speech and Drama, London. Stanley had been exposed to puppetry ever since he was young as he grew up on the theatre barge. Puppetry has been part of his life as he frequently performs with puppets. He developed his skills over time and had been working with the show for 13 years. In addition, Puppet Barge has a collection of various types of marionettes from around the world that were handed down to him ever since his grandparent's time.

Figure 3.9: Stanley Middleton of Puppet Barge, London

During the interview, some of the topics we discussed were: the control, manipulating marionettes, and acting training. According to Stanley, there were many different types of control for marionettes, ranging from a simple piece of rod and strings to the most advance and complex control system that can control almost every part of the puppet's body including the eye and mouth movements. The manipulation system that they were using on the Puppet Barge was an *upright control* type (see Figure 3.10), which was

[10] Puppet Barge was established as a touring company named Movingstage in 1979 specialising in marionette plays. Gren Middleton and Juliet Roger are the founders of the Puppet Barge, which was officially opened as a unique theatre on the boat in 1982. Since then, it has been actively involved in children's theatre and has been recognized by London-based arts councils and many non-profit trusts. Source: http://www.puppetbarge.com/Aboutus.htm

designed and invented by John Wright, the man who opened the Little Angel Theatre[11]. This control has a separate bar for the legs from the main control for the other parts of a puppet. Making the puppet give a small or big gesture such as scratching his head or waving, depend on how much the puppeteer pulls on the string attached to the puppet's hand or elbow. Puppeteer needs to be aware of the connection with their finger movements when holding the control. For example, the control handle needs to be held between the thumb and the index finger, while the thumb and index finger also hold a rod to control both hands of the puppet. The other fingers play their parts in manipulating the puppet (Figure 3.10).

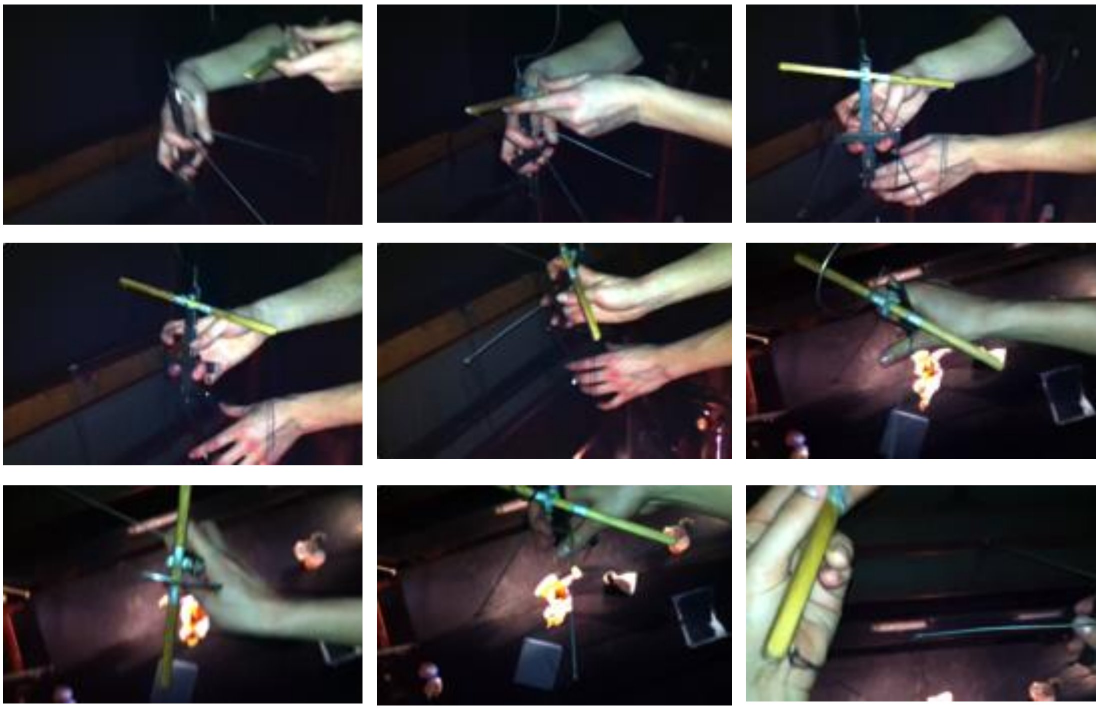


Figure 3.10: Puppeteer's hand manipulation

When it comes to preparing for a performance, Stanley admits that it is important for puppeteers to have a sense of performance in order to portray emotions and be in control of the character the marionette portrays at the same time as physically controlling the performance of the marionette. He added that some basic acting knowledge was useful and could help them in the process. However, Stanley stated that at Puppet Barge, they

[11] Little Angel Theatre is a puppetry-based theatre located in Islington, London. Founded in 1961 by a marionette master John Wright, Little Angel Theatre is known for all types of puppet shows including their specialization in marionette play.
Source: http://www.littleangeltheatre.com/about-us/sub-page-1/

do not undergo any formal acting training. Rather, they prefer to train with the puppets from the start. The ways to portray emotions and storytelling are developed through years of experience practicing along with the puppet to become confident about operating it. In this way, the puppeteer and the puppet have a close connection, rather than training separately.

This interview was held over two separate days. On the second day, I had the chance to go back stage to see the actual setting of a marionette theatrical play. Moreover, I had a hands-on session on handling a marionette. Controlling a marionette of the type used on the barge is complicated and difficult as everything happens simultaneously. I had to be in character, move my hands in order to manipulate every single limb and string of the puppet. For example, to move the puppet's head, I needed to push the handle forward and move it from side to side. To make the puppet bow, I had to pull a small bead attached to the string attached to the back of the puppet. The function of the puppeteer is mechanical, but requires years of observation and practice to develop the necessary skills.

3.4.2 Evaluation

A marionette puppeteer's role can compared to that of a stage performer who performs as a character other than himself. A puppeteer is also a storyteller who performs the stories through a mediated tool that is communicable with their hands. They communicate emotions, thinking, and the motivations of a particular character, which are then conveyed to the puppet directly. However, their physical appearance is usually hidden from the audience but the articulation of their voice and hand movements are highly significant during the performance. One important attribute of a puppeteer is a sense of body movement and timing that enables them to distinguish movements-timing going from the control to the puppet.

Figure 3.11: Puppeteer and his puppet

It is arguable about whether it is appropriate to compare a puppeteer to a real life screen or stage actor, although they are both performers. An actor embodies a character within their physical body, while a puppeteer transfers the character that they envisage to an inanimate object (Figure 3.11). Moreover the skills of handling puppets such as understanding the mechanics of the puppet's control and puppeteer's own hand gestures and articulation need to consider different training and routine.

Hands and the Controller

Between puppeteer and the puppet, there needs to be connection as if they were one embodied object. In this situation, the control becomes the 'mediator' that communicates the thinking and emotions of the puppeteer to the puppet. The control consists of rods and strings connected together. It comes in different forms and degrees of complexity depending on how realistic the movements the puppet has to achieve are. The strings attached to the rods on the control and the joints of the puppet determine whether a mechanical or natural impression is given to the movements. Furthermore, the lengths and distance of the strings can give a 'wiggle' look, or a bounce, which often characterises the movements of puppets.

Figure 3.12: Hand and the Marionette Control

The puppeteer’s hands have the great responsibility of managing the rods and organising the strings on the control (see Figure 3.12). Being in full control of his/her hand articulation helps the puppeteer communicate the appropriate thoughts and emotions of the puppet. For example, to make the puppet walk or run, the correct positioning of the control rod and pulling the strings appropriately is essential, so that the puppet will accurately portray walking or running. That means the puppeteer’s hands need to deliver a dynamic exertion with the correct timing to create gestures by the puppet. As the puppet hangs from strings, which are controlled from the top, the puppeteer also needs to be aware of when to give some sense of weight through their hands to the puppet. It should physically be bound to the ground to give a ‘believable’ impression. In some ways, the puppeteer’s hands and the control represent embodied time and space in between the player and an inanimate object.

Puppeteers work with the puppet in the real world, where everything happens in a physical and tactile way. From this observation, I found that marionette puppetry suggests more than just a medium of communication and entertainment. I shall not consider the audience's perspective, but rather from that of the puppeteer, who is the *soul* of the puppet. Puppetry is known as a way of communicating ideas that play in our minds. The exploration of the imagination and expressing emotions shift through the articulation of the puppeteer's hands, instead of their whole body, in order to manipulate the whole figure of a puppet. This can be very challenging and complex as the manipulation process happens by directly improvising a puppet's movement and timing at the same time. This involves the skill of controlling many forces through the puppeteer's hands.

Through the art of puppetry, the puppeteer learns by actively doing and performing with inanimate objects. This means developing interactions that rely on the movement and timing between puppeteer and the puppet. This is affected by direct communication from the puppeteer translating certain behaviour to the inanimate object, the puppet. The puppeteer himself knows what set of movements he is going to use in the scene. In addition, marionette puppetry stimulates the intuition, which encourages the development of a sense of movement in the puppet, as puppeteers are aware of their own body movements.

The idea behind looking at marionette puppetry in this research became a turning point to formulate a novel approach to animation techniques. The concepts behind hand-finger manipulation in handling marionette puppetry somehow provided inspiration, an opening to a new perception of animation techniques for virtual character animation. Merging a traditional method of keyframe animation with the use of Leap Motion, a motion-sensing device that is able to directly connect an animator in the physical world and a virtual character could encourage closer interaction in the time and space between them. Moreover, observing marionettes in operation motivated a more hybrid action plan for this research of merging the previous practices from keyframing, performing a character, and the hand articulation control of the marionette to the concept of using midair as a space for 3D manipulation techniques. This lead to formulating a novel technique for learning character animation, which I call Kinaesthetic Animation- a direct manipulation technique that uses our sense of movement intuitively to animate inanimate object in a 3D environment.

3.5 PART 2: FROM PRACTICES TO INTERACTION DESIGN

At the beginning, I adopted a User-Centred Design (UCD) to explore a system to meet the process needs for designing a hand gesture interface. This UCD design process emerged from previous self-reflecting practices, which then focused on building a system that users would be able to use effectively. Reflecting previous experience as part of the user (puppeteer) contributed as much as the factors which impact on the UCD design process.

The development of the UCD design process for this hand gesture interaction is moving into the second phase, that is, the Interaction Design Phase.

3.6 Interaction & Interface Design

This marks the beginning of a self-exploratory exercise to embark on Human Computer Interaction (HCI) and incorporate a Natural User Interface (NUI) into the animation process. This involved an initial study of devices and their compatibility with 3D animation software. In addition, I suggested a basic model of hand gesture vocabulary for the interface. As work is iterative between the device and hand gestures, further gesture models were elicited through working with some users. This step was further elaborated into three parts:

3.6.1 PHASE 1: Exploring Technologies

In this step, I explored a number of possible motion-sensing devices to understand gesture-based technologies and how the devices would work with the animation process. Many motion-sensing devices can be used for this purpose but this research focuses on hand-manipulated systems that enable users to stylize the movements created, rather than needing to realistically imitate a full-body movement. The approach is motivated by the idea of the traditional puppeteer, whose hands manipulate the puppet. In this case, two motion-sensing devices, Wiimote and Leap Motion, were used. These devices work in tandem with 3D animation software.

1) Tool 1: Using Nintendo Wiimote

Wiimote is the first device used to experiment with gesture-based control animation. The 3D character is manipulated through the accelerometer and motion-sensor feature of this wireless device. Wiimote is commonly used for playing computer games. However, I used the device to replicates the idea of how a traditional puppeteer manipulates a marionette by holding a control rod and strings in his/her hands. In other words, it resembled a digital marionette manipulation system with a frontal controller.

The Wiimote is used alongside OSCulator as intermediary to leverage motion onto 3D characters in Maya.

To connect the Wiimote controller and the software, I used Osculator, an open sound control (OSC) protocol using processing software (Figure 3.13) to synchronise the physical device in real time to provide a direct response and interaction with the 3D character.

Figure 3.13: Wiimote and OSCulator

I attached the link to the IK handle on the hips of the character. To automatically set the keyframe, I arranged the following script (Figure 3.14):

```
def handleRotation(self, addr, tags, data, source):
    print "handling rotation ", self.count
    if(self.count > 100):
        self.count = 0
        self.count2 +=1
        #print "CHECK CHECK CHECK..."
        #print "received new osc msg from %s" % getUrlStr(source)
        #print "with addr : %s" % addr
        #print "typetags :%s" % tags
        print "the actual data is : %s" % data
        #print(self.cube1)
        cmds.setAttr(self.cube1+".rotateX", 180*(float(data[0])-0.5))
        #cmds.setAttr(self.cube1+".rotateY", 180*(float(data[2])-0.5))
        cmds.setAttr(self.cube1+".rotateZ", 180*(float(data[1])-0.5))
        cmds.refresh() # update the viewscreen
        cmds.setKeyframe(t=self.captureFrame)
    else:
        self.count += 1
```

Figure 3.14: Automatic Set Keyframe

I set the curvy *B* button underneath the controller to automatically set up the keyframes, controlled by the index finger. The user holds the device and points it at the 3D character in Maya. Upon releasing the button, the animation stops.

Figure 3.15: Using Wiimote to control a 3D character

The basic control system of the hand-held device was used to move up or down, left or right, forwards or backwards, or to rotate. As the user rotates his/her hand clockwise or in the reverse direction, the 3D character follows the assigned direction. When the user tilts the Wiimote upwards or downwards, the 3D character will arch or bend its body (Figure 3.15).

Although Wiimote can be used at a distance of more than one metre, for the purpose of this experiment, I limited the distance to 30 inches from the computer screen. This was to observe the manipulation easily by not being too distant from the 3D character. I found that Wiimote was able to act as a tool to link hand/control movements in the real world to directly manipulate a character in the virtual environment. The 3D character is manipulated using the power of the hands. However, certain limitations can occur from holding a device in the hand. The usability relies on limited hand movements to manipulate or and rotate the 3D character the fingers having any separate function like pinching or tapping on the controller, unlike the hands of the puppeteer. In addition, using Wiimote to animate a character in Maya makes the movements of the 3D character look jittery and the animation appears jerky.

Wiimote provides flexibility in terms of controlling 3D character as the user gets direct control to create movement-timing compared to keyframing, where the 3D character is animated frame-by-frame. Animating with Wiimote also allows the user to manoeuvre his/her hands naturally as it captures real-time motion. Unlike using a conventional mouse and keyboard, the user is attached to the WIMP (windows, icons, menus, pointer) system. This creates a constraint, especially to the Z-axis coordinating system. Interesting aspect of using Wiimote was the creation of an automated keyframes function. As the user's hands control and move the device, keyframes are automatically added on to the animation timeline. The recorded animation can be reviewed on playback. Since the device translates real-time movement, it produces a large number of keyframes.

2) Tool 2: Using Leap Motion

I developed a preliminary prototype interface with the use of Leap Motion. The system consists of three basic components: a Leap Motion device, a LeapStreamer[12] interface, and 3D animation software, Autodesk Maya version 2013 (Figure 3.16). This was to explore the calibrations of left and right hand movements and synchronised input/output data to a 3D character in Maya. This experiment included identifying the navigation of distance, orientation, transfer of instruction, location and exertion of the hands within the proximity of Leap Motion.

Figure 3.16: Leap Motion, LeapStreamer interface, Autodesk Maya 2013

The process takes place when users move both hands; motion data from the hands gestures are received by Leap Motion through its sensory tracking feature. The raw data is received by LeapStreamer (Figure 3.17) and is used to identify the movements of the left and right hands and the fingers. This data is converted into commands in MelScript, which can be understood in Maya and then sent via a network socket to Maya.

[12] LeapStreamer is an interface developed by Marco Gillies in collaboration with this project using openFrameworks in C++. It is for connecting, and sending/receiving input/output data from Leap Motion and Maya. During the experiment, the LeapStreamer two versions of LeapStreamer, MyApp and MyApp2 were developed with improved functions from previous interface.

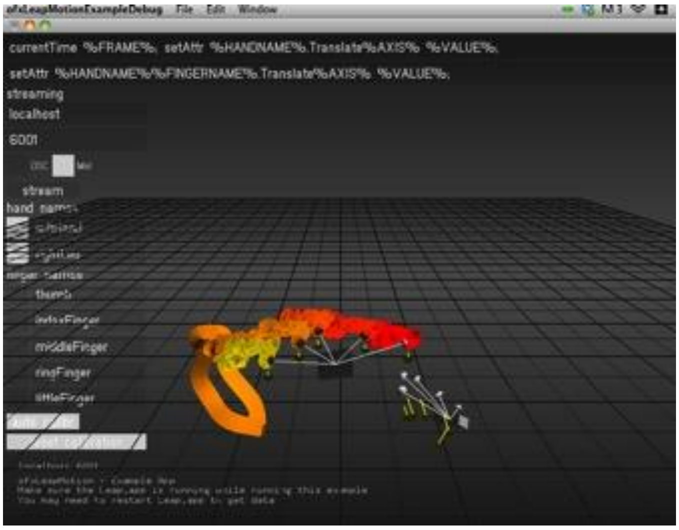


Figure 3.17: LeapStreamer Interface

Within Maya, the hand movement data is mapped onto a 3D animated character. In this preliminary experiment, I used a 3D character called AndyRig[13] with full basic skeleton rigging. In order to receive output data from the user's hands, I assigned Set Driven Key (SDK) onto the character's IK controllers. A Set Driven Key consists of a driver and driven objects; the former is the handle that controls the values of the key attributes (i.e. translate and rotate X, Y, and Z), which are determined by the attributes from the driver/handle. For example, in this experiment (Figure 3.18), Andy's left hand on translate Y is connected to the Set Driven Key handle's leftHand translate Y attribute. I did the same to translate X and Z on both Andy's hands. Consequently, the character's hands move on the Y-axis as the data is received by the Driven Keys handle.

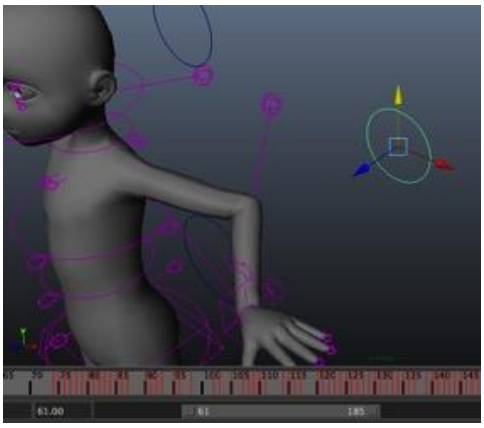


Figure 3.18: IK handle and Set Driven Key

[13] AndyRig is a freeware rig-ready 3D character created by John Doublestein in 2007 for his students use for various purposes in animation.

This function makes the animation process easy to follow, as the keys are set within the preset value range of the attributes. The Driven Keys allow more control over data mapping onto the character. In particular, many different mappings are possible. For example, the user's left hand does not need to be mapped to the character's hand; users' hands can be mapped to the hips, legs and head, to simulate the practice of puppeteering.

Figure 3.19: Calibrating LeapStreamer, hand gestures and animating the character

Both hands need to be calibrated in LeapStreamer, selecting left and/or right hand function so the character can recognize the information data. When the character's hand is moved, the keyframes are automatically marked to the timeline; at the same time, the spacing of the keyframes that occurred indicated the timing, which is detected by the pressure from the user's hands (Figure 3.19).

3) Evaluation

Keyframe animation, where creating movement and timing are formed by how sequences of keyframes are arranged is hard work and time-consuming. Bringing everything together can be very difficult to achieve. Movement and timing are embodied together in real time, but are detached from each other in keyframe animation. Keyframing required setting a key pose on a frame followed by another pose on a different frame after repositioning the adjoining parts of the different poses. The timing depends on the distance and spacing of the assigned keyframes. The entire process monotonously goes forwards and backwards, repeating the procedure to set in place a sequence of frames in order to create the appropriate timing that determines the right movement. The appropriate timing for the key frames can only be seen by playing back the animation. There is no direct feedback of the timing during the process of assigning keyframes. The detachment between assigning the keyframes and guessing the timing, makes the manipulation process indirect, that is, the keyframing, movement, and timing process are not integrated as one component. Nonetheless, the advantage of this non-direct animation technique is that it allows full control of the manipulation. It provides flexibility for stylization and a cartoon-like appearance by exaggerating the actions and adding elasticity to the movements of the characters.

Looking at the intervening of tool during the process of animation can open up different kinds of technique. The devices that I used as a method of animation in this practice enable me to have a stronger sense of connection between myself, as the animator, and a 3D character. The animator can directly manipulate the animation by using the motion timing of their own body. Taking control of real time motion does not mean the aim is to capture real life movement realistically. Rather, it functions as motion input data derived from real time in order to avoid the tediousness of assigning keyframes.

I used motion-sensing based devices such as Wiimote and Leap Motion as an alternative to the conventional tools such as the mouse, keyboard, trackpad, and graphics tablet used with the WIMP interface. It is common for animators to use these devices in creating their animations. These 2D controller tools have been comfortably used for many years and have proven functionality; however, are intended to stick to flat surfaces, 2 dimensional space. This limits the third dimension in 3D animation. However, motion-sensing devices used as part of the animation process can eliminate the boundaries between the animator and 3D character. The can open up the notion of intuitiveness by promoting more natural and spontaneous interactions that embody all the essentials of movement and timing.

The use of Wiimote and Leap Motion was to replicate the handling of the classical marionette control bar. What is important in the traditional marionette does not lie in the animated puppet, but in how the puppeteer articulates his hand movements and gestures while manipulating the rods and strings. Manoeuvring the rods and strings and the timing of both hands' gestures play a crucial role in puppeteering. Wiimote and Leap Motion were used as an attempt to create a similar role between the animator and the animated character. Leap Motion allows the user to virtually grab and select a desire object directly using both hand and finger gestures. The control system provides a simpler and more flexible application. It does not restrict the movement or dexterity of hands and fingers, which can operate in midair, in every dimension, depth, and space.

Nevertheless, some limitation can occur in using Wiimote and Leap Motion for animation. Like holding a mouse or a graphics tablet, with Wiimote, users tend to grasp something in our hands. This can limit the functionality of our hand gestures and movement of the fingers. In addition, a specific animation function has to be assigned to each individual button on the control device. This requires the user to choose, select and press a button to operate a function. In my experiment, I noticed that Wiimote makes a lot of 'noise' even when still, which means the resulting 3D character makes jittery movements. Although Leap Motion is highly sensitive to tracking hands and finger movement when they are simply placed above the device, jittering also occurs in the signal received from the hands and fingers motion data. I suspect this is due to the natural phenomenon of the human body movement. With Leap Motion, I also experienced certain limitations of the tracking motion on its X, Y, and Z-axes. The device was unable to tracks hand and finger movements at a certain distance on the vertical and horizontal planes.

3.6.2 PHASE 2: Participatory and Gestural Design

Users are not involved from the outset during the UCD process. However, they need to participate in the design, as the prototype requires some involvement to experience using the interface.

To test this out, I set up a user-elicitation study, a method introduced by Wobbrock as a guessability study to evaluate "symbolic input" (Wobbrock et al., 2005: 1869) through user experience. In a guessability study, a symbolic input, according to Wobbrock, is when users create certain symbols that they relate to as "referents". He used 14 participants (of whom 4 were motor-disabled users) to evaluate his EdgeWrite interface. While it is unnecessary to be skilful at using it, the users were asked to draw some letter of the alphabet using a stylus pen within the square in order to create a certain pattern that symbolised the alphabet (Wobbrock et al., 2003). The method was part of participatory design process (Vatavu and Wobbrock, 2015: 1325).

In addition, user elicitation is commonly used in analysing gestures interaction design (Dong et al., 2015; Morris et al., 2010). Some elicitation studies evaluated mid-air gestures control using motion-sensing devices. Koutsabasis and Domouzis used

Microsoft Kinect to evaluate a mid-air hand gestures of selecting images within a controlled user setting (Koutsabasis and Domouzis, 2016). In another experiment, Vatavu and Zaiti conducted a similar study using Leap Motion to evaluate users' interaction in selecting a TV menu in comparison to the conventional way of using a remote control (Vatavu and Zaiti, 2014; Zaiţi et al., 2015). The aim of every elicitation study was to acquire a set of frequently used gesture vocabulary.

The user elicitation in my study took a slightly different approach whereby a hand-miming study was used to gather hand gesture information from the users. After the hand-miming study, small-scale technical feedback came from two users to consider the technical issues related to the interface. I established a set of common hand gesture vocabulary for the next pilot study.

1) Hand-Miming Study

Hand-miming study is a method that was part of the participatory design to obtain a preliminary evaluation of the hand gesture interface. The aim was to observe user experience using hand gesture to control a 3D character. As the name implies, the method requires users to move their hands as if they were animating a pre-animated 3D character. In other words, each participant was given a recorded video of an already animated character. The character carried out various movements at different speeds. What the participant needed to do was perform hand gestures anticipating how the character was going to moving. The participants were not given instructions as to which gestures to use, so they were free to choose the movements that they felt were most appropriate. Like other elicitation studies, the purpose of this experiment was to develop a hand gesture vocabulary and to observe user interaction with the 3D character, for future development.

i) Material and Interface

The interface was designed and created using Unity 3D software. The character was set-up and animated in Unity 3D. To accompany the interface, a Leap Motion device was used to capture the user's hand movements. The development of the interface was accompanied by 4 buttons referring to pre-set actions (see Figure 3.20):

i) *Hands LR* – The 3D character in T-pose moves both hands (left/right) up/down and front/back in quick and slow movement timing.

ii) *LeanFwdBkwd* – The 3D character in T-pose leans forward/ backward in quick and slow movement timing.

iii) *LeanSides LR* – The 3D character in T-pose leans towards on each side, left or right in quick and slow movement timing.

iv) *Legs LR* – The 3D character moves both legs (left/right) front/back and sideways in quick and slow movement timing.

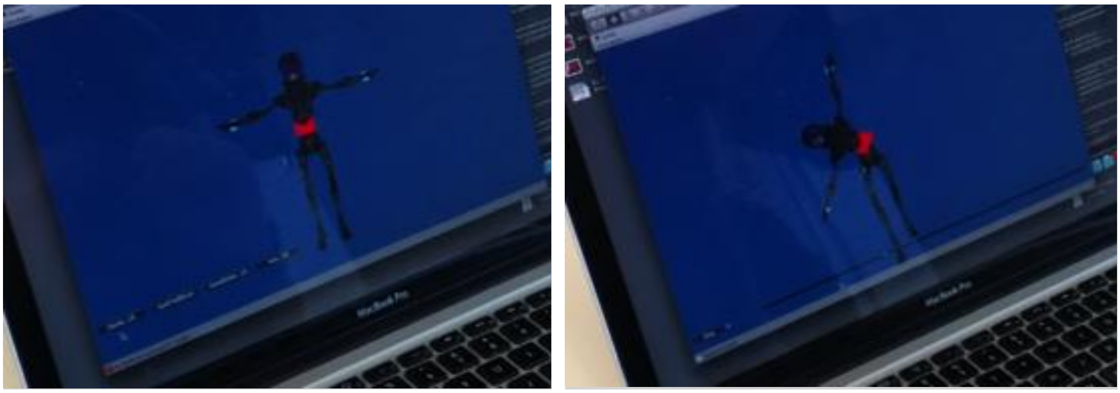


Figure 3.20: Preliminary prototype of hand gesture interface

When the user selects a button, the 3D character will automatically become animated. For example, when a *Hand LR* button is selected, the pre-animated 3D character moves his left hand or right hand individually upward or downward, and to the front and back. These movements were created in different movement times. The user only needs to imitate the movements using their own hands, as if they were controlling the character.

ii) Procedure

In this experiment, I asked each volunteer to 'play' with the 3D character to exploring the hand gesture-based interface. Upon agreeing to do the task, each user was given brief instructions on how the experiment worked. The user needed to imitate the character's actions using hand gestures when each of the character's limbs moved. The duration of the entire task took approximately 2-3 minutes. Six volunteers were chosen randomly to take part in the experiment. Users with various experiences were selected without any specific background in animation or interaction.

2) Interface Development

While the interface for hand-miming study provided a mock-up of some predetermined functions of *Hand LR*, *LeanFwdBkwd*, *LeanSides LR* and *Legs LR*, an improved version was developed. The fully functioning interface allowed the user to manipulate the 3D character by themselves, without having to mime. The interface consisted of two functional buttons, that is, *Record* and *Play*, while the Slider Bar indicated the recorded time of the animation in progress. The user began to animate the 3D character when they selected the *Record* button. When the animation ended, a new button (i.e. Anim 1, Anim 2, and so on) automatically appeared to indicate the recorded animation had been saved (see Figure 3.21). All the animations were recorded in real time and could be played back by selecting the *Play* button.

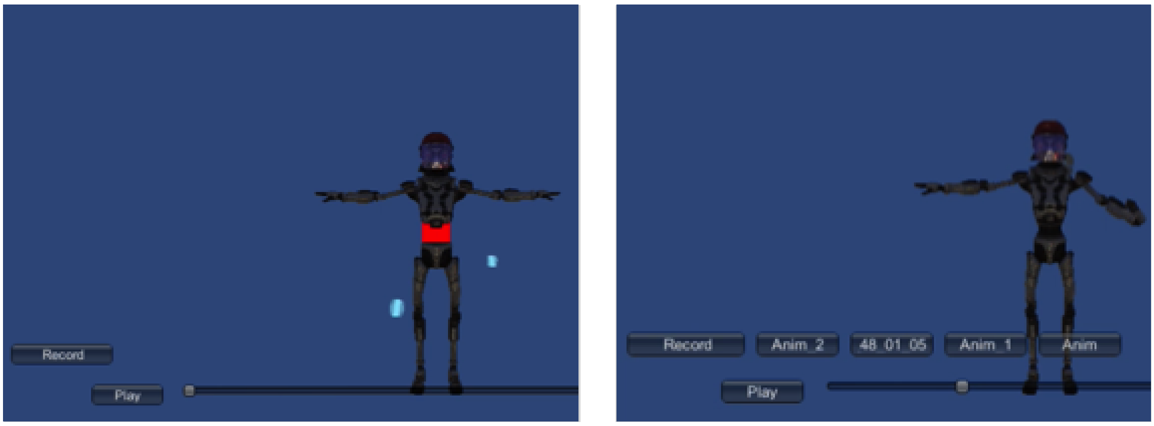


Figure 3.21: Interface development after the hand-miming study

3) Prototype Technical Feedback

Following the hand-miming study, I conducted a prototype technical feedback exercise. The mock-up of the interface used in the hand-miming study is re-evaluated in this study through a fully functional prototype of a *live* manipulation process. This is important to assess the functionality of the interface and overcome issues pertaining to the prototype before a pilot study is carried out. Two participants were employed in this process in order to measure the interface's usability. They were asked to animate the 3D character by waving the character's hands. Further analysis of the technical feedback can be found in Appendix A-2: Interface Technical Feedback.

4) Evaluation

A detailed analysis of the study can be found in Appendix A-1: Hand Miming Study. Before the study, two participants had used a Leap Motion device, while four participants were not used to the device and it was their first experience using a mid-air control device. As a result, it took them some time to familiarise themselves with the controlling system. Although the system is new to them, most participants were enthusiastic and became more explorative with their hand gestures, making different kinds of hand movement. At times, their hand movements were tracked beyond the sensory radius of Leap Motion.

Some participants had a second attempt at performing after the first task due to unresponsive movements from the 3D character. In the second attempt, there were some improvements to the hand gestures that control the 3D character's movements. Some participants admitted that it was difficult to act out their hand movements as they were not in control of the 3D character's actions. Below are some observations of how users responded to the four control buttons:

i) **Button 1- *Hand LR***: As instructed before performing this exercise, the users placed both hands above the device and started acting the character's hands. However, unanticipated character hand movements at different speeds led to a delay between the user's hand gestures and the character's.

ii) **Button 2- *LeanFwdBkwd***: When moving their hand to make the 3D character lean forward and backward, most participants seemed to use both hands by either pushing/pulling their hands forward/backward or tilting their hands up/down at an angle.

iii) **Button 3- *LeanSides LR***: When they used only one hand to make the character's body lean sideways, most participants tended to use both hands throughout the process. The instructions given at the beginning of the test asked the participants to place both hands above the Leap Motion buttons (2 and 3).

iv) **Button 4- *Legs LR***: Users hand gesturing was similar to how they used them in the *Hand LR* exercise, although some delays occurred due to unexpected movements and the speed of the 3D character.

3.6.3 PHASE 3: Hand Gesture Interface Design

Much of the participatory design process contributed to the development of the hand gesture interface. Before discussing the pilot and usability studies, I present the gesture vocabulary and an improved version of the interface.

1) Gestural Design

From the previous hand-miming study, I elicited hand gesture responses that users frequently used. The hand gestures were selected based on how the users reacted to the pre-animated 3D character during the experiment. The common gesture terms used when animating a 3D character using hand gestures and control technique are presented in see Figure 3.22:

Gesture Referent 1: ***Character's Hand Moves Up and Down***

Description:

i) When 3D character's hand/s moving upward and downward
ii) User's hand moves up/down on Y axis
iii) User controls speed (fast/slow) of their hand
iv) User learns their hand movement by imitating the 3D character's current orientation of its hand movement (left/right)

Gesture Referent 2: ***Character's Hand Moves Front and Back***

Description:

i) When 3D character's hand/s moves forward or backward
ii) User's hand moves front/back on Z axis
iii) User controls speed (fast/slow) of their hand
iv) User learns their hand movement by imitating 3D character current hand movement (left/right)

Gesture Referent 3: ***Character's Hand Moves Sideways- Left/Right***

Description:

i) When 3D character's hand moves inwards or outwards
ii) User's hand swings inwards/outwards (sideways)
iii) User controls speed (fast/slow) of their hand
iv) User learns their hand movement by imitating 3D character's current hand movement (left/right)

Gesture Referent 4: ***Character's Torso Tilt Up/Down***

Description:

i) When 3D character's torso bends forwards/ backwards
ii) User's hand tilts up/down on Y axis; wrist remains still
iii) User controls speed (fast/slow) of their hand
iv) User learns their hand movement according to their preferred hand (left/right)

Gesture Referent 5: ***Character's Torso Free-form Rotation***

Description:

i) When 3D character's torso rotates
ii) User's hand and wrist rotate on X, Y and Z axes
iii) User controls speed (fast/slow) of their hand
iv) User learns their hand movement according to their preferred hand (left/right)

Figure 3.22: User-Elicited Hand Gesture for Controlling 3D Character

2) Interface Design

The current interface prototype has a more complete functionality than the previous prototype, which allows the user to interact with the 3D character using the navigation buttons (see Figure 3.23). This prototype is an improved version of the mock prototype created for the hand-miming study.

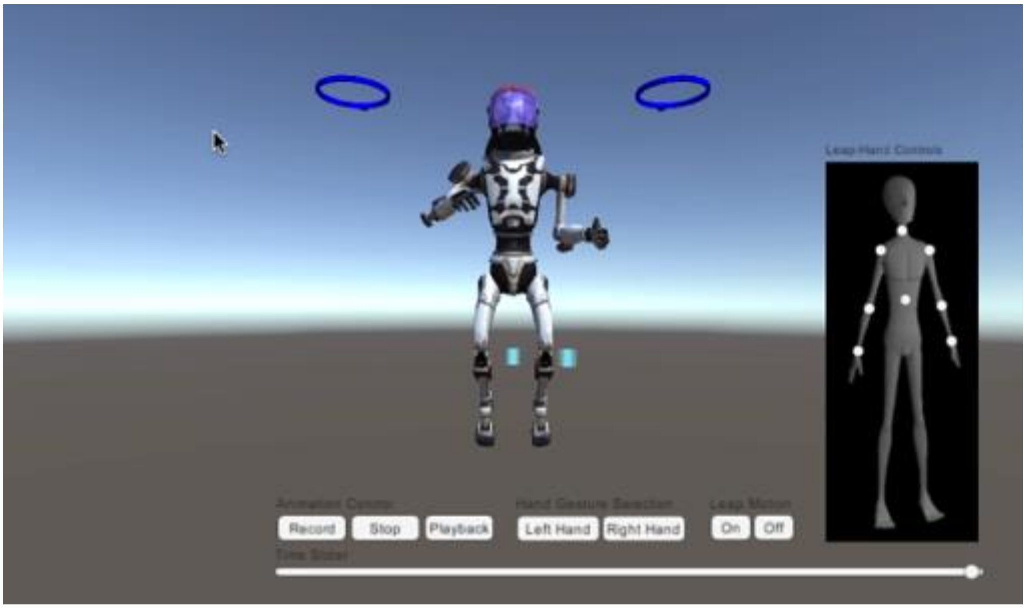


Figure 3.23: Second phase of hand gesture interface prototype created in Unity 3D

The interface is divided into five sections with its controls and function:

1) **Animation Control**
   - *Record*: Record the animation that is being made
   - *Stop*: Stop animation
   - *Playback*: Preview animation made
2) **Hand Gesture Selection**
   - *Left Hand*: Left hand control only
   - *Right Hand*: Right hand control only
3) **Leap Motion** - *On/Off*: Enable/Disable Leap Motion device
4) **Time Slider** - Indicates duration of animation
5) **Leap-Motion Controls** - Each button on the dummy's upper body is functional. The user chooses a particular joint to animate.

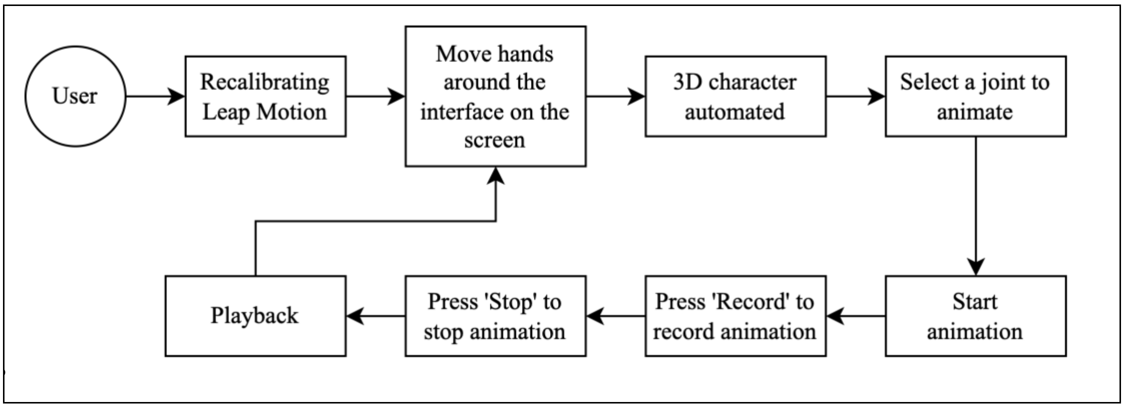


Figure 3.24: Hand gesture interface system design

The idea of the above interface system design (Figure 3.24) was initially proposed in a sketch, which contained several other functions (see Figure 3.25). This was the design concept that I envisage before a fully interactive prototype was developed. The hand gesture interface is intended to simplify the GUI-based animation tools and produce NUI-based control that relies on the user's hand gestures.

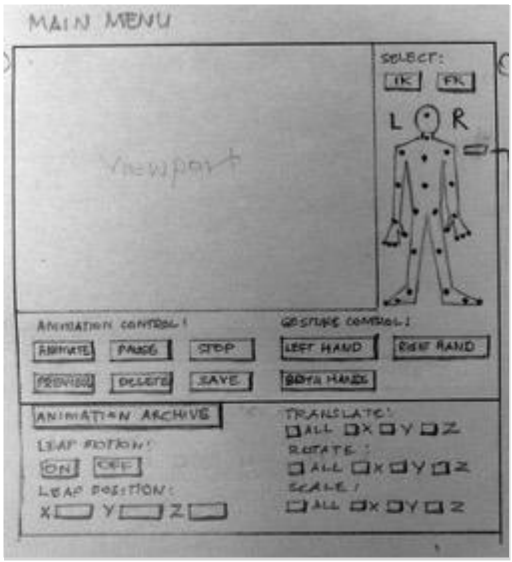


Figure 3.25: Initial sketches hand gesture interface design

In the initial design, I proposed several animation functions that enabled the user to control the 3D character directly through hand gestures. The intention was to provide a NUI-based animation that could intuitively operate character's movements and eliminate the notion of the frame-by-frame animation process.

3.6.4 Evaluation

While the purpose of this research is to eliminate the keyframing process in creating animation, I found that the prototype was capable of allowing the user to interact directly with the 3D character by using hand gestures in real time. I noticed that both participants interacted intuitively by moving their hands at different speeds i.e. slow and fast, in order to control the movement-timing of the animation. However, the users tended to move their hand outside the Leap Motion sensory radius and caused the prototype to recalibrate each time. The participants used both their hands to animate. This caused the animation to become aimless, without specifically focusing on a particular body part. A more specific function that enables the user to select a particular section of the 3D character needs to be incorporated. The Slider Bar that indicates the duration of the recorded animation takes too long before the recording stops. For this reason, a Stop button needs to be added so the user can end the animation.

3.7 Discussion

The research originated from the intersecting ideas of keyframing, puppeteering, performance, and considering an NUI-based interaction system. The second part of this practice-based research led to designing interaction between the participants and a 3D animation model followed by an experimental study based on the later development. Previous experience opened up the path to designing a more interactive user interface for animation. The idea behind the hand gesture manipulation system is to propose a novel concept of animation methodology that integrates reality and virtual environments in instantaneous practice and reduces the learning curve to a minimum. Designing hand gesture animation was inspired by the relationship between the puppeteer and his/her marionette. Some of the aspects observed to conceptualise hand gesture animation follow.

3.7.1 Human Gesture Factor

The human body is an animate object, so that we possess more abilities than inanimate objects. One of the remarkable things is how we take control of our hand gestures. We move our hands every day to do different kinds of activities, and use gestures as part of our non-verbal communication. There are numerous types of gestural expressions, but, the interest here is patterns of gesture. Aigner classified gestural patterns into categories such as *Pointing, Semaphoric, Pantomimic, Iconic, and Manipulation* (Aigner et al., 2012). I selected *Pointing* as the closest pattern in this work for its basic pattern function unlike other patterns that have certain symbolic or other meanings. Pointing is quite flexible as it does not require complex gestural control as it may be used either as pointing with the index finger or with 'multiple fingers, the thumb, a flat palm, etc' (Ibid.). Humans are capable of making various types of hand movement (Saffer, 2008: 35). Saffer identified the basic mechanics of human body movements in categories such as flexion-extension, abduction-adduction, and rotation among others.

3.7.2 The Presence of Body Movement and Timing

Movement and timing communicate different types of actions. These two elements are crucial for creating animation and emphasised in Disney's Principles of Animation. In the case of hand gesture animation, we apply this method through an interface. Laban's Effort is based on four principles: Space, Weight, Time and Flow. These efforts have different qualities such as being Direct or Indirect, Strong or Light, Sudden or Sustained, and Bound or Free. Movement and timing are controlled intuitively through how the user choreographs their hand gestures.

3.7.3 Real-time Interaction

The natural-based interface like the hand gesture animation technique proposed involves the manipulation process taking place in real time. Animating in real time differs from the non-real time keyframing process, as frame-by-frame time applied does not immediately occur and can be time-consuming. Animating in real time enables the user to be present in the same time frame as the evolving 3D character, which means the 3D character is engaged with the user and provides an instant response.

3.7.4 Mid-air Space

To complement the hand gesture control system, I proposed a touch-less method to replace the conventional mouse and keyboard system. Thus, the input and output data are obtained from the hands gesticulating in mid-air without having to be attached to a surface. For this reason, a motion-sensing device was used to send and receive motion data. A mid-air method was expected to facilitate the quick and easy transfer of movement data onto a 3D character, so that the user can make immediate modifications and get instantaneous feedback. It could also allow the user to determine the action and poses of the 3D character. The free-form three-axis coordinating system allows the user to make the 3D character move easily as they can see the results of their hand gestures.

3.7.5 Gesture-based Manipulation

According to Rogers, the basis of designing gestural interaction is the user's need of experience (Rogers et al., 2011: 9) to improve the way they work and communicate. Gesture-based manipulation differs from the WIMP interface, as it requires more actions from the user. In the case of animation, this is to enhance the way the user interacts with 3D character animation by providing a sense of connection through a seamless environment. While designing the interaction, I reflected upon the meaning of animation, which is about creating movements. With that in mind, exploiting physical action was essential as it can produce various movements. By using this ability, the user has directly controls the movement and the motion timing of a 3D character. The control methods are more natural and flexible making the learning curve simpler than handling the many functions of regular software.

Both GUI and NUI interfaces in computer animation exploit a direct manipulation system to interact with the tools in the animation program. The transformation tools in 3D animation such as *translation, rotation, and scale* are important to the animation user although the approach of manipulation in NUI is different.

3.8 Summary

This chapter presented the approach and methodology behind the research in order to design a hand gesture interface for creating animation. Due to the immediacy naturalness of the interaction, I suggest the use of hand gestures, mid-air space, and the presence of the body in real-time could be combined as a novel approach to animation. The next chapter, which the Evaluation Phase, I further examine how far users can cope with the functions of the interface.

4 Chapter 4

A Usability Study for Gesture-based Interface

4.1 Overview

After the various stages of exploration described in Chapter 3, I embarked on the Evaluation Phase– a functionality study of the hand gesture interface to evaluate its operational level for animation learners. I conducted a user experiment by giving some tasks using the conventional keyframing technique and others using the proposed hand gesture interface to inform the different methods of animation. This chapter addresses the main research question of whether hand gesture animation could provide users with some advantages. This chapter discusses the interface to allow participants to experiment with the practicality of hand gesture interaction as an instrument for creating animation. This study attempts to answer several questions and hypotheses:

1) **RQ:** Would users be able to use hand gesture animation as effectively as they use keyframe animation?

   H: Users would be able to gesture-based animation effectively than keyframe animation

2) **RQ:** Would users be able to learn hand gesture animation more easily than keyframing animation?

   H: Users would be able to learn hand gesture animation easily than keyframe animation

3) **RQ:** How much time would users need in order to create animation using hand gestures compared to keyframing animation?

   H: Users would spend less time creating animation using hand gesture animation

After designing a gesture-based manipulation technique for animation, it was possible to suggest that direct interaction with hand gestures is able to resolve the frame-by-frame tedious process of animation. Hence, to validate this claim, an experimental design is employed to investigate the following variables:

i) *Usability*: Do users find the interface contained the necessary functions to complete the task?

ii) *Satisfaction*: Do users feel comfortable with the overall interface?

iii) *Task Completion Time*: Do users have to spend a long time completing each task or was it straightforward and speedy?

4.2 Experimental Design

The experimental design had two parts, the first of which is the Usability and Satisfaction study reported in this chapter together with study on task completion time.. The second part of the experiment is reported in Chapter 5, which evaluates the quality of the animation. The same independent variables are used in both studies to measure the difference between the individual dependent variables, as illustrated in Figure 4.1 below.

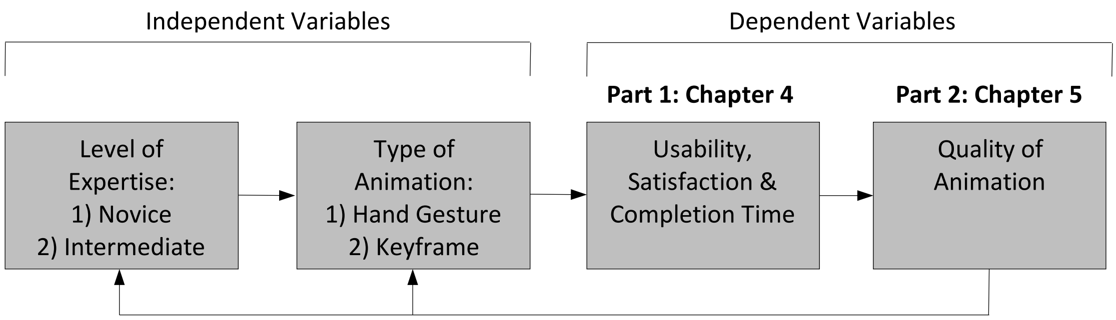


Figure 4.1: : Independent and dependent variables in two experiments

As the experiment has more than one independent variable, a factorial design (Lazar et al., 2010) within-subject (Cairns and Cox, 2008) was useful. The design typically has two conditions in each of the two tasks users complete.

4.2.1 Hypotheses

Measurable hypotheses to test the independent variables of the user experience fro Gesture-based Interface:

1) Usability

Hypothesis 1.1: There is a **significant improvement** in the usability of hand gesture animation over keyframe animation.

Hypothesis 1.2: There is an **interaction effect** according to the level of expertise (novice or intermediate) in the usability of the type of animation (keyframing or hand gesture).

2) Satisfaction

Hypothesis 2.1: There is **significant difference** in user satisfaction between hand gesture and keyframe animation.

Hypothesis 2.2: There is an **interaction effect** in user satisfaction according to level of expertise (novice or intermediate) and type of animation (keyframing or hand gesture).

3) Task Completion Time

Hypothesis 3.1: There is **significant difference** in task completion time in hand gesture and keyframe animation according to the users' level of expertise.

Hypothesis 3.2: There is an **interaction effect** in task completion efficiency according to the level of expertise (novice or intermediate) and type of animation (keyframing or hand gesture).

4.2.2 Within-subject

A within-subject design in this study. A total number of 23 participants were involved for data sampling in this study. Each was required to perform under two different conditions, which were determined prior to the experiment. Figure 4.2 (below) describes a typical within-subject structure that consists of two levels of independent variables to observe the effects on the three dependent variables.

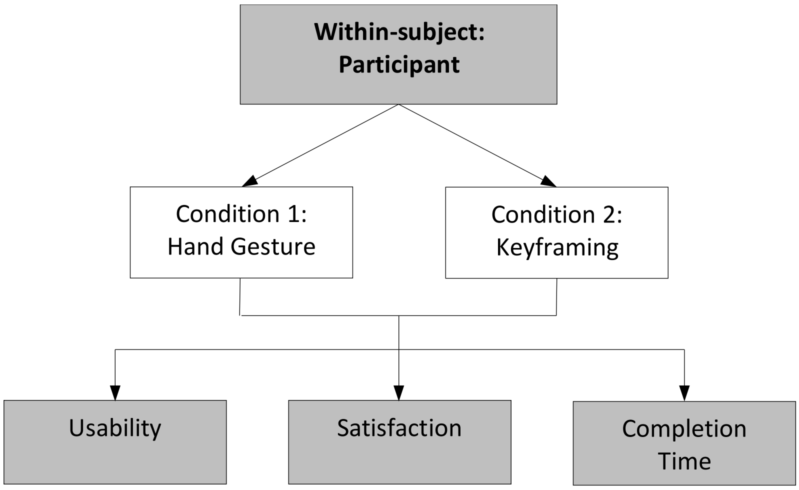


Figure 4.2: Independent and Dependant Variables

4.2.3 Variables

The variables relating to this study are outlines in Figure 4.1. The experimental data were measured in the two sets of quantifiable values of the independent and dependent variables. Two measures of the independent variables were used to obtain three types of result:

1) **Independent Variables**
   - *Type of animation*: whether hand gesture animation or keyframe animation was used.
   - *Level of expertise*: whether the users were novice or intermediate users.
2) **Dependent Variables**
   - *Level of usability*: the SUS questionnaire of hand gesture interface was used to assess whether users were novice or intermediate learners.
   - *Level of satisfaction*: the PSSUQ questionnaire of using hand gesture interface was used to assess the level of satisfaction of novice and intermediate learners.
   - *Task completion times*: the time the participants took to complete the tasks under each of the two situations was measured.

4.2.4 Tasks

Each participant was presented with a sheet explaining the tasks they would undertake (see Figure 4.3). As described in the instructions, the participants were asked to perform under two tests conditions, each having of two tasks. No specific completion time was given for each test condition or task as the participants could take as much time as they required, up to a maximum of 30 minutes for both tests.

TASK FOR USABILITY TEST

Thank you for choosing to participate in this experiment. Please read the instructions below before you begin.

1) In this experiment, you will need to animate a character under TWO different conditions:
   i) **<u>CONDITION 1: Using Keyframe Animation</u>**
      - Software use: Autodesk Maya.
      - Additional device use: a computer mouse (optional to Trackpad).

      TASK:
      - Animate the character with happy hand knocking; OR
      - Animate the character with sad hand waving

      Once completed, please answer the survey about this task.

   ii) **<u>CONDITION 2: Using Hand Gesture Animation</u>**
      - Software use: Hand-gesture Interface in Unity3D.
      - Additional device use: Leap Motion- a motion-sensing device.

      TASK:
      - Animate the character with happy hand knocking; OR
      - Animate the character with sad hand waving

      Note: The tasks chosen cannot be the same as in Condition 1
      Once completed, please answer the survey about this task.

2) You are required to create a character that can ONLY move its upper body.
3) A full-rigged IK-based character will be provided for you in both software programs.
4) You are free to choose how much time you spend animating using both pieces of software. However, there is a maximum of <u>30 minutes total duration</u> for this test to complete both scenarios.
5) Please be aware that there will be two ways of recording what happens:
   i) Your animation will be screen captured.
   ii) Your hand gestures during the animation process will be recorded.

6) When you have completed each task, there will 10 minutes to fill in post-test questionnaires, followed by a short interview of approximately 10 minutes.

Thank you for your cooperation.

Figure 4.3: Sample task sheet for participants

4.2.5 Survey Questionnaires

In the usability part, 12 questions were based on the System Usability Scale (SUS) standard items, which consists of positive and negative (Lewis and Sauro, 2009: 94) sentences which the participants chose to agree or disagree with. Another 12 satisfaction questions were based on the Post-Study System Usability Questionnaire (PSSUQ) (Lewis, 1992: 1261) standards. However, the basic questions were slightly modified and added to, according to the context of this experiment. A Likert-type scale of 1 (for Strongly Disagree) to 4 (for Strongly Agree) was used for both SUS and PSSUQ questionnaires. A set of two survey questionnaires consisting of three sections - two sections contained two parts as described below:

i) Section 1: Demographic Information

ii) Section 2: Experience of Using Keyframe Animation
    Part A: Usability Survey of Keyframe Animation
    Part B: Satisfaction Survey of Keyframe Animation

iii) Section 3: Experience of Using Hand Gesture Animation
    Part A: Usability Survey of Hand Gesture Animation
    Part B: Satisfaction Survey of Hand Gesture Animation

4.2.6 Post-Study Interview

A 10-minute post-experiment, semi-structured (Chua, 2012:138) interview with each participant was cunducted. Some basic questions were prepared in advance; however, some questions evolved as a result of the comments from the participants or were spontaneously added by the researcher as interviewer. When the participants were young undergraduate students, the conversation during the interview was kept informal, as formal procedures could have caused these students to be reserved with their comments. As the interviewer and the participants did not know each other, the interview becomes relaxed and without any feelings of bias or unbalanced power relations. All the interviews were conducted in English. However, a mixture of *Bahasa*

Melayu was used when the participants felt was most easy for them to communicate. The interviews were translated and transcribed directly from *Bahasa Melayu* into English.

The interview was used to evaluate both the techniques tested from participant's personal experience. A 'content analysis' technique (Robson, cited in Lazar et al., 2010: 208) was used to analyse the interview data. The interview responses were analysed according to three levels of usability:

1) **Usability** – the interview questions revolved around how helpful each interface tested was for users to achieve their animation goals.

   Interview Questions:

   i) Do you think the hand gesture animation helped you to complete the animation tasks?
   ii) Do you think hand the gesture technique is a practical way of animating a 3D character?
   iii) Do you think this technique fits in well with the Animation Principles?
   iv) Which method did you prefer to use for animation- the hand gesture or keyframing?

2) **Satisfaction** – the interview questions centred on learnability, of how easy and comfortable users found it to learn to familiarise themselves with the interfaces tested.

   Interview Questions:

   i) Which of the two techniques did you feel more comfortable with?
   ii) Do you think animators could learn the gesture technique more quickly?
   iii) Which element/s from the principles of animation are easy or difficult to control?
   iv) If you found the test system awkward or difficult to use, which particular part(s) were hard to control and why?
   v) While animating, did you feel you were using your sense of movement to create specific movement-timing for the character?
   vi) What technical problems did you encounter while animating using the keyframing and hand gesture techniques?

3) **Task Completion Time** – the interview questions were about whether the tested interfaces saved animation time animate and/or made the process of animation more productive.

   Interview Questions:

   i) Which of the techniques took you less time to complete the animation?

The feedbacks from the interviews are presented in the Qualitative Results in Section 4.7 in this chapter.

4.3 Methods

4.3.1 Participants

In this study, 23 participants were selected from a group of animation learners[14] from two different locations[15] in Malaysia. All participants[16] are native Malaysians, and the selections was based on budgetary limitation, logistic, and time restrictions. They were divided into small groups according to the day the experiment was conducted, as different class schedules meant the participants were available on different days and at different times. The tests were conducted on a one-to-one basis with the researcher. All the participants were volunteers.

The participants' experience in animation was either novice or intermediate[17]. The novices were inexperienced students who previously had little experience or no a formal training in 3D computer animation, and were not familiar with some animation principles. Nonetheless, the novice learners were familiar with the 'keyframe' method, which means they had previously done some work in 2D classical drawn animation or stop-motion animation. The intermediate learners were expected to have some understanding of creating animation, to know the fundamental process of frame-by-

[14] Animation learners as defined here are categorised as either in novice or intermediate groups of 3D computer animation users. It is important to note that, for this study, the novice learners are Diploma students while intermediate learners are Undergraduate students.

[15] The locations are at the Management and Science University (MSU), and Multimedia University (MMU). It is important to note that this experiment is not evaluating any significant difference in these places or their locations.

[16] Participants from MSU were Diploma or Undergraduate students specialising in Games Design and Animation. Participants from MMU were Undergraduate students from the Bachelor of Multimedia (Hons.) Animation and Visual Effects course.

[17] It is important to clarify here that there is no *Advanced Level* group in this study as advanced level ability and skills belong to the graduate level and/or industry practitioners who have higher levels of competency and experience.

frame animation and how to handle 3D animation. The intermediate learners were also expected to possess a basic understanding of the Principles of Animation. For both sets of learners, it would be an advantage for participants to have experience in computer gaming, especially simulation or action games which use handheld-control game consoles or devices. This is helpful for the natural-interface interaction.

A descriptive summary of the demographic information was analysed for the novice and intermediate group (see Table 4.1). As mentioned earlier, the participants involved in this experimental research were students from MSU (69.6%) and MMU (30.4%). The group, majority were male (novice 75.0%, intermediate 81.8%), and a small number of female (novice 25%, intermediate 18.2%). In The distribution of age, the novice participants were between 18 to 23 years old (100%) while 54.5% of participants at intermediate level were between 18-23 years old and the remaining 45.5% were 24-29 years old.

In terms of experience of producing animation, the majority of participants in the novice group had less than one year's experience (91.7%), while the intermediate group's experience varied, with 36.4% having less than one year, 27.3% with 1-2 years experience and 9.1% with more than 4 years experience. All the participants in both experience groups involved in this study were familiar with keyframe animation (100%).

Looking at the level of experience of creating animation, the majority were at beginner level (91.7%) hence, novice learners, while 45.5% were intermediate learners, and only one participant claimed to have an advanced level (9.1%).

Table 4.1: Participants' Demographic Information

Profile	Novice Group		Intermediate Group		Overall	
	n	%	n	%	n	%
Gender						
Male	9	75.0	9	81.8	18	78.3
Female	3	25.0	2	18.2	5	21.7
Age Categories						
18-23 years old	12	100.0	6	54.5	18	78.3
24-29 years old	-	-	5	45.5	5	21.7
Involved in Producing Animation						
Less than 1 year	11	91.7	4	36.4	15	65.2
1-2 years	1	8.3	3	27.3	4	17.4
3-4 years	-	-	1	9.1	1	4.3
More than 4 years	-	-	3	27.3	3	13.0

Familiar with Keyframe Animation						
Yes	12	100.0	11	100.0	23	100.0
Experience in Creating Animation						
Beginner	11	91.7	5	45.5	16	69.6
Intermediate	1	8.3	5	45.5	6	26.1
Advanced	-	-	1	9.1	1	4.3
Type of Animation[a]						
3D Animation	8	66.7	8	72.7	16	69.6
2D Animation	10	83.3	6	54.5	16	69.6
Stop Motion	5	41.7	4	36.4	9	39.1

Note: [a]This is multiple response analysis, which means each participant was allowed to select responses to more than one type of animation. The percentage value is based on the number of participants (not responses), i.e. the novice group has 12 participants, and there are 11 participants in the intermediate group.

Moreover, the type of animation technique most participants were familiar with in the novice group was 2D animation (83.3%), followed by 3D animation (66.7) and Stop Motion (41.7%). In the intermediate group, the majority were acquainted with 3D animation (72.7%), above the figure for 2D animation (54.5%) and Stop Motion (36.4%). The overall demographic information showed that the participants in both groups came from a variety of backgrounds and exposure to animation. These factors contributed to the outcome of the study.

4.3.2 Materials

All the necessary equipment for the experiment was stated in the task sheet (see Figure 5.3) for participants to read before commencing the experiment. The purpose was to make the participants aware of and anticipate the use of the equipment supplied. The animation material included an Inverse Kinematic (IK) complete-rigged 3D character for keyframe animation using Autodesk Maya software, another 3D character for hand gesture interface in Unity 3D. These items were installed on a MacOS-based laptop connected to a Leap Motion device and a mouse.

4.3.3 Procedure

The experiments were conducted at the locations where the participants studied. The test was conducted using a MacBook laptop, a mouse, a Leap Motion device, and related 3D animation software was arranged appropriately for each participant. Before each experiment began, the researcher who acted as the moderator in the interview, verbally explained the aim and process of the experiment and upon agreement, each participant signed a consent form, filled in the pre-test questionnaire, completed the conditions and tasks to be undertaken, filled in the appropriate questionnaire after each situation, and then had the post-test interview. The explanation was followed by a short demonstration to the participant about how each situation worked - the keyframing process, hand gesture manipulation, and how to deal with the Leap Motion device. Each participant was given enough time to familiarise him/herself with all the test situations before commencing the actual test. After each sub-test was completed, the participant was required to fill in questionnaires form about it. There were no external interruptions when the test was in progress. The moderator interfered only if the participant needed some assistance in handling each test condition situation. The experiment concluded with a 10-minute semi-structured interview. All the animations produced by each participant under both conditions were video-recorded for further evaluation of the task completion times. The post-test interviews were audio-recorded and transcribed for qualitative evaluation.

4.3.4 Reliability Analysis

Cronbach's Alpha reliability analysis method was used to analyse the internal consistency of the instrument used, in this case, the questionnaire feedback. The experiment measured two sets of test questionnaires (Usability, and Satisfaction) prepared with two sections (Section A: Keyframe Animation; Section B: Hand Gesture Animation). Each contained 12 items on a Likert-type scale. A good Crombach's alpha value is >.75 (Coolican, 2014: 217).

Table 4.2: Cronbach's Alpha Reliability Analysis

Variable	Number of Items	Cronbach's Alpha	Mean inter-item Correlations
Usability Keyframe	12	.556	.211
Satisfaction Keyframe	12	.777	-
Usability Hand Gesture	12	.624	.225
Satisfaction Hand Gesture	12	.895	-

The reliability analysis in Table 5.2 shows all the measurements for the instruments used. Based on Cronbach's value range, the scores are mostly >.75, and indicating the items were satisfactory. To measure usability reliability, an average mean inter-item correlation was used, as according to Briggs and Cheek (1986), the ideal range is between .15-.50 (see Clark and Watson, 1995: 15). Clark and Watson claim, "the optimal value necessarily will vary with the generality versus specificity of the target construct" (Ibid: 15). In this case, the inter-item correlation for usability is considered "desirable" (Ibid: 15).

4.3.5 Ethics

Before commencing the experiment, I applied for ethical consent by submitting an Ethical Approval Form (EAF1) form to the Research Ethics Committee at Goldsmiths, University of London. As this investigation requires people to participate in several experiments, I had to ensure that this research followed ethical procedure throughout the process. All the procedures in this study adhered to the ethical guidelines (MacKenzie, 2012: 159) stipulated by the committee.

Before the experiment, each participant was given time to read the tasks. The researcher, who was the moderator for the study, also briefed the participants about procedures of the experiment. Each participant then signed a Consent Form (see Appendix B-1: Usability Test Consent Form). It was stated in the procedure that in the case of a participant feeling uncomfortable about continuing the experiment for whatsoever reason, they could withdraw at any time. Although the participants' information was used to produce the results for this research, their data remains confidential and anonymous to respect their privacy.

4.4 Results

Descriptive Analysis

The quantitative evidence collected from questionnaires in this study was statistically analysed to organise and present the data. In order to compare the means of the two groups (Lazar et al., 2010: 76), I used an Independent-sample t-test. In this case, I investigated whether there was a significant difference in the usability, satisfaction and efficiency between the two levels of expertise and two types of animation. All the quantitative results are presented in Section 5.4 of this chapter.

4.4.1 Usability Level

A within-subject Factorial analysis of variance between the groups was conducted to discover the influence of the two independent variables (level of expertise, type of animation) on the level of usability. The level of expertise had two levels (novice and intermediate) and there were two types of animation (hand gesture and keyframe)[18].

The mean scores for usability showed using hand gesture animation received a higher score, M=3.24 than using keyframe animation, M=3.15 in the novice group. Likewise, using hand gesture animation, M=2.95 was higher than using keyframe animation M=2.89, in the intermediate group. The novice group showed a higher percentage (1.41%) than the intermediate group (1.03%) in preferring hand gesture animation to keyframe animation. The scores are presented in Table 4.3.

Table 4.3: Factorial Design Analysis for Usability Level

Group	Using Keyframe (M ± SD)	Using Hand Gesture (M ± SD)	Changes (%)
Novice	3.15 ± 0.23	3.24 ± 0.29	1.41
Intermediate	2.89 ± 0.26	2.95 ± 0.22	1.03

In terms of the types of animation, $F(1, 21) = 1.382$, $p = .253$, $\eta^2 = .062$, Hence, there was no significant effect on usability between hand gesture and keyframe animation. For level of expertise between novice and intermediate, $F(1, 21) = 9.741$, $p <.05$, $\eta^2 = .317$, hence, no significant interaction effect was found from the level of expertise. This means that the participants in the novice group had a better level of usability using both keyframe and hand gesture animation than those in the intermediate group.

[18] The reporting template for Factorial analysis can be found at: http://www.slideshare.net/plummer48/reporting-a-factorial-anova

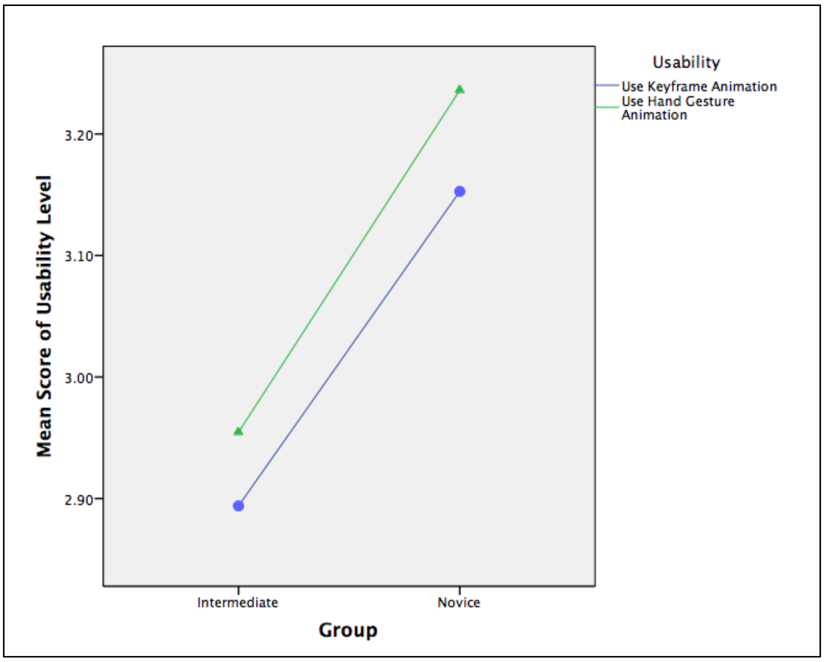


Figure 4.4: Level of usability between type of animation and level of expertise

The line graph in Figure 4.4 shows the dependent variable for level of usability as a combination of two independent variables; level of expertise (novice and intermediate) and type of animation (hand gesture and keyframe). The results indicate that there was no significant interaction effect F (1, 21) = 0.034, p =.855, η^2 = .002. The lines indicate the main effect was level of expertise, and not interaction. There was no main effect from the type of animation but a change for the level of expertise

The usability score for level of expertise indicated that the novice group were interested in the keyframe at M=3.15, but had more interest in hand gesture animation at M3.24. Also, the intermediate group showed more interest in using hand gesture at M2.95, higher than using keyframe at M2.89.

4.4.2 Satisfaction Level

A within-subject between groups Factorial analysis of variance was conducted on the influence of two independent variables (level of expertise, type of animation) on the level of satisfaction. The level of expertise included two levels (novice and intermediate) and two types of animation (hand gesture and keyframe)[19].

The mean scores for satisfaction level shows hand gesture animation received a higher score of M=3.24 than keyframe animation of M=3.20 in the novice group.

[19] The reporting template of Factorial analysis can be found at: http://www.slideshare.net/plummer48/reporting-a-factorial-anova

However, hand gesture animation at M=2.95 is lower than keyframe animation at M=3.05 in the intermediate group. The intermediate group had a lower change percentage (1.67%) than the intermediate group (0.62%) in using keyframe animation rather than hand gesture animation. The results are presented in Table 4.4.

Table 4.4: Factorial Design Analysis for Satisfaction Level

Group	Using Keyframe (M ± SD)	Using Hand Gesture (M ± SD)	Changes (%)
Novice	3.20 ± 0.31	3.24 ± 0.52	0.62
Intermediate	3.05 ± 0.36	2.95 ± 0.26	1.67

For the types of animation, F (1, 21) = 0.103, p = .751. Hence, there was no significant difference in satisfaction level between hand gesture and keyframe animation. Concerning the level of expertise between novice and intermediate participants, F (1, 21) = 3.069, p = .094, η^2 = .128. Hence, no significant interaction effect was found in the level of expertise. This means the novice group did not turn out to have any greater satisfaction level using keyframe or hand gesture animation than those in the intermediate group.

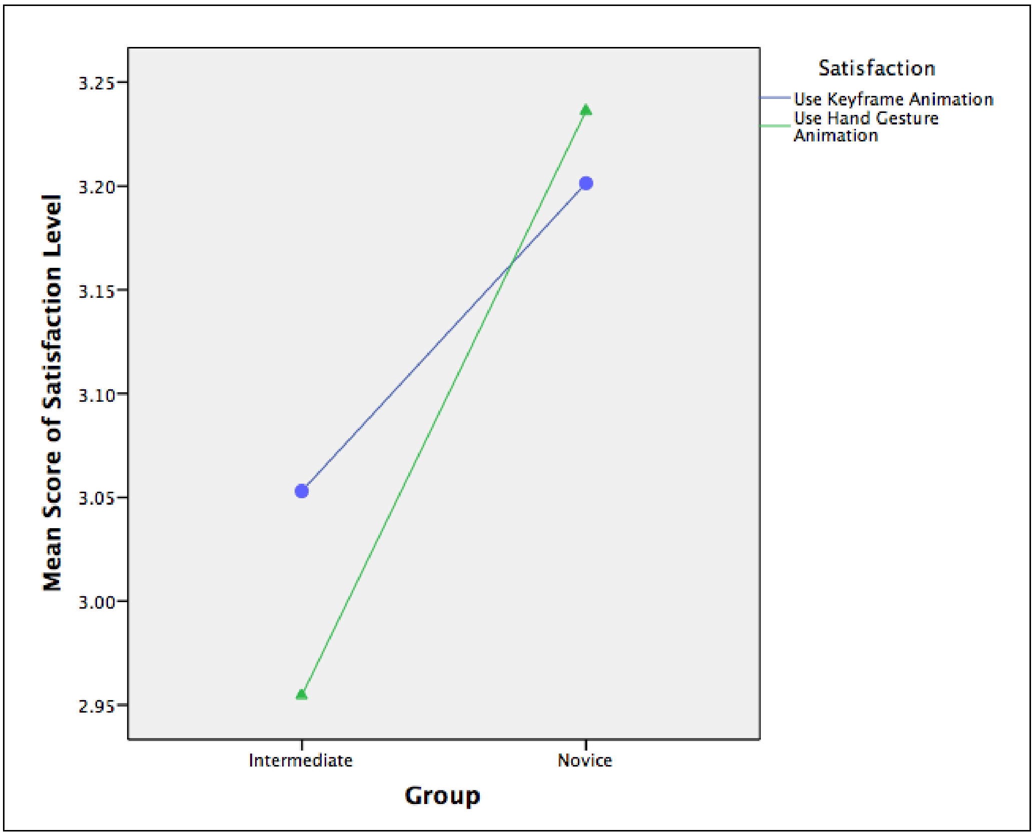


Figure 4.5: Level of satisfaction between type of animation and level of expertise

The line graph in Figure 4.5 shows the level of satisfaction between the type of animation (hand gesture and keyframe) and level of expertise (novice and intermediate). The lines illustrate that there was no main effect for type of animation, and no main effect for level of expertise. The results show the lines are not parallel but a crossover interaction F (1, 21) = 0.451, p =.509, η^2 = .021.

4.4.3 Task Completion Time

This was to measure the time each participant spent on completing the tasks in both test conditions to find out the efficiency level - the time the participants' needed to complete the animation.

Factorial ANOVA two-tailed paired t-test was conducted to discover the influence of two independent variables (level of expertise, type of animation) on the task completion time. The level of expertise included two levels (novice and intermediate) and two types of animation (hand gesture and keyframe).

Table 4.5: Factorial Design Analysis for Task Completion Time

Group	Using Keyframe (M ± SD)	Using Hand Gesture (M ± SD)
Novice	8:06 ± 0.26	1:46 ± 0.04
Intermediate	6:41 ± 0.11	2:30 ± 0.04

The average scores presented in Table 4.5 for task completion time showed that hand gesture animation required much less task completion time at M=1:46 minutes compared to keyframe animation at M=8:06 minutes in the novice group. Similarly, in the intermediate group, while hand gesture animation time was higher at M=2:30 minutes, it was lower than keyframe animation at M=6:41 minutes. This shows that hand gesture animation is much faster than keyframing. However, the novice group worked faster using hand gesture than the intermediate group.

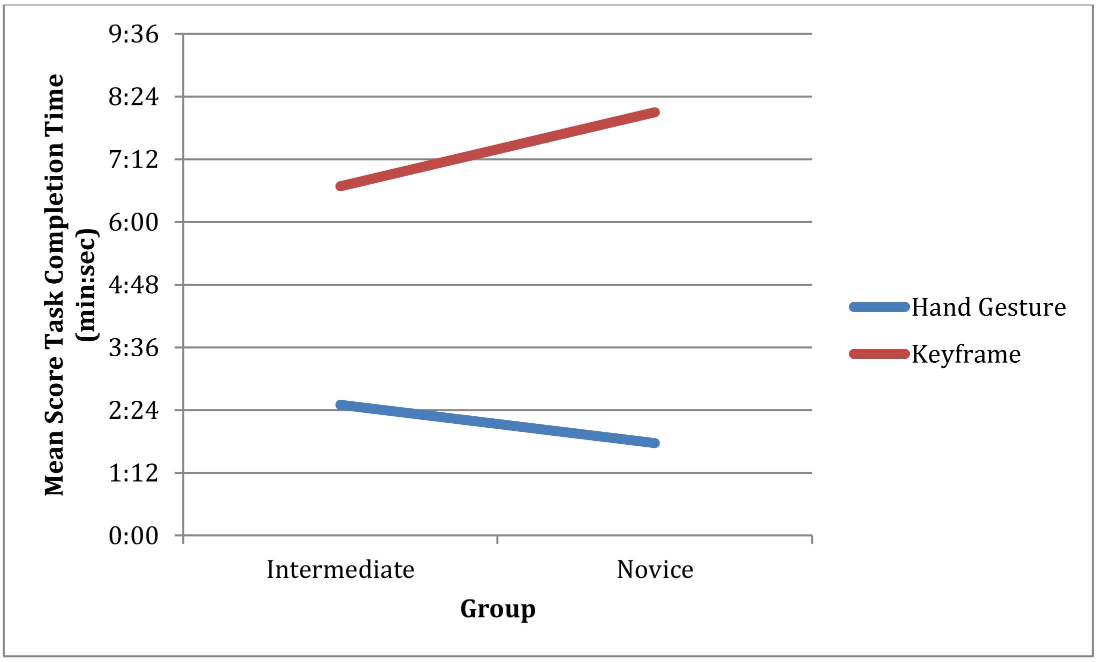


Figure 4.6: Task completion time between type of animation and level of expertise

The line graph in Figure 4.6 shows task completion time for level of usability, which combined two independent variables; level of expertise (novice and intermediate) and type of animation (hand gesture and keyframe). The results indicate that there was no significant interaction effect. The lines describe the main effect for level of expertise, and no interaction. There was no main effect for level of expertise but there was for type of animation.

4.5 Qualitative Results

In the study, I conducted a post experiment interview with each participant individually. All 23 participants were interviewed to evaluate their experience of handling the tasks given. The results of the interview are categorised according to the three usability measurements in user-centred design: Usability, Satisfaction, and Efficiency (using task completion time). Each category is categorised according to its thematic area.

4.5.1 Usability

The usability aimed to identify whether the users found the interface could help them achieve a desirable result in producing their animation. From the interview, they seemed uncertain about how hand gesture could successfully aid the animation process, perhaps because hand gesturing was relatively new to them, and their level of experience of handling keyframing.

1) Hand gesture controls movement and timing simultaneously

Compared to keyframing, seven out of the 23 participants found hand gesture animation user-friendly as it controls both movement and timing. Some participants gave interesting responses about the effectiveness of hand gestures. For instance, realising that keyframing requires a lot of time to harmonise the accurate setting of frames in order to obtain a certain outcome, one participant observed:

> *"It can also control the timing of the movement at the same time without having to determine how many keyframes are needed to create snappy or slow animation timing".*

In contrast, one participant commented that it was unlikely that hand gesture animation could create the snappy style of movement for cartoon-like animation. He commented:

> *"It depends on what type of animation are we creating; for example, animating a cartoon might need fast and snappy movements. Hand gestures might not be able to create this type of movement".*

From another aspect, a different participant noted that the process of thinking ahead of an action to animate before choreographing the hand can help to create a better-looking result in terms of timing:

> *"To control timing with hand gesture, we should know beforehand the movement that we want to make. For example, if we want to animate a 'happy hand waving', we can visualise in our head what it looks like and when gesturing with our hands, we can use our intuition about the timing needed".*

Another participant mentioned he found hand gesturing enabled users to provide instant 3D character poses within a short amount of time. He said:

> *"In terms of movement, hand gesture is quicker because it can move several body parts at once, for example, animating the 3D character bending his body down to pick an object from the floor and lifting it up".*

2) Details of movement such as timing works effectively only with keyframing

Nonetheless, five participants commented that timing in animation is related to giving details for any movement created in order to provide expressive movements. They felt that hand gesture animation is limited and unable to achieve some of the more detailed aspects of animation. Moreover, keyframing is preferable hand gesture animation because of how the system of creating timing is generated in 3D software. Below are some of the mixed opinions from five participants:

> "*Keyframe animation is much more detailed in creating movement.*"

> *"I personally would choose keyframe to create animation because I like the way timing is created through keyframe".*

> *"When you get into complex animation such as animating a ball bouncing, creating squash and stretch, and animating bipedal characters, it starts to get more complicated and you have to learn a lot more in order to perform keyframe animation accurately and effectively".*

> *"In terms of creating timing with hand gestures, the movement flows more naturally but if I want to be more accurate, I think I would use keyframe because I could just insert a frame at an exact spot. I can get accurate timing with keyframe, but I can go more naturally with hand gestures".*

4.5.2 Satisfaction

Most participants tended to give comments of satisfaction with both tested interfaces. They appreciated the simplicity of use and learnability of Hand Gesture Animation.

1) Hand gesture animation is simple, straightforward, easy to learn and enjoyable

Eleven out of the 23 participants who took part in this experiment were pleased with hand gesturing for many reasons such as it is simple to learn, comfortable, and user-friendly, with comments such as:

> *"Hand gesture animation is simple".*

> *"Hand gesture is much easier to learn and straightforward".*

> *"Hand gesture is a lot easier to use because no keyframes were used while animating".*

> *"Hand gesture animation is quite simple to use and easy and takes less time to learn".*

> *"It is easy to learn both keyframe and hand gesture animation".*

Although the majority of participants felt comfortable and excited about hand gesturing, two participants were aware of some slight discomfort during their first attempt:

> *"I find hand gesture animation is quite interesting. It's a bit uncomfortable to use at first".*

> *"Hand gesture is quite user-friendly and easy to understand how its interface functions. However, the rotation of our hand/wrist is limited to certain extent and unable to rotate 360 degrees".*

Two participants found hand gesturing to be a fun and enjoyable method for animating:

> "*I don't feel tired moving my hands in the air with hand gesture animation and I enjoyed using it the most".*

> *"It can be fun using hand gestures to animate* because we can animate while standing or sitting in different places unlike animating using keyframe when we need to sit all the time*".*

2) Hand gesture is difficult to learn

Almost half of the participants enjoyed hand gesture animation, but eleven participants found it awkward to use as an animation technique. For them, hand gesture animation requires a set of new skills of learning to articulate hand gestures in order to animate a 3D character. Additionally, as they were first-timers using this technique, more time was needed to train and become familiar with the hand gesturing style of manipulation:

> *"I think I need more time to learn how to use hand gesture animation".*

> *"Hand gesture animation is simple but not effective. Moving the hands looks natural but it is hard to control the 3D character".*

> *"Since hand gesturing is new, I might need slightly more time to learn gesturing and controlling the speed of my hands".*

> *"I find it is interesting to use hand gesture animation but quite difficult to control because I am not familiar with this method".*

> *"For new users, hand gesturing can be quite uncomfortable but one becomes accustomed to it after a while".*

> *"As it was the first time I had used hand gesture animation, I found it hard to control the movements of the character".*

> *"I think it would take some time for me to adapt to using hand gesture but I think if we spent more time learning it, it would be easier to get used tousing it".*

> *"It can be quite difficult for those who are not familiar with hand gesturing but should not be a problem after a while once we know how to control using it".*

Some participants made more specific observations about hand gesturing. One participant claimed that the system could get out of control: *"…in hand gesture, if we are unable to control our hands accurately, the animation of the character can get* *chaotic".* Another participant, commenting on the outcome of hand gesturing, said it was *"... quite troublesome and sometimes the movement is not like I expected it to be".* Another participant found the limitations of tool function in the interface made navigating difficult: *"I think hand gesture is hard to use to animate a character because we are unable to see the character from different angles. Due to that, I was unable to see the position of the character's hand".*

3) Keyframe takes time to learn

Keyframing is known for the complexity of its process. From the interview, eleven participants referred to keyframing as a "difficult" technique to learn especially for "beginners" and it could take "some time" to understand and grasp the necessary skills. One experienced participant found it manageable but what made it time-consuming was how movement-timing is managed for an appropriate action. He said, "*I have been familiar with keyframe animation for several years and had no problem learning it although at the beginning, I found it quite difficult because I could not anticipate the timing between the frames".* Another participant had a similar belief, *"For people starting out or those with only a few years of experience, it takes a lot of time to learn how to create the proper speed and distance between keyframes".*

Some participants who had to switch from different 3D software to another, similar software took slightly longer to familiarise themselves with the tools. This is probably due to the different interface arrangements in every 3D software package. One participant commented, "*I think it is slightly difficult to familiarise oneself on switching from Blender to Maya. This is the first time I used Maya and I think Maya is easier to animate".* In contrast, three participants found keyframing is easy when switching to similar software: "*I had no difficulty switching to Maya because I have used Blender before", "I felt it was easier and easy to learn switching from Blender to Maya although I am not familiar with Maya, but the functions are almost the same"*. One participant from a 2D animation background said *"I have experience of using Flash, therefore I could easily learn and be comfortable using keyframing".*

Meanwhile, two participants suggested the keyframing process and the use of WIMP interface for long hours could lead to health concerns like developing Carpel Tunnel Syndrome. "*Keyframe animation can take a long time using a mouse, which can lead to wrist pain such as Carpel Tunnel Syndrome',* and *"For the most part, using* *a mouse means my hand stays on the mousepad and after a while, you feel uncomfortable and might end up with Carpel Tunnel Syndrome".*

4) Keyframe is easy to learn

While some participants found keyframing challenging, eleven participants seemed to enjoying the keyframing experience from various aspects. One participant commented, "*At the beginning, learning to keyframe is tricky, but as the learning progresses, it becomes easier".* Some participant preferred animating using keyframe animation to hand gesturing because of the simplicity of the technique, as one said, "*…every movement in keyframing is easier to control due to the frame-by-frame concept."* Another participant added*, "Keyframe is easy to control for fast or slow timing. We need to set key frames and then we playback to see the animation".* The well-established 3D animation software makes it user-friendly, as one participant commented, *"Keyframing is quite simple to use because the interface is right there so that you know to move frames back and forth".*

5) Hand gesturing in mid-air could lead to tiredness

Most of the participants were satisfied with hand gesture animation as a relatively a new approach to animation. They felt the mid-air hand gesturing technique was "exciting", "practical" and flexible to use for animation. Three participants commented, *"I didn't feel tired while hand gesturing because what was in my mind was fun and I enjoyed doing it. I felt like I was playing a computer game", "Using hand gestures made me feel more relaxed and I was able to stretch my hands while gesturing. Hand gesturing was a relief for me". "I felt comfortable doing hand gesturing in mid-air but pretty silly".* One participant seemed happy switching between hands so that he could avoid his hands feeling tired. He commented, *"For the length of time that I was doing it, it wasn't tiring at all. It's because you can change hands from left to right and I suppose it wouldn't be as tiring as if you stuck to just one hand. A lot of problems can happen while using a mouse".*

In contrast, some participants expressed their concern that mid-air hand gesture animation could lead to tiredness. Hand gesturing, they thought, could be practical for a short period of time but if one animator takes many hours to produce an animation, they could feel tired and uncomfortable. Three participants believed that the conventional tools were still their preference,

> *"I felt tired while doing hand gesturing in mid-air and it takes too long to perform animation work. I think most people are more comfortable using a mouse".*
>
> *"I think hand gesturing can be tiring if the process takes more than 10 minutes. But if it takes a whole day of lifting up your hands in mid-air to create animation for a production, it could be tiresome. Using a mouse can be tiring sometimes but at least we can rest our hands on a flat surface".*
>
> *"I would feel tired if it took a long time to do the animation because I think it puts burden on the hand and mind to think how to move. Unlike using a Wacom pen, which I feel comfortable with, which is what I normally use in most of my work".*

6) Required assistance how to use hand gesture animation

A few participants believed that hand gesture animation requires training in order to get acquainted with the technique. Three participants stated, *"I agree that I need someone to teach me how to use both methods", "For hand gesture animation, we have to know how to control it"* and *"I need someone to teach me to learn how to use hand gesture animation comfortably"*. One participant felt odd using the technique and that he needed assistance while doing his task: *"Since it is the first time I have used the software, I have to keep referring back to you to understand how to move the hand".*

4.5.3 Efficiency

Through the task completion time test, most participants were inclined to comment on the less effort needed and time saving elements of hand gesture animation during the experiment. Almost all the 23 participants agreed that hand gesture animation made their work much faster and less expensive compared to the time they spent on keyframe animation. Some of the comments were: "*…it is a lot quicker to complete an animation", "…it does get the job done more quickly", "With hand gesture animation you immediately get a response",* and *"I am attracted to animation using hand gestures because it is a new approach to animate. It could make the process of animation much faster".*

While seeing himself as an advanced learner of keyframe animation, one participant saw hand gesture animation as a method for a beginner who had difficulty understanding keyframing. He thought that hand gesture animation could help with the demands of working capacity that is increasing higher for animators:

"It is good for ordinary people like us dealing with keyframes. You can finish up your work faster to cope with demand right now and improve your work".

1) Keyframing is a complicated and time-consuming process

While examining how efficient hand gesturing could ne, all 23 participants accepted that keyframing could be a tedious and time-consuming process. Various comments explained that what makes the process laborious is the construction of frames and modifying new sets of keyframes:

"*If we wrongly set the keyframe, we have to redo the animation".*

"I think keyframing is tedious because we have to animate frame-by-frame".

"In keyframing, I have to animate frame-by-frame".

"Unlike keyframing, where we have to move the character's body parts one-by-one".

Four participants commented that keyframing is a complicated process. It is a complex method because it is not a real-time based creation of movement and timing but an imperceptible construction of timing that requires reiteration to obtain feedback:

"Keyframing is complicated because every frame is adjusted using a mouse but the overall desired animation cannot be seen".

"You need to determine the distance between the keyframes you need to place between each pose because you do not get a real time response".

"With keyframes, you have to guess or determine the timing of the movement in order for it to look smooth on the animation".

"It takes time to correct the inserted keyframes. We need to imagine how the timing should be before we insert the keyframe. We also need to playback to see whether the animation works as intended".

2) Hand gesture animation is a real-time based animation that provides smooth and spontaneous movements

While keyframing is perceived as a time-consuming process, hand gesturing is observed to be a real-time based animation. Eight participants found that animating with hand gesture was quicker, practical and uncomplicated. The simplicity of the method is because movement and time are processed from the actual world, by directly manipulating the character using our hand gestures. Seven participants commented, *"Hand gesture animation is faster and easier way to create animation because it is real time based".*

"Hand gesture is much simpler because the character moves as our hand moves".

"The movement of the character imitates my hand movement in real time".

"I think hand gesture animation is very practical to use because this method is not using keyframes to animate. All we need to do is to move our hands".

"For bipedal characters, hand gestures work perfectly because you don't have to go into the whole process of learning keyframes. For certain manoeuvres, you just move your hand and he character moves along with you".

"While gesturing, my attention is on the 3D character rather than my own moving hands. For example, if the hand is leaning forwards or backwards, the character will automatically imitate the hand".

One participant saw the potential of hand gesture animation as a low-cost and inexpensive method to create real-time based animation:

"Hand gesture animation has a lot of potential, especially for companies, as they don't have to invest in motion suits".

Generally, creating animation in real time made the movements of 3D characters look more natural and spontaneous. Two participants, among others, commented

"I think hand gesture is more spontaneous and quicker to animate than keyframe".

"I think it help my work a lot in the sense that the movement comes naturally from me".

4.5.4 Recommendations from participants

It is understandable that hand gesture animation technique is relatively new to the users compared to keyframing, so they had not got used to it. Most participants accepted hand gesture as a novel approach to animation. They believed that hand gesturing has great potential for further development as a technique that could create unique animations. Two participants suggested the hand gesture interface should be enhanced with more functions such as rotating the character to allow viewing from different angles. They suggested, *"Hand gesture should enhance its interface functions such as being able to rotate the character to view it from different angles"* and *"I suggest that with hand gesture, the camera could rotate as well so that the 3D character could be viewed from* *different directions".* This function could make the character more accessible to the process of animation.

4.6 Discussion

The statistical results show the task completion time for hand gesture animation was significantly less than for keyframe animation. This suggests that the participants created their animation more quickly using the hand gesture interface than the keyframing technique.

Based on the qualitative results that were categorised into several aspects (see 5.7), the findings were that hand gesture made animation work less complicated and reduced the time spent on creating an animation. Keyframe animation, for novice learners, is a complex and laborious technique for creating animation, while hand gesture animation is much simpler and interacts spontaneously in real time. From the observations during the keyframing experiment tasks, the users struggled with the complexity of positioning and swapping keyframes. Upon playing back the animation, the outcome is often not as desired. Hand gesture animation, on the other hand, is an inexpensive and convenient technique compared to other real-time based methods of animation. The real-time interactivity between user and 3D character also increased the interest and motivation of some users when they saw they could interact instantaneously with virtual characters.

However, when gesturing, I noted that users experienced some confusion between their hands and the character's limbs they were trying to move. They were unsure which hand they should use to synchronise with the character's movements. The users were also perplexed by the XYZ axes directions when they were moving their hands both in real time and in virtual space. For instance, if the user moved his/her hand forward in real time, s/he pushed the 3D character's hand backwards in virtual space. As a result, the users were confused between their moving hands and movements of the 3D character and lost focus. This made interruptions in hand gesture animation rather common to determine which axis was the direction of movement. This has caused some difficulty in learning the hand gesture interface and it became "troublesome" for some users. Appropriate training is also required for hand gesture animation to help users familiarise themselves with the method and understand the technique. Another disadvantage of hand gesture animation is that, for some users, it caused discomfort and fatigue due to its interface requiring users to exploit mid-air as their manipulation space rather than the usual way of resting the hands and using a mouse and keyboards on a desk while working with computers.

4.7 Summary

The results of the usability study suggest that although there are significant advantages in using hand gesture animation and an increased level of interaction between the user and 3D character, the result also revealed the weaknesses of the system. There are also possible debatable issues surrounding the potential quality of hand gesture animation, which occurred during the process of the feedback and interviews. This issue is explored in the next chapter.

5 Chapter 5

Quality of Animation Using Hand Gesture Interface

5.1 Overview

The results from previous chapter showed that the hand gesture technique worked faster and increased the interaction between the user and 3D character compared to keyframing. Nonetheless, the participants found the interface impractical for producing animation. This chapter investigates how far hand gesture animation is worth exploiting, while also addressing the fourth research question concerning over the appearance and quality of the hand gesture animation.

5.2 From Usability to Quality of Animation

This experiment is derived from the outcome of the usability and satisfaction studies to investigate the level of quality a user can create in the animation. However, this study does not measure the quality of the appearance of the finished animation each participant produced at the end of the test. Rather, this study evaluates the quality of the hand gesture interface from the user's perspective of hand gesture as an approach that could help them create animation. This study addresses questions such as: If hand gesture was able to produce movement and timing naturally, could users work effectively with it? Keyframing is renowned for its laborious process, so how could it be made to work more effectively?-If users think the hand gesture interface is efficient and were satisfied in terms of their task completion time, are they able to produce a good piece of animation? Can hand gesture animation be compared to keyframe animation in terms of handling the interface?

5.3 Experimental Design

This is the second part of Implementation Phase in which I evaluate the interface through a quality of movement animation study. I used a similar experimental design, however, some components have been altered in the hypotheses, and changes made to the study task, and survey questionnaires. This study was also accompanied by a semi-structured interview. The experiment has two independent variables in which a factorial design (Lazar et al., 2010) within-subject (Cairns and Cox, 2008) was employed.

5.3.1 Hypotheses

From the quantitative and qualitative results in the previous study, I formulated another hypothesis statements. In order to examine the consistency of the previous results, I evaluated the quality of the interface according to whether or not the hand gesture technique is capable of providing good animation.

Hypothesis 1.1: There is a **significant difference** in the quality of movement between hand gesture and keyframe animation.

Hypothesis 1.2: There is an **interaction effect** on the quality of animation between the level of expertise (novice or intermediate) and the type of animation (keyframing or hand gesture).

5.3.2 Within-subject

For this study, I asked for 20 volunteers. Each of the participants was assigned to perform under the two different conditions of Hand Gesture Animation and Keyframe Animation in order to obtain one dependent variable. The within-subject structure is shown in Figure 5.1.

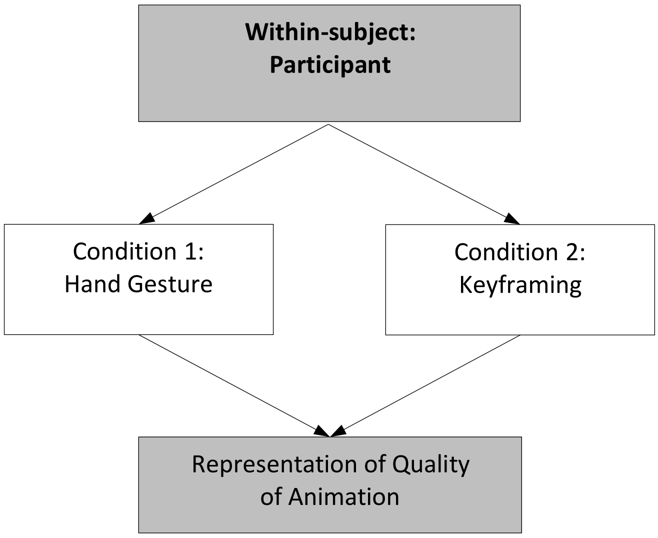


Figure 5.1: A within-subject structure

5.3.3 Variables

The purpose of this study was to test the hypotheses resulting from the previous study. The two independent variables were re-claimed from the previous study in order to obtain a different dependent variable (see Figure 4.1 in Chapter 4).

1) Independent Variables

- *Type of animation*; whether the participants were using hand gesture animation or keyframe animation.
- *Level of expertise*; whether they were novice or intermediate users.

2) Dependent Variables

- *Level of animation movement quality*; assess with the three questionnaires (from each type of animation group) based on the results found from the previous usability and satisfaction study.

5.3.4 Task

All the participants in both groups performed two tests: Hand Gesture Animation and Keyframe Animation. In each, they were asked to choose and complete one of the following tasks:

i) Animate the character waving its hand with a:
   - Happy (movement-timing: quick) OR
   - Sad (movement-timing: slow)

ii) Animate the character with a punching or pushing hand:

- Hard punch (movement-timing: heavy/quick) OR
- Soft punch (movement-timing: light/slow)

In each task the participants could choose one of two actions with accompanying expression, but not the same type in both tests. These everyday actions with descriptions functioned as guidelines for the participant to imagine the type of action to be performed - with quick or slow, heavy, or light movement-timing. It would have been difficult for the participants to imagine a form of expression if the instructions were only to animate waving or a punching fist. Both tasks had to be completed in a maximum 30 minutes.

5.3.5 Survey Questionnaire

For this study, the questionnaires were straightforward with fewer details. The participants were required to rate three question items for each test on a Likert-type scale, with 1 for 'Strongly Disagree' and 5 for 'Strongly Agree' (see Figure 5.2). The question items were based on the feedback from the previous study test (Chapter 4) about how users perceived the benefits and drawbacks of hand gesture and keyframe animation (see Appendix C-2: Quality of Animation Survey).

Hand Gesture Animation

	1 Strongly Disagree	2 Disagree	3 Neutral	4 Agree	5 Strongly Agree
1) I think the animation I created using hand gestures looked good					
2) I think the movement and timing of my hand gestures was at the right time and place					
3) I think I was able to express emotions (i.e happy/sad waving hard/soft punching) when animating hand gestures					

Keyframe Animation

	1 Strongly Disagree	2 Disagree	3 Neutral	4 Agree	5 Strongly Agree
1) I think the animation I created using keyframe look good					
2) I think the movement and timing of the keyframes were at the right place and time					

3) I think I was able to express emotions (i.e happy/sad waving hard/soft punching) while animating using keyframes					

Figure 5.2: Questionnaires for quality of movement animation study

5.3.6 Post-study Interview

A 10-minute post-experiment interview was conducted after each participant had completed the experimental and questionnaire parts of the test. The semi-structured interviews were carried out informally to make the participants feel at ease. Although most questions were prepared in advance to guide the flow of the interview, some questions were also arose from unanticipated comments from the participants. All the interviews were audio-recorded in English. However, a mixture of *Bahasa Melayu* was used, depending on each participant's choice of language at a given point. The interviews were translated and transcribed from *Bahasa Melayu* into English.

The interview questions (see below) were randomised but centred on how movements are naturally or mechanically created in the different coordinating systems of the two test conditions. The feedback from each question was then analysed using 'content analysis' ((Robson, cited in Lazar et al., 2010: 208) into several themes based on the important keywords frequently used by the participants.

Interview Questions:

1) Considering hand gesture and keyframe animation, which method do you think makes it easier to control movement and timing while animating the character? Why?
2) Between hand gesture and keyframe animation, which methods do you think is looking more natural or mechanical to manipulate its movement and timing?
3) Which method do you think takes less time and/or is less time-consuming to animate, hand gesture or keyframe animation?
4) Which of the X,Y,Z axes did you find easier to move and control?
5) Which method do you think makes it easier to apply the notion of timing from the Principles of Animation?

6) While using keyframe animation, was your attention focused on dragging the selected object on X, Y, Z axes in 3D space or in anticipating where to insert the keyframing process on the timeline?
7) While using hand gesture animation, was your attention focused on the movements of the character in 3D space or on your own hands moving in mid-air?
8) Do you think hand gesture animation or keyframe animation or both are useful for producing animation?
9) Do you think interaction between the user and the3D character could help you to produce animation? If so, in what way?
10) Of the two methods, which do you think could provide good quality of animation?

5.4 Methods

The methods used in usability study (Chapter 4) were also used in this experiment.

5.4.1 Participants

The participants in this experiment were also selected from among animation learners. However, these participants came from a different location to the participants in the previous experiment. They come from Years One to Three undergraduate students in the Animation and Screen Technology[20] programme. The participants were divided into novice and intermediate groups[21] based on the level of their animation skills from their year/s of study. In this experiment, there was no demographic survey as the participants were selected according to their animation experience by year of study, as explained above and in the footnote. The novices were mixed learners ranging from new students and those who had developed an understanding of animation through 2D drawn animation as their introduction to the principles of animation. The intermediate

[20] This is a 3-year bachelor degree programme offered at the Faculty of Film, Theatre, and Animation, *Universiti Teknologi Mara* Malaysia (UiTM). The programme comprises 6 semesters. For the purpose of this study, the novice group are Year One students who are in Semesters 1, 2, or 3, while the intermediate students are in Semesters 4, 5, or 6.

[21] It is important to clarify here that there is no 'Advanced Level' group as the ability and skills for this type of category is appropriate to graduate level and/or industry practitioner with a higher level of competency and experience.

group were students who had progressed to learning 3D computer animation and have knowledge of the principles of animation. All the participants had voluntarily agreed to take part in this experiment.

5.4.2 Materials

The equipment used in the usability study were used again in this study as it study is a continuation of the usability experiment. Therefore, the same 3D characters, Autodesk Maya and Unity 3D, gesture interface, Leap Motion, and a mouse were all installed and connected to MacOS platform laptop, as in the usability study.

5.4.3 Procedure

The experiment was conducted with each participant one by one in an enclosed room where there were no distractions. A MacOS laptop, a mouse, a Leap Motion, and other related software were provided and setup for use. The moderator, who was also the interviewer, verbally described about the order of the experiment to each participant. After they had verbally agreed to take the test, they were given the Consent Form to sign. The participants were given a short demonstration on how to operate the equipment for both parts of the test. The demonstration included the functions of the software that they would be using in the test. A few minutes of hands-on practice time was given to each participant to familiarise themselves with the entire procedure. While the test was in progress, there was no external interference from other sources except assistance from the moderator, if necessary. After each test situation had been completed, the participants were asked to fill in a questionnaires based on the test they had just completed. The experiment ended with a 10 minutes semi-structured post-test audio-recorded interview for further qualitative evaluation. All the animations made in both test conditions were video-recorded for future reference.

5.4.4 Reliability Analysis

Cronbach’s Alpha reliability method was used to analyse the internal consistency of the instrument used, in this case, the questionnaire feedback. The data comes from two sets of Quality of Animation questionnaires: 1) for Hand Gesture Animation, and 2) for Keyframe Animation. Each contained questionnaire items with Likert scale responses. A good Cronbach’s alpha value is >.75 (Coolican, 2014: 217).

Table 5.1: Cronbach's Alpha Reliability Analysis

Variable	Number of Items	Cronbach's Alpha	Mean inter-item Correlations
Quality of Animation in Keyframe Animation	3	.774	-
Quality of Animation in Hand Gesture Animation	3	.562	.292

The reliability analysis in Table 5.1 showed the entire measurement for the instrument used. Based on Cronbach's value range, scores for the quality of animation in keyframe animation is >.75, indicating the items were acceptable. For the quality of hand gesture animation, an average Mean inter-item correlation was used, as according to Briggs and Cheek (1986), the ideal range is between .15-.50 (see Clark and Watson, 1995: 15). Clark and Watson claim, "the optimal value necessarily will vary with the generality versus specificity of the target construct" (Ibid: 15). In this case, the inter-item correlation for quality of animation in hand gesture animation is considered "desirable" (Ibid: 15) items.

5.4.5 Ethics

The ethical matters applied to the usability study (see subsection 4.2.4) were also conformed to in this experiment. A sample of participant's consent form can be retrieved in the Appendix C-1: Quality of Animation Test Consent Form.

5.5 Results

A statistical analysis presents the quantitative data from this study. A reliability test was used to check the consistency of the instrument used and a factorial design analysis to see if there was any interaction effect on the quality of movement of the animation due to the level of expertise and type of animation. An Independent t-test was employed to examine the quality of the movement in the two animation types and two levels of expertise. All the quantitative results are presented in the Results section (5.7) of this chapter.

5.5.1 Descriptive Analysis

From the design (Section 5.3) and method (Section 5.4) in this study, the statistical[22] analysis and interview results of the two types of independent variables are presented in the form of tables and a graph (for the factorial design). I used the same participant demographic information as in the usability test into this experiment.

A within-subject factorial analysis of variance was carried out to discover any influence of the two independent variables (level of expertise, type of animation) on the quality of movement animation. The levels of expertise were novice and intermediate and types of animation hand gesture and keyframe[23].

The means scores for the quality of animation movement showed hand gesture animation at M=4.00 received a higher score than keyframe animation at M=3.30 in the novice group. Similarly, in the intermediate group, the score for hand gesture animation at M=4.17 is higher than keyframe animation at M=3.53. Obviously, in terms of percentage using hand gesture animation and keyframe animation, the novice group had higher score of 9.59% compared to 8.31% in the intermediate group (see Table 5.2).

Table 5.2: Factorial Design Analysis for Quality of Animation

Group	Using Keyframe (M ± SD)	Using Hand Gesture (M ± SD)	Changes (%)
Novice	3.30 ± 0.74	4.00 ± 0.50	9.59
Intermediate	3.53 ± 0.61	4.17 ± 0.48	8.31

There is a significant main effect in the quality of animation $F(1, 18) = 13.611$, $p < .05$, $\eta^2 = .431$. So, the quality animation changes significantly from quality of keyframe animation to quality of hand gesture animation (see Figure 5.3).

[22] Being inexperienced in statistics, I required technical support to tabulate the statistical data using SPSS for this study to place everything in order. For this purpose, in June 2016, I worked collaboratively with Mohd Hanafi Azman Ong, a graduate in Applied Statistics.

[23] The reporting template of Factorial analysis is : http://www.slideshare.net/plummer48/reporting-a-factorial-anova

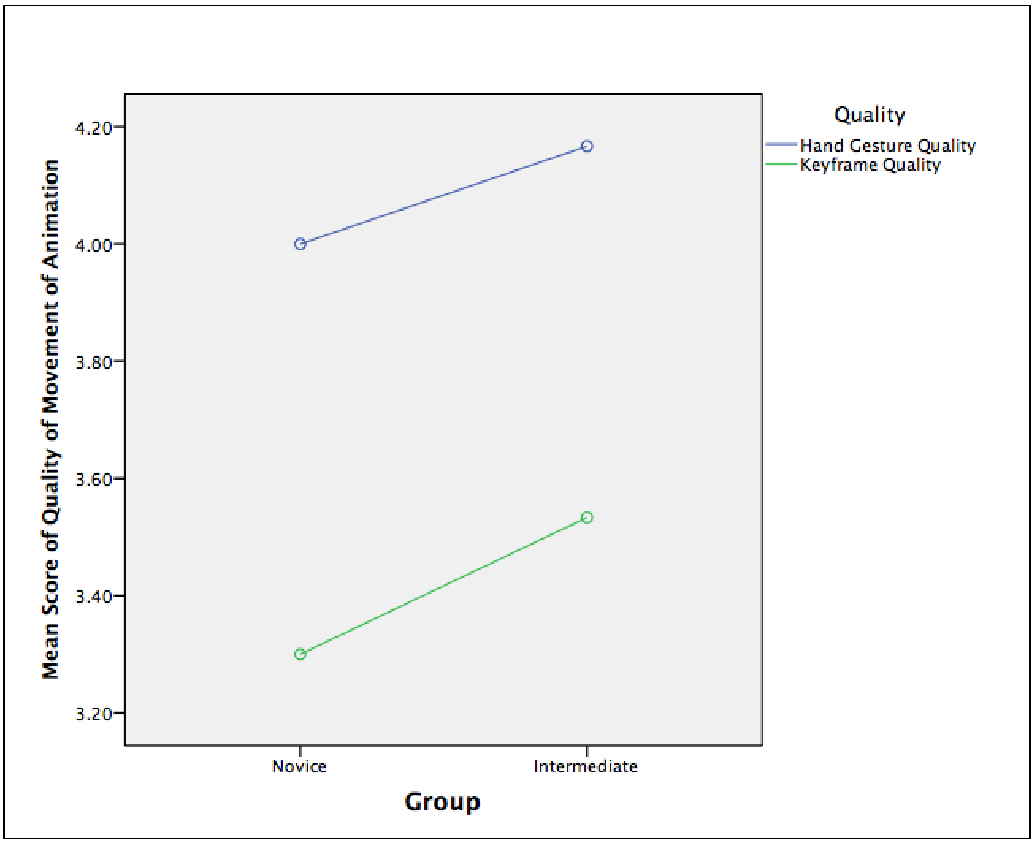


Figure 5.3: Mean Score Quality of Movement of Animation

Figure 5.3 (above) shows the non-significant interaction effect F (1, 18) = 0.034, p =.856, η^2 = .002. The lines are parallel and there is no interaction effect. Hence, it is likely the main effect on the quality of hand gesture animation is higher than the main effect on keyframe animation. Also, the quality scores in the intermediate group for in both types of animation are higher than those for the novice group. So, the graph shows the main effect on the quality of animation for each type of animation is level of expertise (novice or intermediate group), and not interaction.

Therefore, the main effects on the quality of animation are the type of animation and level of expertise of the users. The quality for hand gesture is perceived as higher than for keyframe animation, and the intermediate group's perception is higher than that of the novice group. In response to the hypotheses (see subsection 5.2.1) made earlier, it is likely that there is a significant difference in the quality of animation according to the type of animation. There were also no significant interaction effects between level of expertise and type of animation.

5.6 Qualitative Results

Based on the participants' feedback from the interview, I identified three ways that the novice participants thought good animation could be produced by: 1) Creating detailed movement and timing; 2) Intuitive interaction; and 3) Exploiting the spatial coordination between free-form mid-air and directed XYZ-axes.

5.6.1 Creating detailed movement and timing

The effectiveness of hand gesture animation relies on how far the users are able to use the interface in order to achieve their goals. One of the purposes of introducing hand gesturing was to be able to physically make movements and timing concurrent, without having to deal with the hassle of keyframing.

From the interviews, seven out of the 20 participants were likely to create the details in their animation using keyframing. For them, hand gesture animation was fascinating to use to produce movements, however, the technique is incapable of providing the accurate animation timing they can achieve with keyframe animation. One participant pointed out "*…hand gesture is trouble-free to create a good movement and timing but, with keyframe, you can produce a lot more detailed movement".* Participants felt it was more desirable to use keyframing than hand gestures. One participant commented, *"Unlike hand gesture, keyframing is much better at applying the concept of timing from the Principles of Animation because we can control the details of movements".* Another agreed, *"In terms of timing, keyframe is preferable for creating detailed timing. I am not sure how to set time using hand gestures".* One participant preferred keyframing, as for him, a GUI interface makes the process of animating more manageable. He asserted, "*In terms of applying timing, keyframing provides more functions in the interface to create it, while we don't know how to do this in the hand gesture interface. What I mean by interface is the graphical interface that is easily seen like the length of time on the Timeline. We know hand gesture moves naturally but it has no time length indicator so that we can control the speed".*

While keyframing was the preferred technique for animation, another point of view concerning hand gesturing suggested the needs for animators to acquire acting skills to choreograph their hands. Two participants pointed out, "*I would prefer to use keyframing because I can add details to the movement by inserting more or fewer frames. With hand gesture, using details to create the correct timing requires knowing* *some basic acting to apply movement-timing effectively".* Similarly, comparing hand gesture and keyframe animation, another participant added that hand gesture is unable to stylise a character's action. *"Controlling timing in keyframe and hand gesture may be different. In Maya, timing is set up frame-by-frame, while hand gesture requires a good idea of acting. In this sense, hand gesture loses out on the cartoony style of animation".* The acting skill, according to another participant, should mean the ability to visualise a particular movement before executing any poses for the character in order to save production time. He stated, "*For me, hand gesture animation is like 'acting' where you need to plan a particular movement before performing it. Once it has been planned, hand gesture saves a lot of time in creating animation".* A different participant gave a more balanced view that hand gesture and keyframe have different purposes, *"For minor parts of animation we need to use keyframe; for instance, giving details of the timing of the movement but for a significant body movement, it would be appropriate to use hand gesture as it gives fluidity to the movement".*

Four participants felt comfortable using movement and timing through hand gesture. These four seemed to understand how hand gesturing works for animation, unlike some of the others. What triggers timing is determined by the user's hand movements, as one participant noted*, "hand gesture would do better because it follows the actual timing according to how we control it from our hand gestures. We need not worry about how fast or slow we need to time the movement".* Two more participants added that hand gesturing provides an immediate response from the character in comparison to keyframing, which is unable to convey instant outcomes. They acknowledged, "*applying timing is preferable with hand gesture because you get faster results and you can also revise immediately. But I can understand why people say keyframe is easier because you can actually control the details of timing through the keyframes".* Another participant offered, *"I think hand gesture works better to get the right movement and timing because keyframe requires a lot of trial and error and outcomes are difficult to anticipate. With hand gesture, we simply use our hand to act out the desirable timing and automatically get the result we wanted.* Another participant was satisfied with movement-timing through hand gesture as he felt it was intuitive. He affirmed *"hand gesture could produce good quality animation in the sense of creating a good sense of timing, which comes naturally from projecting our gestures onto the object, whereas when using keyframes, we need to adjust the timing from frame-to-frame, at the same time as monitoring consistently the part that we are animating.*

Although keyframing can produce good animation, it can get messed-up by too many keyframes being inserted".

Undoubtedly, when comes to detailing movement-timing, most participants preferred keyframing to hand gesture animation, as various comments indicated:

> *"When applying timing, I prefer to use keyframe because it is editable. I am not sure how to edit using hand gesture".*
>
> *"In terms of movement and timing, keyframe is preferable for creating timing because we can set the frames individually".*
>
> *"I feel more comfortable using keyframe because I can adjust the frames individually every now and again".*
>
> *"In terms of timing, keyframe is better because we can set how many frames we want to create on the Timeline".*
>
> *"In terms of creating movement and timing, it depends on what we want to create. For example, using keyframe may take time but we can create movement that we wanted. Hand gesture is easy because the movement comes from whoever controls it in real time, but sometimes, the movement can be misplaced and not how we wanted it".*

5.6.2 Natural interaction and responsiveness

Another aspect of how users perceive hand gesture animation is whether they feel naturally responsive to interacting with a 3D character. Creating movement and appropriate timing are crucial in order to communicate the exact action poses required to the 3D character. In contrast to an ordinary animator who works painstakingly bringing the character's emotions onto the keyframes, hand gesturing proposes a more intuitive approach to animation. Due to its ability to capture movement in real-time, most participants agreed that hand gesture animation provides spontaneous interaction and were fascinated when the 3D character acted upon their hand gestures. Six comments from participants follow as examples:

> "*I think hand gesture gives more interaction because it is real-time based, while keyframe requires playback to see how the 3D character responds in the animation we created".*
>
> *"Hand gesture is much more interactive because the object moves at the same time as I'm moving my hands".*
>
> *"Between hand gesture and keyframe, hand gesture gives natural movement because the 3D character moves according to how we move our hands".*

> *"While using hand gesture, my focus was very much on the character's movement than my own hand moving. I think I enjoyed it when the 3D character responded to my moving hands".*
>
> *"My focus is always on how the 3D character moves because it instinctively responded in parallel with my hand gesture".*
>
> *"Hand gesture gives better interaction because I feel 'connected' to the object in 3D space and it responds according to how I want it to be".*

In addition, some feedback noted that they are happy with hand gesture animation. The process allowed them to directly connect to the 3D character intuitively in real-time without having to create movements in sequence, as in keyframing. One participant commented, *"The interesting thing about hand gesture is that it does not delay the movement made because it captures movement in real time, while keyframe does not interact and it is time-consuming to create every movement"*. Meanwhile, on top of being able to animate in real-time and intuitive, two participants related their hand gesture experience to puppeteering: "*In terms of interaction, hand gesture helps a lot, as if I'm manipulating a puppet"*. Another participant elaborated, "*Real-time interaction is a lot better because anyone who has ever played with dolls knows how to use hand gestures. I have experience of making stop-motion animation. It very similar; when I push my hand forward, the hand of the character follows. It's definitely like real playing with puppets"*.

The purpose of the intuitive interaction of hand gesture animation is to enable users to manage the notion of timing being synchronised with the real-time hand movements that they carry out. This means movement-timing with hand gesture is created naturally, as opposed to the concept of frame-by-frame in keyframe animation. Seven participants generally agreed that the movement-timing of hand gesture animation occurred naturally compared to keyframing automated animation:

> *"I think hand gesture is better for controlling movement and timing because it moves naturally according to what we want, unlike keyframes, where we have to set up each frame individually and sometimes, they do not appear in the way we expected them to".*
>
> *"I think I prefer to interact with the character using hand gesture. It's just that at the beginning I felt confused about how to move the character with my hand movements. Keyframes can be tedious, as we have to check the frames by going back and forth".*

> *"In terms of interaction, definitely hand gesture because it responds immediately from my control compared to keyframes, where I need to insert a keyframe and then to preview it, I have to use playback to see the result ".*
>
> *"I think keyframe gives a mechanical look; hand gesture gives a natural look because it captures movement from real time. In keyframe animation, we have to carefully adjust the frames for it to look smooth".*
>
> *"Keyframe gives a mechanical look because we have to create movement frame-by-frame. With hand gesture, it is more natural because it is based on the movement of our hand in real time".*
>
> *"In terms of natural movement, hand gesture gives natural movement because the movement is taken from real time. This is different from keyframe, and we cannot achieve a completely natural look with it".*
>
> *"I think hand gesture is useful for making emotion and movement look natural. We can do the same in keyframe, but is difficult because of the nature of its frame-by-frame technique".*

Other related comments from participants on this matter are noted collectively. They found hand gesture animation gave natural and spontaneous movements because "*it originated from our own gestures", "we can anticipate how we want to move the character", "it captures real life movements*". Two participants added it was only appropriate for real-time animation: "*hand gesture is useful if we want the character to move in real time*" and "*hand gesture is suitable if we want to animate human-like characters".*

5.6.3 Exploiting the space between free-form mid-air and grid-based three-axes coordinating systems

Another aspect of what quality of animation can be achieved is that it is likely to depend on how space and the coordinating system are used. Hand gesture is naturally controlled through the free-form axis representation in real time, while keyframe animation uses the common Cartesian coordinating system of a three-axes handle in 3D space. Both methods whether hand gesture or keyframing, however, affect the user's performance significantly.

Could a grid-less coordinating system of hand gesture animation make the animating process more viable? It seems that the majority of participants preferred the standard three-axes coordinating system rather than the free-form mid-air axes of hand gesture. Generally, all 20 participants commented that the three-axes are comparatively "easy" to move in 3D-space. Three comments suggest that the XYZ-axes functioned as controller to move in a particular direction:

> *"To move on the XYZ axes, keyframe is more accurate because we can move on a particular axis individually, while hand gesture is so flexible until we lose control of which axis we want to move on and have lost track of the position that we wanted".*
>
> *"In terms of moving on the XYZ axes, keyframe is preferable because it provides the 3D axes as a guide for us to move".*
>
> *"I think keyframe is easier to move on the XYZ axes because it indicates moving on those axes. I was confused using hand gesture because it is mirror image".*

Users made mixed comments about the advantages and disadvantages of hand gesture and keyframing. In addition, nine participants found some difficulties choreographing their hand gestures in mid air. Their comments ranged from being "confused" and getting "unexpected movement" from the direction of their hand mapped onto the moving 3D character; being "new" and "unfamiliar" with the technique so the animating process took longer; and the hand gesture interface was somehow new and "unstable" software. Moreover, two participants pointed out the drawbacks of the hand gesture interface:

> *"Controlling movement on the XYZ axes is easier with keyframe because I can actually see where it is going. The problem with hand gesture is because it has a limited detection range, for example, when I raise my hand a bit too high it goes out of range and the interface stuck".*
>
> *"I feel much more comfortable using keyframe because I don't really quite understand how hand gesture works. Furthermore, I cannot rotate the character to view it from different angles, therefore, I don't know in which direction the character's hand is moving".*

Nonetheless, two participants commented that the free-form hand gesture could provide an unrestricted coordinating system by giving autonomous control to the user to create movements:

> *"Controlling movement on XYZ axes is easier with hand gesture because we simply move our hand freely without being bound to any particular direction".*
> *"Keyframe is easy to move on the XYZ axes. Hand gesture is also easy but it needs time to get familiar with the method. It easy because we can freely move without any constraint."*

5.7 Discussion

In this study, while the results showed a significant difference in the efficiency of participants using hand gesture animation, I observed that there was a significant result in terms of the quality of animation. Based on the interviews, although hand gesture is able to create animation naturally and more quickly than keyframe, the quality of animation produced is debatable. Hand gesture loses the advantage to keyframe animation when comes to creating detail. Due to the functional limitations of the system in hand gesture interface, users are most likely to prefer to use keyframe in order to create more advanced animation. Most users were distracted by finding out the range of their hand gesturing controls in mid-air and virtual space, while they felt keyframe animation was more controllable.

5.8 Summary

The results suggest that the hand gesture interface requires extensive functional improvement to provide an enhanced understanding of and performance using the system. The hand gesture interface is relatively new system to use for creating animation. The main investigation into implementing direct interaction was to see if it could overcome the time-consuming process and tediousness of keyframe animation, and while the hand gesture interface effectively demonstrated its capability for creating faster animation, the quality of its animation was less impressive.

6 Chapter 6

A Usability Study for Immersive-based Interface

6.1 Overview

In the previous chapter, we explored the usability, user satisfaction, and efficiency of how hand gesture animation affects users' performance in animating a virtual character in comparison to conventional Windows-based animation. We know that creating animation is an exciting craft of the art of movement, particularly when exploring different animation techniques. Animation is known for its laborious and time-consuming process, nonetheless, producing fascinating end products. In this case, interaction with the interface plays a significant role in embodying the user's performance during the animation process effectively.

This chapter investigates the usability study of how immersive-based animation interface would influence user experience in producing animation. It aims to extend our study using virtual reality environments in animation settings comparing its effects between VR and conventional applications.

The general research questions for this chapter are addressed in equivalent to the previous chapter (Chapter 4) to ensure similar goals: Would users be able to use VR animation as effectively as they use keyframe animation?, Would users be able to learn VR-based animation more easily than keyframing in Windows-based?, How efficient would users need in order to create animation in VR animation? In the context of this study, more specific research questions are formulated in accordance with the hypotheses of this study (see 5.2.1). This study employed an experimental design in which both quantitative and qualitative results supported to address the hypotheses.

6.2 Experimental Design

A within-subject design was employed in the experiment with two independent variables, where Autodesk MAYA (for Windows-based Animation) and Tvori (for Immersive-based Animation) software applications were used. There were two conditions, corresponding to the groupings of each independent variable: fast hand waving, and slow hand waving of a 3D character model. The main task in both conditions are focusing on user experience on animation using different applications. In each independent variable, there were six dependent variables to measure: *Attractiveness, Perspicuity, Efficiency, Dependability, Simulation,* and *Novelty* (Figure 6.1). The themes of the variables are based on the User Experience Questionnaire (UEQ) model used in this study in order to obtain more robust results.

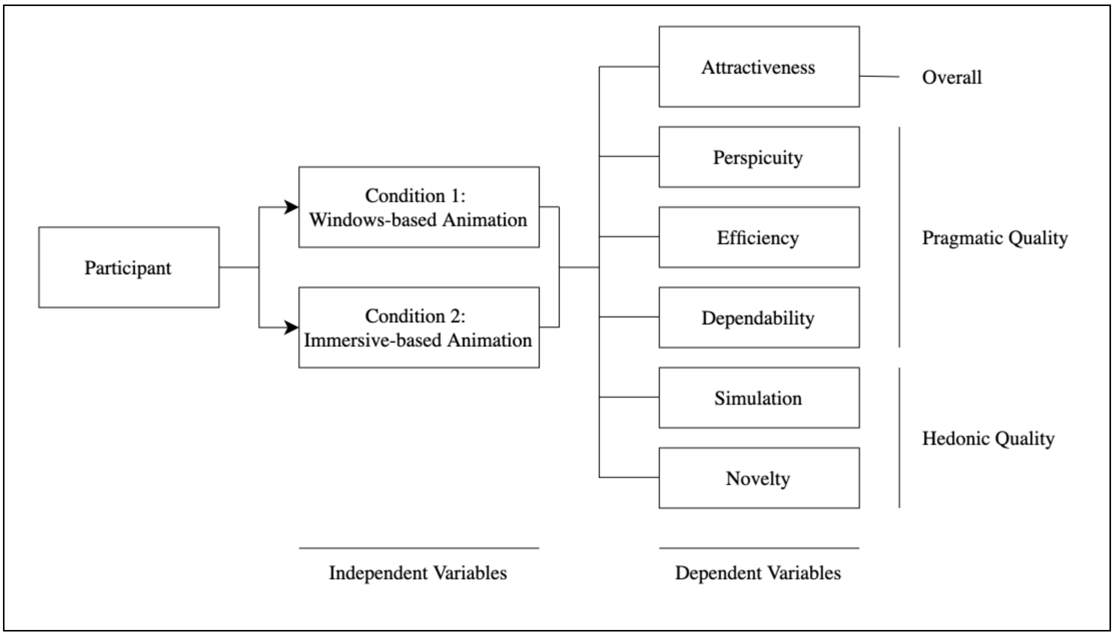


Figure 6.1: Independent and Dependent Variables of the study

For qualitative outcome, semi-structured interview questions were prepared bilingual in English and Malay language. Six main predetermined questions are based on the original UEQ scales (see 6.2.2) with slight modifications that conform to the context of this study. Additional four questions and probes were constructed spontaneously to support the main questions in which these questions will be asked to obtain user's responses specifically in terms of their interaction with the 3D character, timeline, and keyframing processes. These questions are not frequently asked during the interview to all participants but were asked when additional elaboration is needed. The additional questions and probes are:

- Q7: What are you thinking as you view the interface environment between character and timeline in MAYA and TVORI? *Apa yang awak fikirkan ketika sedang animate dan timeline interface MAYA dan TVORI?*
- Q8: If you were looking for keyframe to animate, where would you expect to find it in MAYA and TVORI? Which one is easier to find? *Semasa anda guna keyframe untuk animate, di mana anda agak2 boleh cari di dalam aplikasi tersebut?*
- Q9: How was the experience of using the timeline to complete the tasks in both app? *Bagaimana pengalaman awak rasa semasa guna timeline untuk animate untuk buat Latihan itu?*

  [Probe:] How easy or difficult was it to navigate/find in both app? *Apa yang senang dan susah semasa explore interface timeline?*

  [Probe:] What are your thoughts on the design and layout of both app? *Apa pendapat anda tentang design interface kedua2 aplikasi ini?*
- Q10: Which app do you think you can complete the task faster? *Aplikasi yang manakah awak rasa dapat bantu anda selesaikan tugasan dengan pantas?*

6.2.1 Research Hypotheses

This study investigates how Immersive-based Animation affects user experience in comparison to the conventional Windows-based Animation. Similar to the previous study in Chapter 4, the aim of this study is to measure the usability in terms of efficiency and user satisfaction between the two approaches used for animation. We formulated three main hypotheses for Overall Impression, Pragmatic Quality with three sub-hypotheses, and Hedonic Quality with two sub-hypotheses to complement this study:

Attractiveness for Overall Impression

RQ 1: Could immersive-based animation attract animators to use to create animation?

Hypothesis 1: Immersive-based Animation is more attractive way to create animation than Windows-based Animation.

Perspicuity, Efficiency, and Dependability for Pragmatic Quality

RQ 2: Could immersive-based animation provides practicality in terms of efficiency and dependability to produce animation in comparison to Windows-based animation?

Hypothesis 2: Immersive-based Animation is more practical, in terms of efficiency and dependability way for producing animation than Windows-based Animation.

a) ***Perspicuity***

Sub-RQ 3a: Would animators feel adaptable when navigating immersive-based interface to create animation?

Hypothesis 2a: Immersive-based interface is more adaptable and navigable when creating animation than Windows-based interface.

b) ***Efficiency***

Sub-RQ 3b: Could animators solve their tasks effortlessly using immersive-based interface to create animation?

Hypothesis 2b: Immersive-based interface is more effortless tool to create animation than Windows-based interface.

c) ***Dependability***

Sub-RQ 3c: Is immersive-based interface dependable to use to create animation? Does the user feel in control of the interaction?

Hypothesis 2c: Immersive-based interface is a more dependable tool to create animation than Windows-based interface.

Stimulation, and Novelty for Hedonic Quality

RQ 3: Would immersive-based animation be an exciting tool and able to capture animator’s interest to create animation in comparison to Windows-based animation?

Hypothesis 3: Immersive-based Animation is more exciting and innovative tool than conventional Windows-based Animation for animator to create animation.

a) ***Stimulation***

Sub-RQ-3a: Is immersive-based interface exciting to create animation?

Hypothesis 3a: Immersive-based interface is more exciting tool to create animation than Windows-based interface.

b) *Novelty*

Sub-RQ 3b: Is immersive-based interface an innovative tool that enable creative animation?

Hypothesis 3b: Immersive-based interface is more innovative for producing creative animation than Windows-based interface.

6.2.2 UEQ Questionnaire

The User Experience Questionnaire[24] (UEQ) framework was chosen as an instrument to evaluate the study. The uniqueness of UEQ is exemplified in the simplicity of the questionnaires and the practicality of its data analysis tools to use. As stated by Laugwitz (2008), the aim of UEQ questionnaire is for "quick assessment", "comprehensive impression user experience", and "simple and immediate". UEQ uses a 7-point Likert measuring 6 aspects of usability scales- *Attractiveness, Perspicuity, Efficiency, Dependability, Stimulation,* and *Novelty*. These scales' structures are based on the following evaluation parameters (Table 6.1) of questions from the UEQ Handbook (Schrepp, 2019, Schrepp, et al., 2017) and statements (Hinderks et al., 2019):

Table 6.1: UEQ's evaluation parameters

Scale	Questions	Statement
Attractiveness	Do users like or dislike the product? Is it attractive, enjoyable or pleasing?	The product should look attractive, enjoyable, friendly, and pleasant.
Perspicuity	Is it easy to get familiar with the product? Is it easy to learn how to use the product? Is the product easy to understand and clear?	I should perform my tasks with the product fast, efficient and in a pragmatic way.
Efficiency	Can users solve their tasks without unnecessary effort? Is the interaction efficient and fast? Does the product react fast to user input?	The product should be easy to understand, clear, simple, and easy to learn.
Dependability	Does the user feel in control of the interaction? Can he or she predict the system behavior? Does the user feel safe when working with the product?	The interaction with the product should be predictable, secure and meets my expectations.

[24] User Experience Questionnaire or UEQ was developed in 2005 by a team of researchers Andreas Hinderks, Martin Schrepp and Jorg Thomaschewski. UEQ was originally created in German version and translated in various languages is intended to evaluate user experience of a product. UEQ can be accessed at https://www.ueq-online.org/

Stimulation	Is it exciting and motivating to use the product? Is it fun to use?	Using the product should be interesting, exiting and motivating.
Novelty	Is the product innovative and creative? Does the product catch the interest of users? Does it capture users' attention?	The product should be innovative, inventive, and creatively designed.

While *Attractiveness* represents the general scale describing the overall impression, *Perspicuity*, *Efficiency* and *Dependability* are classified as Pragmatic Quality, and *Stimulation* and *Novelty* as Hedonic Quality (Figure 6.2). Each of the scale contained measurable components in which it was arranged in the form of semantic differential format with each term represents positive and negative meanings. According to Schrepp, Attractiveness is a 'valence dimension' which described the overall feeling of a product in a usability test (2019). In our case, we measure how attractive would user feel toward the systems between Windows-based (Maya) and Immersive-based (Tvori) interfaces.

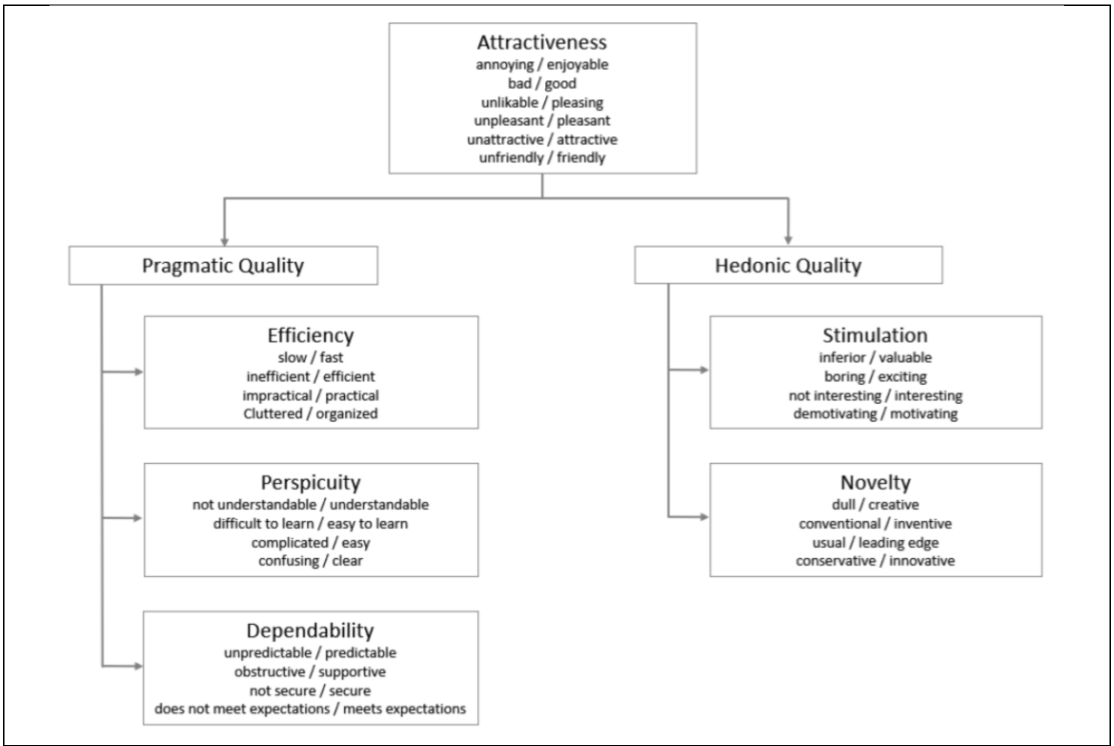


Figure 6.2: UEQ's assumed scale structure model

6.3 Methods

6.3.1 Participants

The sample chosen was targeted at students who are studying animation with an interest and some basic understanding of animation process. A total number of 40 participants were recruited in this experiment. The participants were among animation students at the Faculty of Film, Theatre and Animation, Universiti Teknologi MARA, Puncak Perdana Campus, Shah Alam, Selangor in Malaysia of which 18 males (45%), 22 females (55%), aged between 18-20 (60%) and 21-23 (40%) (N=40). They were among Diploma (60%) and Undergraduate (3D Animation = 30% students, 2D Animation = 10%). The average of animation skills from absolute beginner to intermediate on scale 1 to 5 was 3 (SD=0.768). Participants preference for using animation technique were 3D animation (45%), 2D animation (50%) and 5% was in Foundation level. For animation software that participants commonly used were Autodesk Maya (40%), Toon Boom (35%), Krista 2D Animation (12.5%), 3D Blender (5%), 3DS Max (2.5%) and None (5%). All participants have no prior experience with VR. (See Appendix D-3 for Demographic Frequencies Analysis).

6.3.2 Materials

The experiment was carried out on a high performance PC laptop ASUS TUF Gaming A15 FA506, AMD Ryzen 7 4800H, AMD Radeon Vega 7 + Nvidia GeForce RTX 2060 to support Oculus Quest VR minimum system requirements. A high speed Oculus Link Cable 16FT USB 3 Type-C was used to connect Oculus Quest headset to the PC laptop to ensure smooth transmission of data. Oculus Quest headset was accompanied by two controllers for left and right hands. A Quest 15W USB-C power adapter was used to charge the headset whenever the device runs out of power. A Rappo C280 Full HD2K webcam was connected to PC laptop and used to record all participant's physical activities alternately between Maya and Tvori applications.

A 3D animation software, Autodesk Maya was installed and used as Windows-based application for participants to perform task for Condition 1. For participant's convenient to use Maya appropriately, a 3-button mouse with scroll wheel was provided. This would make navigation such as tumble, track, dolly and zooms in Maya viewports easier. A full-rigged character, Andy Rig was downloaded and used as an object for participants to animate.

For the VR software, Tvori[25] was used as Immersive-based application to perform task for Condition 2. At the time when this VR animation experiment was proposed in December 2020, there were very limited VR-based software that featured animation with 3D object. Most of the VR animation software were specialised in painting, drawing, and sculpting. One of the advantage of Tvori was that it provides built-in character models, easy and does not required prior advance skill for handling VR application. Tvori was installed and operated on the PC laptop. Tvori's environment can be viewed from the laptop while it was in used by participants with the headset on, so researcher could monitor user's navigation in the VR setting. At times, Tvori system was crashed and not functioning properly due to software bugs. When this happened, participants had to redo the task.

Before the start of every session, researcher would ensure to reset Maya and Tvori applications for accessibility of the next participants. Upon switch on the Oculus Quest headset, then VR commands for Floor Level was confirmed, and to ensure safety Guardian Boundary was defined within 1.5 metres radius.

A UEQ Questionnaires was used as instrument for participant's survey for both conditions, Windows-based and Immersive-based. The survey form was provided as online version using Google Form. The form used bilingual English-Malay to increase understanding among participants about the terms used in the English version. A semi-structured interview questions was prepared according to the UEQ scale structure that consist of Attractiveness, Perspicuity, Efficiency, Dependability, Stimulation and Novelty. For post-test interview, the conversation with participants was audio recorded in the Voice Memo on iPhone SE.

6.3.3 Procedures

The experiment was conducted in room 12-3-6 Laman C, Block 6, Faculty of Film Theatre and Animation, UiTM Cawangan Selangor, Puncak Perdana Campus, Shah Alam, Selangor, Malaysia. Before the test takes place, each participant is mandatory to observed the COVID-19 Standard Operating Procedures (SOP) stipulated by the Ministry of Health Malaysia and the Government of Malaysia (Malaysia National

[25] Tvori website: https://tvori.co/

Security Council (MKN) in an effort to prevent the spread of the disease. A website[26] of this experiment was created for everyone's convenience during pandemic crisis.

All participants were tested individually and separately in the study. However, in certain unforeseen circumstances, some sessions would involve a group of 2-3 participants. It was noticeable that having more than one person would give more motivation for them to increase confidence level and to speak more. Prior to the experiment, all participants were required to choose a time slot in a booking appointment in the spreadsheet provided online. On the day of the experiment, each participant was asked to be seated at a desk in the experiment room as they arrived. The study was divided into three sections:

Section 1: Briefing, Familiarisation, Consent Form and Demographic

A short briefing and demonstration was given by the experimenter, explaining about the process of the experiment and the operation of Autodesk Maya, Tvori (VR application) and handling Oculus Quest headset and controllers (Figure 6.3). During VR demonstration, participants was able to view interior of the Tvori-VR from the laptop. Depend on 'awkwardness' situation among participants, some were given a trial experience to understand the VR, headset and controllers during demo session. Upon agreement to participate in the study, participants were given Instructions of the study, and then sign a Consent Form followed by answering demographics information provided in Google Form. The briefing and demo took around 10-15 minutes.

[26] **Website link for the experiment. It consists of Participant Information Sheet, Procedures, COVID-19 Guidelines, Instruction and Tasks, Experiment Booking Appointment Sheet:** https://sites.google.com/view/vranimationexperiment/home

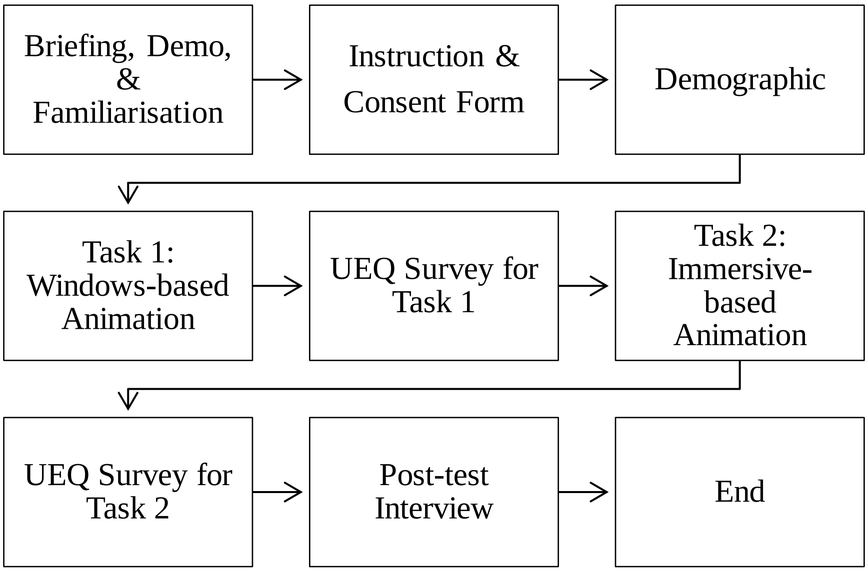


Figure 6.3: Flowchart of the experiment procedures

Section 2: Treatment of Conditions

After briefing was finished, participants were informed to perform Condition 1. They were asked to animate a character in Autodesk Maya- a Windows-based animation software that was commonly used among participants. For the convenience of the participants, a full-rigged character called Andy Rig[27] was used. To navigate Maya interface, a 3-button mouse (with scroll wheel) was used to enable user to zoom in/out, pan left/right, and tilt in the viewport. Participants were given two tasks to animate hand waving with different expressions; happy (fast movement) and sad (slow movement) hand waving. All participant's activities in Condition 1 were recorded and archived in the respective participant's folder on the experimenter's PC laptop. Once participants has completed the tasks, they were required to answer a post-experiment UEQ survey about their experience using Maya. Each participants were required to rate their experience based on interaction with the interface in the given condition. Once completed, they moved to perform the second condition of the experiment.

After completing Condition 1, participants would move to Condition 2. Here, participants was asked to animate a character using Tvori- a VR-based animation application that relatively new to most participants. To begin with, the experimenter assisted the participants wearing the Oculus Quest headset and holding the controllers on their left and right hands. They get fascinated when they able to view the

[27] Andy Rig was provided online as a free-download 3D character for Maya: https://www.highend3d.com/maya/downloads/character-rigs/c/the-andy-rig-for-maya

environment in VR, in our case, Tvori interface. Being first time in VR, most participants felt awkward in handling the environment and the device. In most situation, experimenter had to instructed the participants to navigate Tvori. Participants were given two tasks to animate hand waving with different expressions; happy (fast movement) and sad (slow movement) hand waving. A selection of rigged-ready characters provided in Tvori were freely to choose and used. All participant's activities in Condition 2 were recorded and archived in the respective participant's folder on the experimenter's PC laptop. Once participants have completed the tasks, they were required to answer a post-experiment UEQ survey about their experience using Tvori-VR. Each participants were required to rate their experience based on interaction with the interface in the given condition. The total time participants took in the main session to complete Condition 1 and Condition 2 was within 30-45 minutes depend on participant's level of competency and familiarity using Maya and Tvori-VR.

Section 3: Post-test Interview

When all conditions were completed, a short semi-structured interview session was conducted. A set of 10 basic questions were prepared for the session, and probing was used (when necessary) for further investigation. Participants were reminded that the interview will be audio recorded as part of the qualitative data collection of the study. An estimated time for the interview was 20-30 minutes depending on numbers of participant/s involved during the session. At the end of the session, a small token of appreciation of RM10 was given before leaving the room. Upon participant's exit from the session, all experiment settings was reset and materials was sanitised according to COVID-19 SOP requirements and ready for the next participant. The whole experiment session took about 1 hour 20 minutes.

6.3.4 Validity, Reliability, and Limitations

Validity and Reliability

Cronbach's Alpha and Guttman Lambda reliability analysis method was used in UEQ to analyse the internal consistency of the instrument used, in this case, the questionnaire feedback. As stated by Laugwitz et.al, the reliability and validity of the construction of UEQ questionnaires was reported "satisfactory" and "congruence" (Laugwitz et.al, 2008). The UEQ questionnaire scales was tested in several usability studies to indicate sufficient reliability (Schrepp et al., 2017).

Limitations

This study has some limitations. At the time of this experiment was proposed in August 2020, there were a limited number of VR applications that is usable for animating 3D character animation. Most VR applications for animation are focused on painting, sculpting and 2D animation. To ensure compatibility of the application, the VR platform i.e. Oculus Quest is to be considered.

This experiment was conducted during the COVID-19 pandemic period when movement and physical contact are restricted. Because of this condition, it affects the recruitment and the competency levels of the participants. The selection of 40 participants was made due to the availability of animation students on campus. The majority of the participants have no prior experience using VR and Autodesk Maya applications. Only few participants are experienced with Autodesk Maya.

Furthermore, the limited time had caused an impact the result of this study. As each participant takes about 1 hour 20 minutes for each session, we had to limit time for participants to adapt themselves to both systems. Therefore, simple tasks are needed in each condition. This factor somehow affected our hypotheses in terms of pragmatic qualities.

6.3.5 Ethics

The Goldsmiths Ethical Approval Form (EAF1 Form) was submitted in November 2021 for approval by the Research Ethics and Integrity Sub-Committee (REISC). All relevant information including Information Sheet, Experiment Instruction for Participant and Consent Form[28] (Available Online) were provided in a bilingual setting in which English and Malay languages were used for the convenient of the participants during the experiment. The form explained about researcher's responsibilities in terms of integrity, risk, data management/protection, and confidentiality. For everyone's convenience during the pandemic crisis, the Information Sheet, Experiment Instruction

[28] Information Sheet, Experiment Instruction for Participant and Consent Form can be retrieved at: https://sites.google.com/view/vranimationexperiment/home?authuser=0

for Participant and Consent Form was converted and later provided in a website of this experiment.

6.4 Results

6.4.1 Descriptive Statistics

Scale	Data Set 1- for MAYA						Data Set 2- for TVORI					
	Mean	STD	N	Confidence	Confidence Interval		Mean	STD	N	Confidence	Confidence Interval	
Attractiveness	1.48	1.07	40	0.33	1.15	1.81	2.11	0.96	40	0.30	1.81	2.41
Perspicuity	1.13	1.08	40	0.33	0.79	1.46	1.56	1.29	40	0.40	1.16	1.96
Efficiency	1.27	0.94	40	0.29	0.98	1.56	1.68	1.08	40	0.33	1.35	2.02
Dependability	1.03	0.88	40	0.27	0.75	1.30	1.33	1.04	40	0.32	1.01	1.65
Stimulation	1.51	1.14	40	0.35	1.15	1.86	2.33	0.71	40	0.22	2.11	2.55
Novelty	0.67	1.15	40	0.36	0.31	1.02	1.95	0.98	40	0.30	1.65	2.25

Note: In UEQ, the evaluation of the 7-scale data per item is transformed on a scale range +3 to -3, in which +3 represents the strongly agree and -3 is the strongly disagree values.

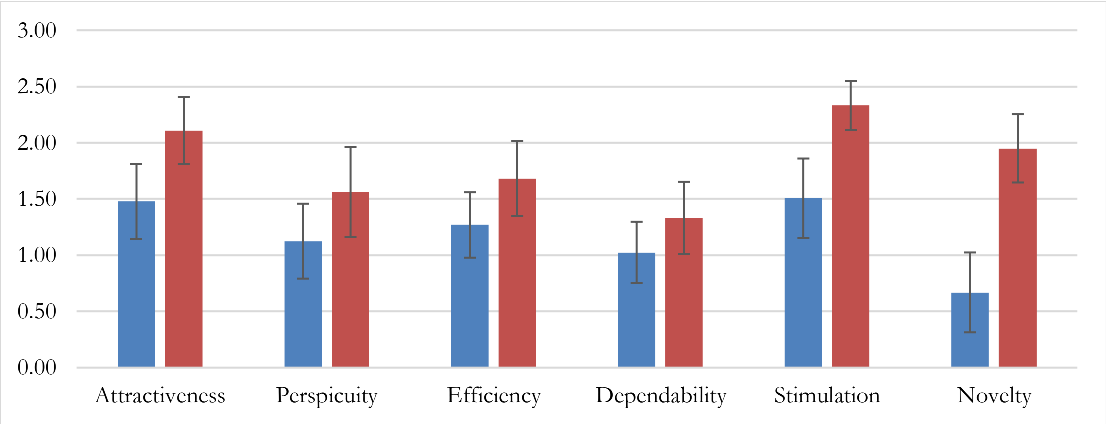


Figure 6.4: Scale means results for Autodesk Maya and Tvori-VR user study

Figure 5.4 describes a descriptive results for this study. A two-tailed paired t-test was conducted on Attractiveness from UEQ questionnaires between Immersive-based Animation (Tvori-VR) and Windows-based Animation (Autodesk Maya). We found a significant difference between the two conditions (p=0.0072) (Table 6.2). As shown in the plot (Figure 6.4) participants in the VR condition reported a higher score of *Attractiveness*, but Autodesk Maya had more consistent score (nVR: 2.11, SD=0.96; nMaya: 1.48, SD=1.07). This result supported Hypothesis 1 that Immersive-based

Animation is an attractive way to create animation for animators than Windows-based Animation.

Table 6.2: T-test results between Autodesk Maya and Tvori-VR user study. P > 0.05.

Attractiveness	**0.0072**	**Significant Difference**
Perspicuity	0.1037	No Significant Difference
Efficiency	0.0716	No Significant Difference
Dependability	0.1592	No Significant Difference
Stimulation	**0.0002**	**Significant Difference**
Novelty	**0.0000**	**Significant Difference**

For *Perspicuity*, *Efficiency*, and *Dependability* in which Pragmatic Quality is measured, we found there is no significant difference between the two conditions in terms of Perspicuity (p=0.1037), Efficiency (p=0.0716) and Dependability (p=0.1592) (Table 6.2). These results failed to support Hypothesis 2 that Immersive-based Animation is more practical in terms of efficiency and dependability for producing animation than Windows-based Animation.

For *Stimulation*, and *Novelty* in which Hedonic Quality is measured, we discovered a significant difference between the two conditions for Stimulation (p=0.0002) and Novelty (*p*=0.0000) (Table 6.2). As shown in the plot, participants in the VR condition reported a higher level of Hedonic Quality; Stimulation (nVR: 2.33, SD=0.71; nMaya: 1.51 SD=1.14) and Novelty (nVR: 1.95, SD=0.98; nMaya: 0.67 SD=1.15) (Figure 6.4). The result supported Hypothesis 3 that Immersive-based Animation is exciting and innovative tool than conventional Windows-based Animation for animator to create animation.

6.5 Qualitative Results

This section discusses the qualitative analysis of data obtained from 40 participants in the post-test interview. All interview data were audio-recorded and verbatim transcribed in their original spoken language (see Appendix ??). While the interviews were mostly conducted in Malay language, there are common for code-switching between Malay and English found in the conversation. For the convenience of data analysis, the interview data was organized thematically using the 6 scales UEQ

Questionnaire model: *Attractiveness, Perspicuity, Efficiency, Dependability, Stimulation* and *Novelty*. We use the 26 semantic differential items assigned in each scale (see Figure 5.??, in section 5.2.2) as a factor to generate codings from the data to ensure robustness of interpretations.

6.5.1 Attractiveness

For UEQ, attractiveness is '[t]he product should look attractive, enjoyable, friendly, and pleasant'. The interview shows that the overall impression of creating animation with Tvori-VR is very favourable compared to Autodesk Maya. As new users to immersive experience and the device, VR is the subject matter that they were attracted to and amazed about:

Scale	Negative Code	Positive Code
Attractiveness	Annoying/*Menjengkelkan* Bad/*Tidak Baik* Unlikable/ Unpleasant/*Tidak menyenangkan Tidak disukai* Unattractive/*Tidak menarik* Unfriendly/*Sukar digunakan*	Enjoyable/*Menyeronokkan* Good/*Baik* Pleasing/*Sukai* Pleasant/*Menyenangkan* Attractive/*Menarik* Friendly/*Senang digunakan*

Positive-Negative Code: Enjoyable-Annoying, Good- Bad, , Pleasing-Unlikeable, Pleasant- Unpleasant, Attractive-Unattractive, Friendly-Unfriendly

For Immersive-based Animation, most participants give positive feedback about animation using Tvori-VR application and feel enjoyable in the sense that it provides **'real-life', real time,** and **natural feelings** as if they were playing with dolls. In other words, participants feel very pleasing by the **immersive environment** and enjoy what virtual reality technology has to offer in producing animation. Interestingly, one participant associates VR animation with stop-motion animation. Examples:

> [P2]: "*Tvori-VR kita boleh merasai real life experience […] kita boleh jadi macam karakter itu sendiri* / "In Tvori-VR, we feel real life experience […] we are 'the character' itself"

> [P7]: *"Tvori-VR* […] *boleh macam terus buat animate sebab dia macam tak ada key shortcut nak kena tekan untuk gerakkan terus gerak pakai tangan, macam seolah-olah dia ada patung kat depan kita; kita gerakkan je"* / Tvori-VR […] can directly animate because it has no shortcut keys, just control using hands, and feels like playing a life-size doll in front of us; we just move it"

> [P34]: *"Tvori-VR dia punya interface dia punya ni semua simple jadi untuk beginner bagi saya senang nak buat la dan mudah untuk macam seolah-olah*

kita animate depan mata kita macam kita menggerakkan patung" / "Tvori-VR's interface is simple and convenient to animate just right in front of us just like playing dolls"

[P8]: "*Tvori-VR memang seronok pakai tu dan nampak senang nak control […] boleh nampak macam realiti"* / "Tvori-VR was really exciting and easy to control […] as if in reality"

[P10]: "*Tvori-VR tu, itu memang best sebab macam kalau kita mau animate kita boleh nampak macam real, apa yang kita mau animate kita boleh tengok sekeliling*" / Tvori-VR is the best because it looks so real and we can look around in the environment"

[P33]: *"Tvori-VR kita boleh tengok di tepi, kita boleh terus nampak […] a'aa saya ada jenguk sebab nak tengok tangan dia ke belakang sangat ke, ke depan ke"* / "In Tvori-VR, we can take a glance (at the 3D model sides) to ensure we position its hands to the back or front"

[P20]: *"Tvori-VR tu lah dia boleh ada hands-on experience, experience on animation, memang pakai tangan sendiri je lah kan sebab basically dia macam controller tu macam tangan sendiri"* / "Tvori-VR gives you real time hands-on experience animating using own hands because of the controllers itself"

[P40]: *"Dia ibarat macam animate stop-motion tapi dalam skala yang besar macam lagi senang nak bawa dia pergi mana-mana"* / "Tvori-VR is like as if stop-motion animation but in life-size scale and easy to manoeuvre around the environment"

Despite being attracted to the immersiveness of VR animation, participants added that the application is more appropriate to use for entry level animators. The 'fun' side and handling of the experience would attract the beginners. Examples:

[P19]: *"Tvori-VR tu pulak bagi saya dia menarik memang totally new experience and um untuk animation saya rasa dia agak mudah lah lagi-lagi untuk new user"* / "Tvori-VR is very interesting and totally a new experience and I think it is much convenient for new user"

[P18]: *"Tvori-VR ni dia lagi sesuai dengan orang yang baru guna sebab dia simple lepas tu dia lagi menarik and then dia punya pendekatan dekat 3D environment tu boleh […] kita boleh tahu position dia"* / "Tvori-VR is suitable for new user because it is simple and interesting tool, and its 3D (immersive) environment enables us to know the position"

[P28]: *"Tvori-VR […] dia tak susah sangat nak belajar tapi dia ada macam tools tu dia macam kurang kat situ"* / "Tvori-VR […] is not hard to learn, but the tools seem lacking"

Commenting on attractiveness, there are also participants who think that VR animation is user-friendly application that could provide simple tools to use. The drag-and-drop intrigues the participants. Examples:

> [P3]: *"... dia punya tools semua tu mudah tengok macam simple tapi kita boleh drag tu senang..."* / "… the tools are very easy to find, simple and just simply drag and drop…"
>
> [P5]: *"Tvori-VR tu um lebih kurang macam Blender la, cuma tak payah nak gerak-gerak mouse, dia gerakkan tangan je lah, movement senang!"* / "Tvori-VR is similar to the 3D Blender, just that it does not need to use a mouse, simply moving our hands!"
> [P11]: *"Tvori-VR pula saya hanya tekan button tu and then dia keluar semua saya tinggal drag je..."* / "Tvori-VR is simply click and drag the buttons"
>
> [P17]: *"Tvori-VR [...] dia lebih senang nak pakai dia sebab dah sedap sedia kan nak pakai..."* / "Tvori-VR […] is easy to use and user-friendly…"
>
> [P16]: *"... very amazing and very interesting to animate using Tvori-VR, and it's very easy to learn..."* / "… (feel) amazed and very interesting (tool) to animate using Tvori-VR, and it's very easy to learn…"

For Windows-based Animation, participants find Autodesk Maya more enjoyable for the **easy navigation** due to its **systematic windows system** and **comprehensive tools** that could assist them with better workflow and provide more options. Users seem comfortable with navigating using the 3-dimensional XYZ coordinate planes. What makes them frustrating was the technical issues occurred that could interrupt the process. Although the competency level of 3D animation skills are between novice and intermediate, most participants seem adaptable to Autodesk Maya. Examples:

> [P1]: *"... saya suka dengan Maya sebab dia sistematik, so dia lebih praktikal lah"* / "I like Maya because it is systematic, and so more practical"
>
> [P6]: *"Maya saya suka sebab dia macam lagi senang nak navigate tapi apa yang saya tak suka macam dia ada masalah teknikal"* / "I like Maya because it is easier to nagivate but what I don't like about it when I have technical problems"
>
> [P10]: *"Maya bagusnya macam banyak itu dia boleh buat banyak benda, dia tak limited"* / "Maya is good because it has unlimited tools and you can do a lot of things"
>
> [P15]: "… it's just that I don't have enough knowledge about it yet. I found Maya is much more easier to learn…"
>
> [P20]: *"Maya yang suka, dia banyak features la, tu lah dia lebih teknikal, banyak options so dia kalau ikutkan boleh jadi lagi kreatif la sebab dia banyak*

> *tools"* / "I like Maya because it has more features/options, more technical, so we should be more creative!"
>
> [P34]: *"Saya suka mengenai Maya adalah dari segi functionality dia lagi banyak la saya nak gerak ni ke nak ni tapi saya mengalami sikit komplikasi dengan Maya tadi sebab saya dah terbiasa guna software"* / "I like Maya because of its functionalities but I faced slight complication due to unfamiliarity with the software"
>
> [P36]: *"Kalau Maya, dia kan kalau kita pilih tool rotate tu kita boleh macam lebih accurate la dia punya rotate tu"* / "In Maya, we can choose the Rotate tool which I think it is more accurate"
>
> [P37]: *"Maya ni lebih cepat/lebih tepat la sebab dia banyak tools"* / "Maya is a lot faster and accurate because it has more tools"

For negative responses, on the other hand, Immersive-based Animation received comments that mostly explain about the interaction with the **external** and **internal physical space** of the VR environment itself. By holding controllers in their hands as a mouse replacement, participants find sometimes this can be un-user-friendly and distract the animation process. Another factor that participants feel unlikeable and unpleasant is being a **first-timer** and **unfamiliar** with handling immersive environment. This has caused difficulties in navigating for tools to use. Examples:

> [P3]: *"Tvori-VR, dia susah sebab dia kena bergerak semua tu la"* / "Tvori-VR is difficult because everything we need to move it around"
>
> [P10]: *"… susah kalau VR ni itulah kalau macam mau buat yang besar kena space yang besar sikit"* / "… it's difficult because we need bigger space to work with it"
>
> [P11]: *"Tvori-VR apa tak suka ni cuma kita kena drag tu, drag tak boleh jauh sangat daripada kawasan yang dah mark tadi; dia macam tiba-tiba saya tak boleh tekan"* / "What I do not like about Tvori-VR is to drag (the windows in the app) and need to place it within the marked area; it happened when it suddenly stuck"
>
> [P15]: "Tvori-VR, because for me VR is a fun experience but I thought it is a bit difficult to control; the animation […] due to I'm not much comfortable with the VR technology yet" / "Tvori-VR is a fun experience but a bit difficult to control because I am new to VR environment"
>
> [P23]: *"… saya rasa susah untuk saya faham macam mana nak gerakkan dia kadang-kadang untuk yang Timeline dia tu pun dan karakter dia gerak gerak lambai tangan tu sedikit susah, saya kurang suka sebab saya tak jumpa button untuk delete bagi Timeline"* / "… I think it is difficult for me to understand how

to use the Timeline tool, moving the character's hand, and I hardly find the Delete function in the Timeline"

[P32]: *"Tvori-VR tu susah sikit nak adjust dia punya pergerakkan tangan dia tu, dia kena betul-betul tekan baru boleh adjust"* / "Tvori-VR is difficult because we need to precisely control our hands movement in order to select (object)"

[P36]: *"Tvori-VR dia mungkin kita kena buat sendiri guna tangan so dia macam kurang accurate ataupun dia akan kadang-kadang lari sikit"* / "With Tvori-VR, we need to control our hands movement to select (an object) otherwise we missed its accuracy"

[P39]: *"Tvori-VR tadi senang nak gerak dia memang lagi senang la daripada nak control dia tapi sebab tak familar lagi so kadang tekan tak tekan dia macam tu lah annoying sikit la tapi senang nak guna"* / "Tvori-VR is easy to use and control, but because of unfamiliar (with the interface) and missed clicking, I feel annoyed"

However, there are participants who pointed out the drawbacks of using VR for animation as the production sometimes required long hours in the process. They feel that wearing the headset could be **bothersome** as the weight of the device would distract their focus. There are also dizziness and tiredness issues among participants: Examples:

[P30]: *"… kalau yang tidak biasa tengok skrin lama-lama seperti macam VR dia boleh buatkan kau dizzy"* / "… for those who are new to VR screen (environment), it can make you feel dizzy"

[P6]: *"Tvori-VR, ya dia lenguh, lepas tu, […] nak gerakkan dia tu susah sebab hampir semua benda dia nak gerak"* / "Yes, handling Tvori-VR can make you feel weary […] because almost everything we need to move"

[P9]: *"… Oculus kan saya rasa kena ringankan lagi ataupun improve kan lagi supaya bila kita pakai tu kita selesa. Bagi saya VR [Oculus] tu dia kurang selesa dan dia struktur dia agak bergegar bila kita nak pegang dia, macam tak stabil"* / "… Oculus is heavy and I think they need to improve it so that we feel comfortable. I feel uncomfortable because the structure of the device is unstable"

[P38]: *"Tvori-VR rasanya sebab tak biasa dengan interface dia jadi untuk personal punya isu saya ada motion sickness jadi saya pening sikit bila pakai"* / "Unfamiliar with Tvori-VR interface, so on personal issue, I think I have motion sickness and I feel dizzy wearing/using it"

Participants find Windows-based Animation can be inconvenient when handling the interface. As beginner to Autodesk Maya, users realised that having **numerous**

functions can be **tedious** and **unfriendly** process, and formal training is necessary for further development. Examples:

> [P1]: *"Maya dia agak membosankan dan complicated; dia agak mengjengkelkan sebab ada banyak butang"* / "Maya can be boring and complicated because of the many buttons and functions"
>
> [P7]: *"Maya lebih complicated sebab kalau kita nak rotate ke, kita kena tekan mouse dengan laptop mesti kena belajar dulu baru boleh buat pergerakkan"* / "Maya is complicated because we need to use a mouse to rotate (object), we need to learn know the 'how-to' first before we can move it"
>
> [P10]: *"Maya, dia macam banyak betul dia punya section [...], setting dia terlampau banyak, jadi macam susah kalau mau belajar satu-satu"* / "Maya has a lot of sections (tool windows) […], too many settings and it is tricky to learn"
>
> [P11]: *"... button-button tu dia nampak macam memang la dia tersusun tapi bagi saya dia agak serabut la sebab banyak kena tekan dan banyak juga shortcut"* / "… it has many buttons and organised but to me it is messy because too many clicking to do and too many shortcuts"
>
> [P12]: *"... since pakai dalam kelas so bagi saya senang la boleh pakai cuma dia macam ada banyak lagi benda dia dalam Maya tu kita kena explore kan tu buatkan saya rasa susah nak pakai"* / "… since I already used it (Maya) in the class I feel it is easy, but there are many more functions to explore in Maya and that makes me feel difficult"
>
> [P14]: *"... baru lagi kan try untuk Maya saya macam kurang sikit about yang bila tekan on the frame..."* / "… still new to Maya, so I feel unfavourable using it when handling keyframes…"
>
> [P16]: "Maya is a little bit complex and it is hard to understand for me"
>
> [P18]: *"Maya ni lagi complex macam susah nak faham walaupun macam ada basic knowledge kita kadang-kadang macam boleh lost juga"* / "Maya is complex and hard to understand even if you have basic knowledge about it and sometimes you are lost"
>
> [P20]: *"Maya, walaupun dia banyak features tu, saya rasa dia terlalu banyak features sampai susah nak keep up, so dia senang confuse"* / "Maya has many features, but too many features can also confused you"
>
> [P19]: *"Maya dia agak complex daripada segi interface tapi disebabkan Maya ni dah lama kan dia punya tutorial apa semua bagi saya lagi mudah untuk saya catch up"* / "Maya interface is complex but because of its well-established software, it has many helpful tutorials that I find it easy to use"

If using VR for animation would make them stand and move physically, they give a fair view when it comes to sitting for a long time at a desktop and using a mouse could lead to exhaustion. Examples:

> [P33]: *"Maya saya tak suka bila nak tengok rotation model tu sebab kita kena gerakkan mouse"* / "I do not like Maya because we need to use a mouse to rotate the (character) model"
>
> [P38]: *"Maya saya rasa yang tak suka lebih kepada tu la sebab duduk je sepanjang masa kita buat kerja jadi kita rasa macam letih sebab position dia static"* / "I do not like Maya because we need to sit at one static position for a long time and that make us feel tired"
>
> [P40]: *"... Maya bagi saya dia macam lagi leceh la nak animate dia sebab dia kena kita guna mouse"* / "… for me Maya is troublesome because we need to use a mouse to animate"

Perspicuity, Efficiency, and Dependability for Pragmatic Quality

The UEQ classified *Perspicuity, Efficiency,* and *Dependability* scales as Pragmatic Quality, which means the usability qualities in terms of learnability of the systems, practicable in achieving goals, and expectations are measured factors. From the interview, we found that most participants seem to demonstrate mixed feelings between Immersive-based Animation and Windows-based Animation considering the strengths and limitations between Tvori-VR and Maya.

6.5.2 Perspicuity

Under the UEQ parameter, perspicuity is when 'I should perform my tasks with the product fast, efficient and in a pragmatic way'. We learned that having clearness and adaptability to software applications requires constant practice in order to understand the level of complexities of the interface. From the interview, our participants indicate that it is unnecessary that a complex interface like Autodesk Maya is difficult to learn and a simple interface like Tvori-VR is easy to learn:

Scale	Negative Code	Positive Code
Perspicuity	Not understandable/*Sukar difahami* Difficult to learn/*Sukar dipelajari* Complicated/*Menyulitkan* Confusing/*Mengelirukan*	Understandable/*Mudah difahami* Easy to learn/*Mudah dipelajari* Easy/*Mudah* Clear/*Jelas*

Positive-Negative Code: Understandable-Not understandable, Easy to learn Difficult to learn, Easy- Complicated, Clear-Confusing

Most participants find that Immersive-based Animation is easy to learn and very adaptable. What makes them easily understand the navigation is due to the **kinaesthetic interaction** that they directly controlled the 3D character in the VR environment. The physicality of VR operation has diverted user's attention from unclear functions in Tvori-VR. Examples:

> [P2]: *"… kita boleh buat pergerakan sendiri; tangan lambai kan dari segi perspektif dari segi ¾ ke, mana-mana perspektif yang ada"* / "… we can move ourselves; waving hands from all angles and views in it"
>
> [P8]: *"Tvori-VR tu lagi senang untuk navigate, gerak kan ke depan ke belakang dan betulkan adjust kan tangan dia"* / "Tvori-VR is easier to navigate, moving to the front and back, and adjusting his (3D character) hands"
>
> [P10*]: "Tvori-VR tu senang saja; saya main pakai controller dia tekan tangan tu terus kasi gerak, pusing, rotate ke depan belakang, tak perlu tekan banyak-banyak key lagi"* / "Tvori-VR is easy; I use the controllers to to move, turn and rotate to the front and back, I do not need to insert too many keyframe"
>
> [P34]: *"Tvori-VR tu kalau tahu simple instruction dah boleh buat animation"* / "If we know simple instructions, we can create animation in Tvori-VR easily"

For Windows-based Animation, participants who have experienced Autodesk Maya, they **become familiar** and **accustomed** to the interface, and feel easy to learn. However, recall when they first use the application, they find it hard to learn, and getting familiar with it takes time. Example:

> [P35]: *"… kalau untuk Maya, disebabkan selalu guna maybe bagi saya mudah la…"* / "… I feel easy for Maya, maybe because of I regularly use it…"

Being a first-timer to experience Immersive-based Animation, most participants commonly find it hard to understand the environment. Some fast learners would adapt to VR quickly, while others would adjust to the environment as they use it. A common incomprehensible occurred with the interface is due to some tools are invisible, and confusion on interacting with selection tool. Example:

> [P9]: *"… dalam Tvori-VR, dia macam benda tu dia samar-samar; memang kita nampak dia tapi kita rasa macam kita tak sentuh apa, attach betul-betul kita pegang…"* / "… in Tvori-VR, I think the selection tool is confusing; we can see it was selected but actually it was not touched, we need to really hold (the controller) to attach it…"

Most participants admit that Windows-based Animation is difficult to learn. The complex tools and functions within the interface make the animation process complicated. The manipulation of windows, icons, and menus are among the major difficulties. Examples:

> [P1]: *"Maya kena click, kena rotate, kena scale lah, kena 'w' lepas tu kena gerak pakai mouse…"* / "In Maya, we need to click, rotate, scale, use 'w' (shortcut key), and use a mouse…"
>
> [P3]: *"… Maya banyak sangat tools yang kena keluarkan, nak kena cari kat mana"* / "… Maya has too many tools to use and we need to correctly locate it"
>
> [P10]: *"Maya kita susah, ada button untuk specific benda; macam untuk kasi move depan belakang button lain, rotate button lain"* / "Maya is difficult, it has different tools for a specific purpose; the manipulator, and rotation tools serve differently"
>
> [P12]: *"… kalau Maya daripada start sem ni start belajar tu ambil masa juga la macam sampai sekarang pun ada lagi saya still ada function ada error"* / "… it takes time learning Maya, from the beginning I started to learning it, I still encountered errors"
>
> [P18]: *"Maya dia untuk benda lain sekali semua tu so dia ada terlalu banyak feature yang jadi terlalu complicated la"* / "Maya has too many features and that makes it complicated"
>
> [P26]: *"… keyboard [Maya] nak tekan mana, kadang-kadang tersilap tekan, tekan-tekan dia tak baca ataupun saya tak tekan pada tempat yang betul"* / "… with Maya we use keyboards, sometimes we wrongly use it (shortcut keys) or maybe I did not use at the right place"
>
> [P33]: *"Maya dia susah sikit sebab dia ada step-by-step kan, dia kena tahu kat mana dia punya location sebab kadang-kadang dia punya features tu tersembunyi*" / "Maya is difficult because we have to learn it (tools) step-by-step and know its location, sometimes the tools is hidden"

6.5.3 Efficiency

According to the UEQ guideline, efficiency is when '[t]he product should be easy to understand, clear, simple, and easy to learn'. We asked our participants which application would complete their work faster with less effort. We received mixed responses between Immersive-based and Windows-based Animation:

Scale	Negative Code	Positive Code
Efficiency	Slow/*Perlahan* Inefficient/*Tidak berkesan* Impractical/*Tidak Praktik*	Fast/*Cepat* Efficient/*Berkesan* Practical/*Praktik*

	Cluttered/*Serabut*	Organised/*Teratur*

Positive-Negative Code: Fast-Slow, Efficient-Inefficient, Practical-Impractical, Organised-Cluttered

For Efficiency, most participants find that Immersive-based Animation and Windows-based Animation make no difference. Being fast or slow at work with these applications also depend on familiarity of the tools that one could rely on. As a first-time user in VR, some participants feel that it is quite slow to work in VR but find it much faster to work in Maya. For experienced participants, Maya is their preference when comes to efficiency. Among the reasons are sitting is better than standing/moving around the space and the tools are properly organised in designated windows. Interestingly, one participant suggested to use Maya and Tvori-VR collaboratively to make the process work faster. Examples:

> [P5]: *"... bagi saya Tvori-VR la, kalau Maya ni memang boleh habis cepatkan kerja tapi ikut kepada dia punya pengingatan, takut kekadang salah key terlupa nak save keyframe, dah kena ulang balik"* / "… for me Tvori-VR is (efficient), we can finish our work faster in Maya but it depends on how we are competent with the tools, otherwise we have to redo"
>
> [P10]: *"Antara Maya dan Tvori-VR, kalau saya mungkin saya akan guna Maya, […] kita masih banyak lagi tak tahu kalau fasal Tvori-VR, jadi takut nanti time kalau kita nak selesaikan tugasan, tiba-tiba kita tertekan benda yang kita tak tahu"* / "Between Maya and Tvori-VR, I would prefer Maya, […] we still have not familiar with Tvori-VR, so we might use wrong tool for different purpose to perform a task"
>
> [P12]: *"... saya pun rasa Maya la lagi senang untuk saya siapkan kerja sebab kita fixed on one spot […] kita senang nak fokus semua benda dalam tu dalam satu skrin; kalau macam Tvori-VR […] kita kena pusing-pusing, jadi lepas tu kita nak cari mana button dia, […] macam ambil masa dekat situ tapi kalau macam Maya dia fixed so kita senang nak tekan mana semua tu"* / "… for me Maya is practical to complete a task because we are fixed in one place […] it's easier for us to focus everything in a single Windows; in Tvori-VR […] we need to turn (physically in the space) and to locate the icons […] it takes time there, but Maya is organised and easier to look for tools"
>
> [P13]: *"I think I can complete the task faster with Tvori-VR better la even though it's my first time using it and for Maya I use the software a couple of times for assignments and for exploring but I still struggle with Maya"* / "I think I can complete the task faster with Tvori-VR though it was my first time using it and for Maya I use the software a couple of times […] but I still struggle"
>
> [P18]: *"... Tvori-VR […] kena banyak gerakkan badan so kena banyak reach benda so dia ambil take time dekat physical contact dengan software; kalau*

Maya dia tak perlu dia macam just gerak sebelah tangan sebelah tangan lagi letak kat keyboard; Tvori-VR kita faham kita boleh tengok 360 degrees la tapi kita kena gerak kena pusing semua dia better detail dekat situ cuma lagi laju dekat Maya la" / "… in Tvori-VR […] we move our body a lot to reach things in the environment, so the physical contact with the software itself takes time; in Maya we just move our hands for the mouse and keyboard; we understand that in Tvori-VR we can move 360 degrees is good but handling Maya is faster"

[P34]: *"… kalau setakat simple movement Tvori-VR lagi cepat sebab dia punya functionality lagi simple lagi direct […] kalau walk-cycle yang tu saya rasa better kat Maya kot…"* / "… for simple movement Tvori-VR is faster because the functions are simple and straightforward […] if to animate a walk-cycle I think Maya is preferable…"

[P36]: *"Kalau habis cepat, Tvori-VR, kalau nak lebih detail, Maya la sebab saya belum lagi explore dalam Tvori-VR macam contoh Maya ada Graph Editor tapi Tvori-VR saya tak tahu kat mana…"* / "To finish work faster, Tvori is the one, but I have yet to explore because I could not locate some of the tools; for detailing I would use Maya because it has the Graph Editor"

[P25]: *"… kalau untuk animate saja, kalau karekter daripada Maya tu dia boleh tukar kepada Tvori [import/export file] ke Tvori itu lebih senang, kita animate kat Tvori lepas tu dia dah settle kita export, lepas tu kita masuk balik Maya..."* / "… to animate a character, perhaps it would be nice to use Tvori-VR and Maya where we can interchangeably import/export files"

6.5.4 Dependability

The UEQ specified that dependability is when '[t]he interaction with the product should be predictable, secure and meets my expectations'. We asked our participants their interaction experience while manipulating 3D character model and the Timeline window in Tvori-VR and Autodesk Maya. We received mixed responses between both interfaces although some participants are inclined towards Windows-based Animation:

Scale	Negative Code	Positive Code
Dependability	Unpredictable/*Tidak boleh diramalkan* Obstructive/*Menghalang* Not Secure/*Tidak terjamin* Does not meet expectations/ *Tidak memenuhi jangkaan*	Predictable/*Boleh diramalkan* Supportive/*Menyokong* Secure/*Terjamin* Meets expectations/*Memenuhi jangkaan*

Positive-Negative Code: Predictable-Unpredictable, Supportive-Obstructive, Secure-Not Secure, Meet expectation-Does not meet expectations

Asking about expectations of the interaction of a window tool (i.e. Timeline) that is commonly used for animation in both applications, most participants are likely preferred Windows-based Animation rather than Immersive-based Animation. They commented that Maya interfaces are more **reliable** and secure in terms of its tools arrangement in the windows. The standard and universal use of shortcuts keys on the keyboard, mouse clicking, and the conventional 3-dimensional coordinate system make users feel more dependable. As VR application, Tvori-VR supports all freedom and excitement allowing physical movement and moveable windows in the environment, some users find sometimes this can be obstructive and unpredictable. Examples:

> [P7]: *"Maya lagi spesifik nak gerak ke bahagian mana sebab ada part untuk boleh gerak (paksi X, Y, Z) dengan boleh rotate boleh nampak siku ke; kalau Tvori-VR gerak limited, lepas tu tak spesifik pergerakan akan terikut sekali"* / "Maya is more specific when comes to move and rotate on X, Y, Z axes; Tvori-VR axes are not specifically designated, sometimes it moves in all axes"

> [P9]: *"Maya kita pakai mouse, kalau kita pakai Tvori-VR kita pakai tarik tangan, kita tak ada penahan, so dia agak kadang-kadang ter-drag skit"* / "We use a mouse in Maya while in Tvori-VR we move our hands and it does not retain (moving in the space), sometimes we accidentally dragged (the object) elsewhere"

> [P17]: *"Maya senang sama je macam Tvori-VR dia akan ke auto in-between tapi Tvori-VR nak letak keyframe susah sebab kita kena spesifik time"* / "Maya is as easy as Tvori-VR when comes to keyframing, but Tvori-VR seems difficult to secure a frame at a specific time frame"

> [P20]: *"Maya nak gerak joint part tangan agak leceh sebab kena precise satu-satu tapi kalau Timeline dia senang nak akses frame one-by-one; Tvori-VR kalau bab animation memang free senang nak adjust movement tapi bagi saya Timeline Maya lagi elok daripada Tvori-VR"* / "To move a character's hand joint (IK and FK handles) is tedious because we need to be precise, but it is very accessible when handling keyframing in the Timeline; we have all freedom to animate in Tvori-VR but for me, Maya's Timeline window is much reliable than Tvori-VR"

> [P25]: *"Tvori-VR [...] Timeline kita nak panjangkan duration kena tarik; key pose macam tak ok tapi kita nak Undo tak boleh, kalau ada option tu untuk delete ok juga. Maya kalau dah biasa guna shortkey untuk delete, untuk cut, undo apa semua"* / "In Tvori-VR, we need to pull out the Timeline window to extend the duration (of the animation); when we wrongly do key poses we cannot find an Undo or Delete functions. I am used to Maya shortcut keys to delete, cut and paste, undo, and others"

> [P28]: *"... Maya Timeline kat situ je tak banyak pergerakan, so tangan tak banyak pergerakan just kiri kanan; kalau guna Tvori-VR perlukan tenaga saya rasa macam lenguh sikit berbanding Maya guna mouse; kalau Tvori-VR saya tak tahu macam mana nak Ctrl z (undo), kalau Maya senang je kat keyboard dan tak banyak pergerakan pun tangan"* / "… the Timeline window in Maya is fixed at one spot, so we do not move a lot; in Tvori-VR we take a lot of efforts

to move around and I feel slightly troublesome compare to use a mouse in Maya; in Tvori-VR I do not know a shortcut for an undo (Ctrl z), compare to Maya is easier on the keyboard and we do not move a lot"

[P34]: *"Timeline Maya lagi detail lagi sharp maksudnya dalam slot 1 sampai 10 macam pembaris, tapi Tvori-VR walaupun include number kat atas daripada 0 ke 10 ada 123 waktu kita tarik tu tapi still confusing [...], Maya lagi predictable berbanding Tvori-VR... kedudukan Timeline Maya fixed kat bawah [...] tapi Tvori-VR saya seronok guna Tvori-VR tu sebab saya bebas nak tarik sini ke buang ke tarik ke buang ke so Timeline dia tu boleh gerak mana-mana saya nak letak..."* / "In Maya, the Timeline window is much more detailed in terms of its frame rate numbers (i.e. 1 to 10 frame marker); although Tvori-VR has the same feature, it is still confusing […], and Maya is predictable than Tvori-VR because the Timeline window is fixed and located at the bottom […], I like to use the Timeline window in Tvori-VR because we are freely to move it anywhere in the environment"

[P35]: *"Timeline Tvori-VR time kita nak gerakkan dia cepat hilang, kita nak tengok keyframe, automatik dia hilang, kena tekan balik gesture tangan tu baru keluar balik, lepas tu kena check betul-betul takut autokey balik bila tutup autokey, dia hilang pula bila nak play, dia tunjuk animation tu je; tapi Maya mudah sebab tekan macam mana pun takkan hilang, yang tu la kelebihan dia"* / "The Timeline window in Tvori-VR seems to have disappeared out of sudden every time I am working on it; while the advantage of Timeline window in Maya is very convenient because it is located at one place and will never disappear"

[P36]: *"Tvori-VR bagi freedom boleh letak mana-mana je kadang-kadang boleh jadi susah juga sebab letak mana-mana je kita suka tapi dalam masa yang sama boleh jauh pergi dia"* / "Tvori-VR application windows are moveable and gives us freedom to move it anywhere in the environment, but at the same time it can be troublesome and goes missing"

[P37]: *"Tvori-VR senang cuma kadang-kadang animate tiba-tiba keyframe dah ada, so tanpa sedar dapat keyframe tambahan keyframe terpaksa delete yang tu, kalau tak perasan mungkin akan jadi cacat sikit la..."* / "Tvori-VR is easy but sometimes it happened when keyframes are automatically added on the timeline, and it can ruined our animation…"

[P38]: *"... graph (Graph Editor) kat Maya senang nak adjust, bila dekat Tvori-VR saya cari graph dia tak ada tapi animation curve dekat movement macam tangan tu ada tapi tak boleh nak reach untuk adjust dia"* / "… the Graph Editor in Maya is effortlessly adjustable, but in Tvori-VR I could not locate the Graph Editor, instead I found animation curves on the character's joints but I could not reach and adjust it"

[P40]: *"Maya boleh delete terus, kalau Tvori-VR kena tarik sebab tu nak alihkan tu susah sangat kena tahan tak boleh genggam sangat tangan"* / "In Maya we can directly delete (a frame), but in Tvori-VR we need to pull out (a section in the window), and removing it (unwanted frame) is inconvenient as we need to carefully grasp the frame while holding the controller in our hand"

Stimulation, and Novelty for Hedonic Quality

For Hedonic Quality, the UEQ framework has specified Stimulation and Novelty as the primary scales. When commenting on the excitement between Immersive-based and Windows-based Animation, majority of participants are pleasurable using both approaches although Immersive-based Animation received a high acceptance rate.

6.5.5 Stimulation

According to UEQ, stimulation is '[u]sing the product should be interesting, exciting and motivating', which means, a user should feel pleasurable towards their experience that could propel and sustain their motivation in the process:

Scale	Negative Code	Positive Code
Stimulation	Inferior/*Kurang bermutu* Boring/*Membosankan* Not Interesting/*Tidak menarik minat* Demotivating/*Tidak mendorong*	Valuable/*Bermutu* Exciting/*Menyeronokkan* Interesting/*Menarik minat* Motivating/*Mendorong*

Positive-Negative Code: Valuable-Inferior, Exciting-Boring, Interesting- Not Interesting, Motivating-Demotivating

Almost everyone involved in the study highly rated Immersive-based Animation as exciting, interesting, and very motivating. For them, it is completely a **new experience** to **actively** use the physical body to work makes it more **interactive**. Again, the **immersed feeling** of exploring the VR environment is what excites participants most. Interestingly, one participant stated that the experience is very much like gameplay. Examples:

> [P1]: *"... satu experience yang saya tidak pernah feel, so ia adalah kali pertama saya animate dalam dunia maya dengan dunia um di mana saya boleh ubah saiz character kan..."* / "… completely a new experience for me, my first time to animate in the virtual world where I can resize the character (to life size)…"
>
> [P5]: *"Kalau nak experience, Tvori-VR lah sebab tak pernah lagi orang buat masa ni"* / "Tvori-VR is a new experience because I never seen this before"
>
> [P6]: *"Saya rasa saya lagi suka Tvori-VR kot sebab macam lagi interaktif"* / "I think I like Tvori-VR because it is more interactive"
>
> [P8]: *"Tvori-VR of course, sebab memang seronok VR sebab nak pakai pun macam boleh la kalau dah tahu button dia memang senang betul nak pakai"* /

"Definitely Tvori-VR because it is really fun, easy to use if you know the tools in it"

[P9]: *"Tvori-VR ni yang bestnya bila kita boleh tengok surrounding dia [...] kita boleh tengok secara virtual lah"* / "What is interesting about Tvori-VR is that we can see and experience its surroundings"

[P10]: *"Tvori-VR saya lagi teruja untuk buat kerja sebab saya tidak pernah lagi try benda tu, [...] jadi rasa macam motivasi kalau mau buat kerja pakai VR*" / "I really excited using Tvori-VR because I never tried before, […] so I feel motivated if I want to do work with VR"

[P14]: *"... kalau exciting atau pun lebih motivated is definitely la yang Tvori-VR"* / "… if to feel excited or motivated, definitely Tvori-VR"

[P18]: *"Saya rasa Tvori-VR lagi interesting lagi banyak dia lagi banyak motivation untuk gunakan"* / "I think Tvori-VR is more interesting and motivated to use"

[P19]: *"Tvori-VR la sebab satu dia benda baru and memang totally new experience, macam saya kata la mesmerised giler dengan benda ni sebab memang tak pernah cuba…"* / "It is totally new experience using Tvori-VR, like I said, I feel mesmerised with it because I never tried before"

[P20]: *"Tvori-VR sebab dia punya cara buat tu dia macam dalam diri sendiri; macam game- macam mission kena buat tu lah 3D model [...] so very dia macam very exciting untuk buat la, so dia lagi seronok nak buat, so orang lagi akan motivated lah, akan enjoy"* / "I feel like immersed within myself in Tvori-VR; it is like a game- like a mission game to animate a 3D model […] so it is exciting, fun, make people motivated and enjoyed using it"

Commenting on excitement for Windows-based Animation, most participants find it is a **valuable** application for more **complex** and **detailed** animation processes. Although windows is a common interface, they perceived GUI and WIMP as something for formal and important usage. Examples:

[P5]: *"... walaupun beginner, saya rasa macam dah biasa jugalah tengok"* / "… even though I am a beginner (Maya), I feel like normal"

[P13]: *"... untuk assignment ni I need to use this software which is Maya so [...] untuk pembelajaran under Maya I'm okay"* / "… for assignments, I need to use this software which is Maya so […] for serious learning, I am fine using Maya"

[P15]: "I'm also excited to use Maya because it's also my first time animate(ing) a 3D in Maya, and I found like it's much more easier to animate in Maya"

[P16]: "Maya maybe like an old way old school way thing, just sitting, on the laptop and just doing it…"

[P20]: *"Maya, dia teknikal lepas tu dalam skrin je lepas tu dia nak kena gerak-gerak tu memang precise pakai mouse so dia"* / "Maya is very technical, screen-oriented but the selection (clicking) using mouse is very precise"

[P38]: *"... untuk yang complex, rasanya Maya senang lagi sebab dia banyak boleh control"* / "… for a complex work, I think Maya is easier because it is controllable"

We found that none of the participants give negative responses in terms of Stimulation for Immersive-based Animation. However, for Windows-based Animation, few participants find that it has become **accustomed, familiar** and **nothing is interesting** about the desktop application. They feel bored and demotivated from ordinary though it is not their main concern. Examples:

[P12]: *"Maya tu kita just gerak tangan dengan mouse [...] so macam bosan la*" / "In Maya, we just move a mouse […] so it is boring"

[P18]: *"Maya tu dia like kita dah biasa guna laptop, so dia kurang motivation kurang interesting la"* / "We used to Maya and the laptop, so it's low motivation and less interesting already"

[P19]: *"Maya pula walaupun dia memang bagus tapi disebabkan kita macam dah biasa menghadap benda tu so dia tak ada la benda yang boleh nak kata macam menarik sangat"* / "Even though Maya is really good, but because of we have used to it on regular basis, so it is not something that is so interesting"

6.5.6 Novelty

As stated by UEQ, novelty is '[t]he product should be innovative, inventive, and creatively designed. In our study, the outlook impression of using VR application in animation has captured most of our participants' interest:

Scale	Negative Code	Positive Code
Novelty	Dull/*Tidak bersifat kreatif* Conventional/*Berdasarkan kebiasaan* Usual/*Biasa* Conservative/*Konservatif*	Creative/*Ada kreativiti* Inventive/*Terdapat rekaan baharu* Leading Edge/*Mempunyai kelebihan* Innovative/*Inovatif*

Positive-Negative Code: Creative- Dull, Inventive- Innovative, Leading Edge-Usual, Conventional-Conservative

In general, most participants feel that both Immersive-based Animation and Windows-based Animation are very innovative and creative way to create animation. But, knowing the VR experience is stronger, it is not surprising that Immersive-based Animation is highly received by all participants. The **'wow-factor'** affects most of the participants impressed by the **advancement** of VR interface brought into animation. There are participants who see VR interface as the **future learning system** for students. Examples:

> [P1]: *"Tvori-VR ni dia lebih inovatif, lebih baru, lebih canggih; saya rasa memang sangat menyukainya la; lebih canggih, lebih moden, lebih maju*" / "Tvori-VR is very innovative, new, advanced; I really like it!"
>
> [P2]: *"Kreatif dan Inovatif kalau dari segi untuk macam advance yang menariknya Tvori-VR"* / "Tvori-VR is really advanced, creative and innovative"
>
> [P10]: *"... dalam Tvori-VR tu, kita macam dalam movie tu sendiri yang kita buat, kita boleh buat susun itu terus kita tengok"* / "… In Tvori-VR, I feel like as if in the movie itself; we create, arrange and watch it"
>
> [P12]: *"Tvori-VR lagi hebat la untuk pembelajaran macam untuk zaman depan depan ke maybe dia boleh apply VR learning untuk student..."* / "Tvori-VR is great for future learning and the VR learning can be applied for students…"
>
> [P26]: *"... it's the future; it's possible la nanti one day kita semua pakai VR animate guna VR semua tu, so it's good innovation"* / "… it's the future; it's possible one day all of us will use VR, so it's a good innovation"

Some participants who showed interest with VR also have a fair interest with Windows-based Animation. They regard the Windows interface as a common application used by everyone. They see WIMP in the context of task and process rather than just an interface as it can be more innovative and provide more **creative solutions** in their work. Examples:

> [P6]: *"Maya tu saya rasa macam, dia standard industri tapi saya rasa inovasi juga sebab macam banyak lagi tak explore"* / "I think Maya is innovative and still have more to explore, it is very industry standards"
>
> [P11]: *"... inovasi saya more to Maya sebab banyak tu lah benda yang kita, lepas tu dia fokus satu-satu"* / "… for innovation, I am inclined towards Maya because it has a lot to offer and we can focus specifically on something"
>
> [P18]: *"Maya pula lagi sesuai bagi kerja-kerja yang lagi complex maybe kerja-kerja yang perlukan detail banyak tak sesuai macam kalau nak for fun [...] untuk kerja industri macam tu dia lagi sesuai sebab interface dia tu complex"* / "Maya is suitable for detail works because the interface is complex, and not for fun use (like Tvori-VR)"

> [P20]: *"Maya dia banyak cara dia boleh buat dia punya objek […] dia punya skop dia lagi luas"* / "Maya has a lot of different ways of using it […] the scope of use is wider"
>
> [P27]: *"... saya rasa kalau nak lebih detail bagi pendapat saya la, Maya tu maybe lagi detail"* / "… in my opinion, I think, if we go for detailing, Maya maybe is the one"
>
> [P30]: *"Maya keluarkan update mungkin ada features baru jadi itu mungkin lebih inovatif la untuk animator sekarang macam ada features yang boleh senangkan kerja ..."* / "Maya has many releases and each release has new features, and that makes it innovative software to make animator's life easy"

None of the participants give negative responses for Immersive-based Animation in this scale. It is crucial to note that none of the participants denied the GUI and WIMP interfaces, for one reason, that the novelty of VR has dominated their new experience. In this case, few participants, find Windows-based Animation is **conventional, dull** yet **realistic**. Examples:

> [P1]: *"Maya saya rasa dia agak lama dan praktikal dan konservatif la"* / "I think Maya is an old way, conservative but practical"
>
> [P10]: *"... kalau kita buat animation selalu kita just buat dalam laptop pakai skrin pakai drawing tablet..."* / "… we stare a lot at laptop screen and use drawing tablet to create animation…"
>
> [P20]: *"... rasa macam dull, macam tu je lah, biasa-biasa je"* / "… I feel dull, feeling usual…"

6.6 Discussion

Our findings highlight the evaluation of the usability study of participants performing tasks using Tvori-VR and Autodesk Maya. The findings also helped to address our hypotheses speculated in this experiment.

Hypothesis 1: Immersive-based Animation is more attractive way to create animation than Windows-based Animation.

The results strongly imply that Immersive-based Animation obtained a higher score for *Attractiveness.* This explained that the innovative outlook of VR and the interface give an impression to participants to feel enjoyable to use compared to the conventional Windows-based Animation. Virtual reality technology is much talked about by some participants, and it has influenced others to explore it. From the feedback that we asked, what makes them feel the excitement is the VR immersive experience itself, something that they had never interacted with before with the VR device and used for animation. A sense of presence of the interface elevates "a state of consciousness, the […] sense of being in the environment" (Slater and Wilbur, 1997, as cited in Roger et al., 2011, p. 177) and perceived as real.

Hypothesis 3: Immersive-based Animation is exciting and innovative tool than conventional Windows-based Animation for animator to create animation.

Similarly, the *Attractiveness* result is further supported by the sub-hypotheses findings in terms of hedonic qualities that attained high scores for *Stimulation* and *Novelty*. Animating in an immersive environment has transformed user's perception and behaviour after they become into contact with VR, an experience that removed themselves from what they have accustomed to normal tools.

a) ***Stimulation***

Sub-Hypothesis 3a: Immersive-based interface is more exciting tool to create animation than Windows-based interface.

The VR virtual environment itself, by nature, somehow stimulates user interaction, at least for new users. It has demonstrated in this study that when novices are exposed to new way of interface interaction, the level of motivation is high. They become fascinated by the bodily active engagement and virtual experience and make them associate it to other events that happened in real life, i.e. playing with dolls, playing video games, and feeling like a traditional stop-motion animation technique.

b) ***Novelty***

Sub-Hypothesis 3b: Immersive-based interface is more innovative for producing creative animation than Windows-based interface.

We would say that the attraction of the advancement of VR technology and its environment much affects our user interaction with the interface. Unlike conventional windows application, bringing VR into the process of animation opens an opportunity to novice users exploring new experience, not just interacting with the immersive environment but actively respond to their bodily movements in the physical space.

Hypothesis 2: Immersive-based Animation is more practical, in terms of efficiency and dependability way for producing animation than Windows-based Animation.

In contrast, the results reported for *Perspicuity, Efficiency,* and *Dependability* are statistically no difference between animating using VR and WIMP interfaces. Pragmatic qualities determine user performance in achieving animation production goals; therefore, this can be justified in terms of practical attributes, both interfaces have equal values for its advantages and drawbacks. It can be interpreted that VR and WIMP interfaces could be convenient for good use or limited in some way. One user from our study points out that it is more practical if both methods are used synonymously in which VR provides a better platform for animation, while WIMP brings more robust tools for detailing. This hypothesis is supported by *Perspicuity, Efficiency,* and *Dependability* as sub-hypotheses:

a) ***Perspicuity***

Sub-Hypothesis 2a: Immersive-based interface is more adaptable and navigable when creating animation than Windows-based interface.

An explanation for perspicuity is having clearness and explicitness of the functions and tools in the interface. Our result for perspicuity is insignificant. Our study suggests, what influences adaptability is the simplicity of the interface that makes users easy to interact compared to a more complex interface. It also depends on the competency level of interaction in terms of beginner, intermediate or advanced users. In our case, most of the users are new to Autodesk Maya, therefore, their understanding of the animation tools of the software are limited. Most users enjoyed Tvori-VR for its simplicity of the interface, but as a new user to VR system, it takes a while to understand the immersive environment.

b) ***Efficiency***

Sub-Hypothesis 2b: Immersive-based interface is more effortless tool to create animation than Windows-based interface.

For efficiency, the feedback obtained is insignificant whether users are able to solve their animation tasks quickly or slower. In one way or another, tools and functions featured in the VR or conventional WIMP interfaces would either aid or hinder one to work effectively. However, the trend discovered from the interview is that experience dictates effectiveness of the usage. It is likely that users with prior knowledge and skill would prefer the application, rather than using a new application that makes them work slower. Being new to software requires one to explore and understand the tool from scratch. Familiarity with the navigation of animation software is key for one would work with little or more effort.

c) ***Dependability***

Sub-Hypothesis 2c: Immersive-based interface is a more dependable tool to create animation than Windows-based interface.

Dependability is another aspect that affects user performance whether it is reliable or not when interacting with the interface. The result obtained was also insignificant between VR and WIMP interactions. However, from the observation in our study, we found that the more established the interface, the better the dependency on the system. From the feedback obtained from the interview, users feel more secure when interacting in windows-based interface as the WIMP system is more predictable.

6.7 Summary

This study suggests that the use of VR in animation is still in its infancy for some population of users. The VR immersive technology is highly attractive and motivating to use. The level of competency and demographic population are factors that influence the adaptability of VR applications in the animation process. However, for certain use of tools during the process of animation which requires comprehensive functions, a more conventional and established application is needed. The robustness of the WIMP interface is still an essential application for a user to rely on and work efficiently.

7 Chapter 7

Conclusion

This thesis generally contributes to the development of a technique in the field of animation, with the aim of the research concerned specifically with the role of hand gesture as a novel method of creating animation.

7.1 Addressing Research Questions

The first research question asked *could hand gesture animation transform the technique of creating character animation*? This question was addressed in Chapter 3 through using a set of methodologies, to investigate the understanding of the traditional method of creating animation, the notions behind string-based manipulation in puppetry, to the development of interface design and prototyping of a hand gesture animation technique. With the use of motion sensing technology, I designed a NUI-based interface to interact with virtual object naturally with the hope that this new form of interaction could enhance learner animators' potential. The initial expectation was that the hand gesture technique could be used as a way to escape from the tediousness of the frame-by-frame animation technique.

To assess the capabilities of the interface design and prediction, I addressed the second and third questions that asked *could hand gesture animation improve the process of animation for learners*, and *could hand gesture assist learners more than keyframe animation technique to create animation efficiently*? These questions were addressed in Chapter 4 by conducting a usability study through the participation of users to assess the effectiveness of hand gesture animation. In comparing the hand gesture technique to keyframing, there was an overwhelmed response from novice animation learners that hand gesture has potential to become a new trend for creating animation. For them, the directness of the interaction between hand gesture and the animated object creates the ‘fun’ side of creating animation in real time. In addition, the results in this chapter report that the system is capable of assisting learners to produce animation more quickly. Nevertheless, the system does not provide an effective interface as it caused confusion concerning the dexterity of the hands moving in mid-air and the matter of the ‘mirror image’ between the user and 3D character as they face each other.

In parallel to these questions, the fourth question asked *would the hand gesture technique provide an adequate quality of animation?* was a great challenge. This research question was examined in Chapter 5 by reporting the study of the quality of animation. While the hand gesture technique can be fun, in one way or another, this approach is somehow lacking in another respect. Concerning the issue of quality, hand gesture was unable to achieve all the appropriate movements for animated characters. This was due to the users' unfamiliarity with the hand gesture controls. The experiment was a comparison of the outcomes of keyframing and hand gesture animation, and the keyframing technique was much more controllable when it came to detailing. Detailing in this respect can be traced back to Disney’s Principles of Animation where the issue of squash and stretch, timing, anticipation, overlapping action, slow in and slow out, and arcs are highlighted as important. These detailing systems are much more controllable in keyframe animation, which can provide a more ‘believable’ quality of an animation, according to the participants.

7.2 Hypotheses Testing

While addressing the research questions, some hypotheses were tested. Reflecting upon the main hypothesis proposed in this thesis, that *hand gesture can improve productivity in creating animation,* the study demonstrated that the technique did help learners to create animation faster than by using keyframe animation. From the findings, this research found that, in regards to work efficiency, hand gesture works faster than keyframe animation. Hand gesture could use less effort to create animation due to the nature of the technique that promotes real-time interaction compared to the laborious and time-consuming technique of keyframe animation.

Although hand gesture animation can have a higher level of productivity, two sub-hypotheses results provided different outcomes. The first sub-hypothesis stated that *gesture animation has a better level of usability and efficiency than keyframe animation* and the second sub-hypothesis claimed that *gesture interface produces a better quality of animation than keyframe animation*. Although the interface provided a faster completion time, the hand gesture technique failed to produce an effective interface. Feedback from the participants showed that the hand gesture interface was difficult to control and caused perplexity. As a result, due to their unfamiliarity with the technique and difficulties in grasping the gesture interface, the study also showed that the interface could not help the participants produce good quality animation. For them, the hand gesture interface was incapable of providing the detailed work of animation like keyframe animation could.

7.3 Future Work

The outcomes achieved so far suggest that hand gesture animation has its own unique system that can be extended through further investigation. The time-saving results from the interface demonstrated that the technique has the potential for creating a more robust system.

i) Improve Usability Drawback of the Interface Design

I built the foundation of the system to accommodate any possible direction that can be used to create animation. The system created for this study is a preliminary, trial one, accessible for other possible developments. During this investigation, the participants made suggestions about how to make the interface more user-friendly so it could be used more effectively. Based on these recommendations in Chapter 4 (see 4.7.4), I realised that more technical functions were needed to provide a more comprehensive interface. One essential feature that they pointed out was the ability to enlarge and reduce (also known as zoom in and zoom out), and rotate the view of the interface and the 3D object using gesture control, so that the object can be seen from different angles. The process of animating could be more effective with this function. The issue of the 'mirror image' of the user and 3D character should also be considered in order to overcome confusion about which hand is operating which gesture at a given time. This is because the user and 3D character face each other, so when the user moves his right hand, the character moves one of his limbs on the left. The features provided by the current prototype are thus limited.

Another useful recommendation for future development is to provide a gesture-based motion editable feature in the interface whereby this function is to be able to control motion. The kinaesthetic-based method could also control the ‘weight’ of the 3D object in order to project a sense of heaviness or lightness onto the animated object. Another potential function is to enable the user to create elasticity for the animated object by squashing and stretching the distance between two fingers in order to give a sense of exaggerated movement to the animation created. These features are expected to improve the interaction between animator and animated object and overcome the complexity of animation control, using the Graph Editor of any computer animation software package. A Graph Editor functions as a method to refine motion work by editing tangent curves in order to enhance the animation timing and actions of an animated object.

The idea of developing real time squash and stretch was inspired by Chenney's work; I was intrigued by his model which proposed a cartoon style of deformation generated in real time (Chenney et al., 2002). In a future extended method, the controlling system will be kinaesthetically controlled through the exertion of hand gestures.

ii) Refine Hand Gesture Vocabulary

With the further development of features in future work, the range of gesture vocabulary should be considered to enhance the robustness of the system. Hand gesture animation was adapted from traditional marionette control. One of the most important factors in puppeteering is the manipulation of the puppeteer’s hands controlling the rods and strings, which move the puppet. The current gesture vocabulary is limited to the rudimentary skills of the puppeteer’s hand movements that were used to make them compatible with the basic gestures recommended in Leap Motion. The puppeteer’s hand manipulation is a technique involving aspects of both art and science that could be further examined.

iii) Laban Movement Analysis (LMA) collaborative development

I was introduced to Laban Movement Analysis (LMA) in the earlier part of this research, and became interested in the concept of analysing the movements behind

LMA. Previously, LMA was investigated and applied by animators using keyframe animation (Bishko, 2007). As this research gradually evolved into designing interaction, LMA came to my attention again concerning how the system could be applied within the hand gesture interface. I realized body movements are in the four LMA Basic Efforts alongside its elements (see Figure 3.8). These are essential elements and need to be understood when creating animation using any gesture-based technique. A certain form of framework can be devised by combining LMA and hand gesture techniques in order to provide a more robust animation technique.

iv) Extend the understanding of animation using gesture controls

A hand gesture based manipulation system is relatively new in the field of animation, and the understanding of the system is still in its infancy. Based on the feedback from the interviews outlined in Chapters 4 and 5, most users found hand gesture animation difficult to learn and claimed it could make them feel tired after a short time. The concerns are due to the fact that the controlling system requires them to exert motion in the mid-air space. The use of both hands simultaneously to control the 3D character is also another reason that contributes to the confusion of using the system. The method itself relies on the user's intuitive sense of movement to float their hands in the air and manipulate their gestures without having the need to clutch or be dependent on any device. The integration between the LMA framework and the development of the interface could increase the study and observation of movement and develop the usability of the system.

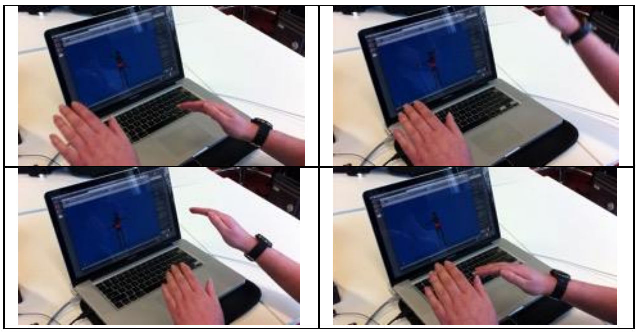
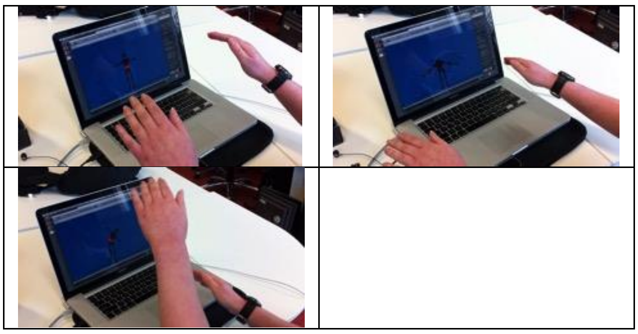
7.4 Summary

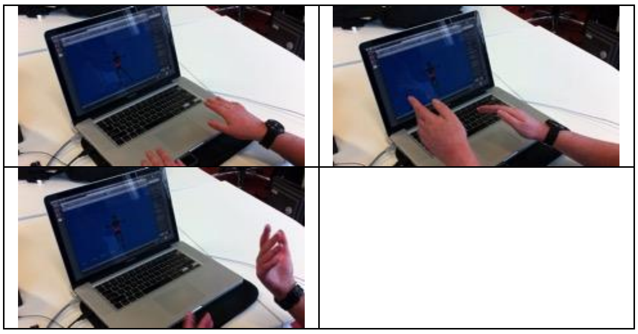
While the proposed system requires further development in many respects, the fundamental concept of bringing in the use of a hand gesture manipulation system from a NUI perspective conveys a different perspective for creating animation. With help from the advancement of HCI in recent years, where technologies have become embodied, intuitive, and interactive, I believe hand gesture animation or what I would refer to as 'Kinaesthetic Animation' could play a greater part in computer animation in the future. Animation today should not be seen only as an 'illusion of life' based on a sequence of images, but should evolve as an aspect of interactive performance of human and inanimate objects engaged within one bodily perception. Hand gesture animation is not intended to replace any existing animation techniques, but rather, as motivation for creating an innovating dynamism in the user interface of animation systems.

Appendix A

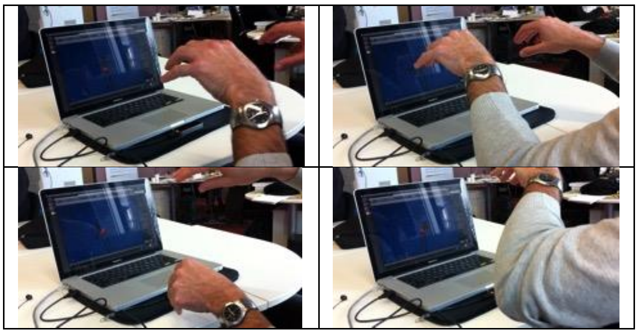
Appendix A-1: Hand Miming Study

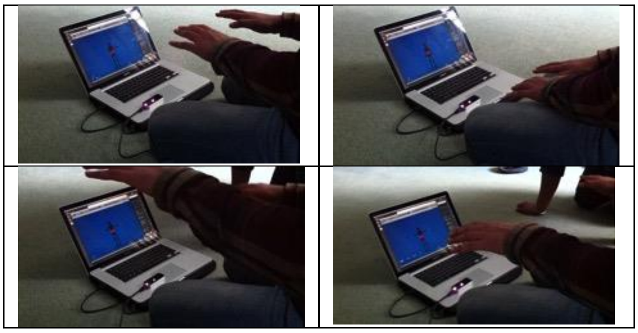
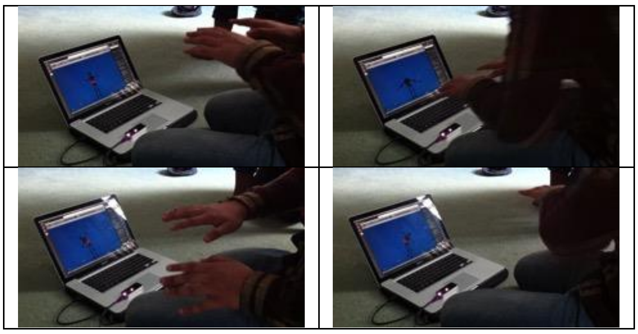
This appendix provides detailed information about the method used to analyse hand gesture interface (see 3.5.2.1 in Chapter 3).

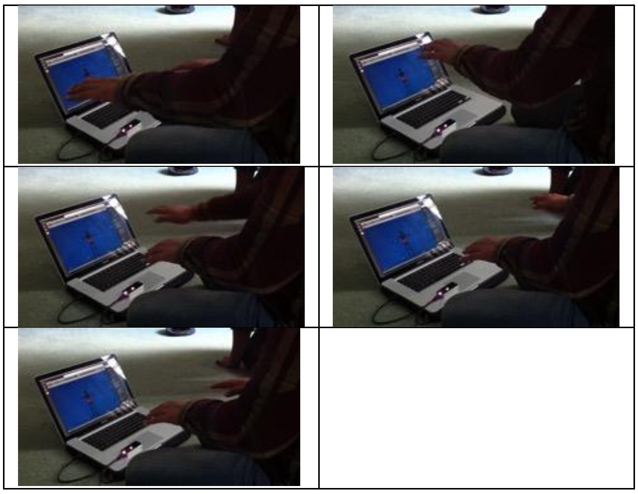
USER 1: Date: 25th March 2015 Duration of test: 1 min 22 secs (including transition time between 4 different exercises)		
When Pre-animated Character moves its…	**User Gesture Responses to the Character**	**Type of Hand Gestures Used by User**
Hands (Up, Down, Forward, Backward)	 1) User places her both hands above LM (Leap Motion) before animation takes place 2) Occasionally user unable to control speed and timing her hands movement and are almost unmatched the character's hand movements. 3) User uses both hands: a) Upward/Downward- to move character's hands upwards/downwards b) Forward/Backward- to move character's hands forwards and backward	1) Moves Up/Down 2) Moves Forward/Backward 3) Swipe (occasionally)
Torso (Forward, Backward, Side Left, Side Right)	 1) User uses both hands to control the character.	i) Moves Forward/Backward ii) Moves Sideways (left/right)

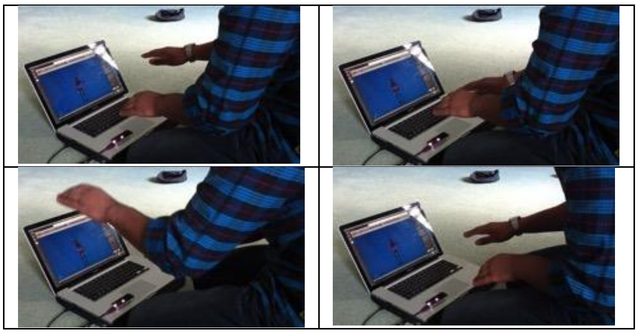
	2) When character lean forward, user tend to spread her hands sideways. 3) When character lean sideways left and right, user follows to move hands sideways with both hands	
Legs (Up, Down, Forward, Backward, Side Left, Side Right)	 1) Hand gesture control for the character's legs is almost similar to how user manipulates character's hands. 2) Occasionally user flipped her hand when character's leg moves sideway (left/right)	1) Moves Up/Down 2) Moves Forward/Backward 3) Flip Sideways (left/right)

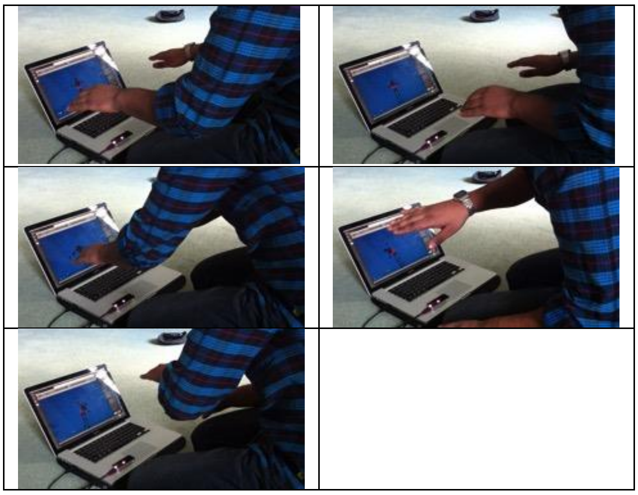
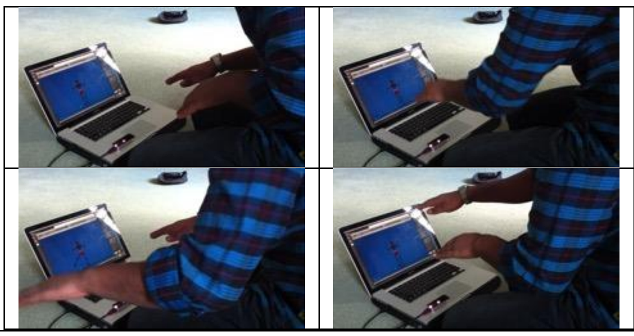
USER 2: Date: 25th March 2015 Duration of test: 1 min 26 sec (including transition time between 4 different exercises)		
When Pre-animated Character moves its…	**User Gesture Responses to the Character**	**Type of Hand Gesture Used by User**
Hands (Up, Down, Forward, Backward)	 1) User places her both hands above LM (Leap Motion) before animation takes place 2) User's hand acceleration and placing in midair are confused by the different timing of character's hand movements. 3) User uses both hands: a) Upward/Downward- to move character's hands upwards/downwards	1) Moves Up/Down 2) Moves Forward/Backward

	b) Forward/Backward- to move character's hands forwards and backward	
Torso (Forward, Backward, Side Left, Side Right)	 1) User uses both hands to control. 2) Move hands forward/backward 3) User able to control the speed and timing of his hands according to the movement of the character's speed and timing although there is slight delay from his anticipation 4) User slides both hands sideways (left/right) as the character leans left and right	1) Moves Forward/Backward 2) Moves Sideways (left/right)
Legs (Up, Down, Forward, Backward, Side Left, Side Right)	 1) User uses both hands to control legs. 2) User tilts hands up/down and left/right 3) User confused in anticipating character's leg movements	1) Tilt Up/Down 2) Moves Sideways (left/right)

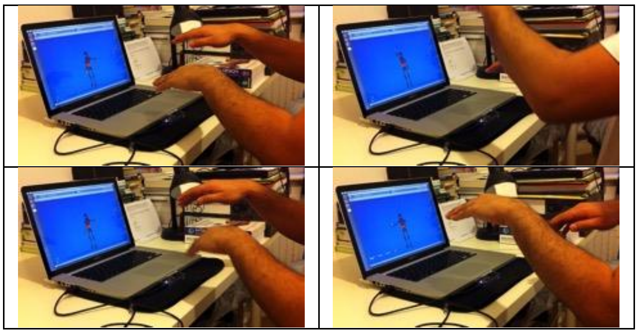
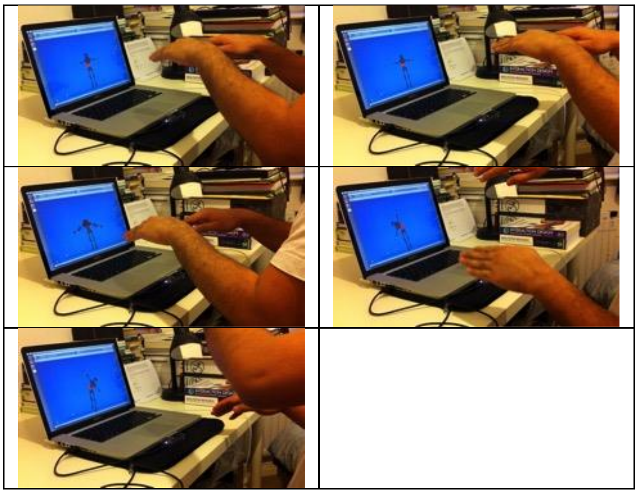
USER 3: Date: 26th March 2015 Duration of test: 1 min 26 sec (including transition time between 4 different exercises)		
When Pre-animated Character moves its…	**User Gesture Responses to the Character**	**Type of Hand Gestures Used by User**
Hands (Up, Down, Forward, Backward)	 1) User sitting on the floor while the system is lower than his hand gestures 2) User places her both hands above LM (Leap Motion) before animation takes place 3) User anticipation of his hand's speed and timing are almost matching character's hand movements. 4) User uses large airspace to move his hands. At times his hands are out of control and go beyond the sensor radius 5) User uses both hands: a) Upward/Downward- to move character's hands upwards/downwards b) Forward/Backward- to move character's hands forwards and backward	1) Moves Up/Down 2) Moves Forward/Backward
Torso (Forward, Backward, Side Left, Side Right)	 1) User moves hands forward/backward as the character leans forward/backward 2) User (unconsciously) moves his body at the same time. **This is probably the term 'imitate' that I used to describe the task at	1) Moves Up/Down 2) Moves Forward/Backward 3) Sideways (left/right)

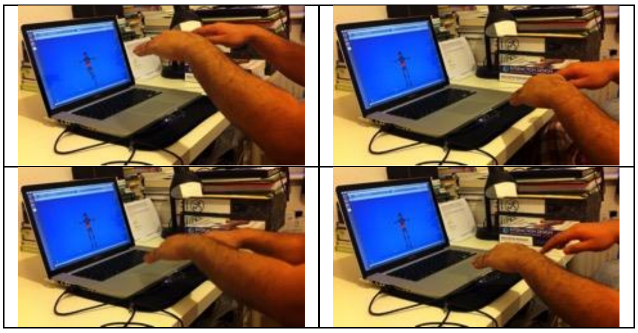
	the beginning of the test affected his movements. 3) User slides both hands sideways (left/right) as the character leans left and right	
Legs (Up, Down, Forward, Backward, Side Left, Side Right)	 1) User uses single hand at a time to control character's legs 2) User moves his hand forward/backward and sideways (left/right) 3) At times user unable to anticipate the speed, timing and movement of the character's legs	1) Up/Down 2) Forward/Backward 3) Slides Sideways (left/right)

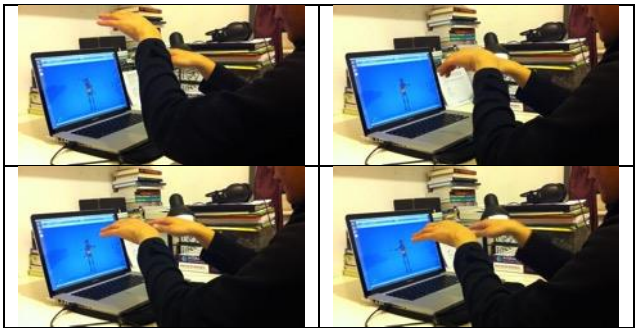
USER 4: Date: 26th March 2015 Duration of test: 1 min 23 sec (including transition time between 4 different exercises)		
When Pre-animated Character moves its…	**User Gesture Responses to the Character**	**Type of Hand Gestures Used by User**
Hands (Up, Down, Forward, Backward)	 1) User sitting on the floor while the system is lower than his hand gestures	1) Moves Up/Down 2) Moves Forward/Backward

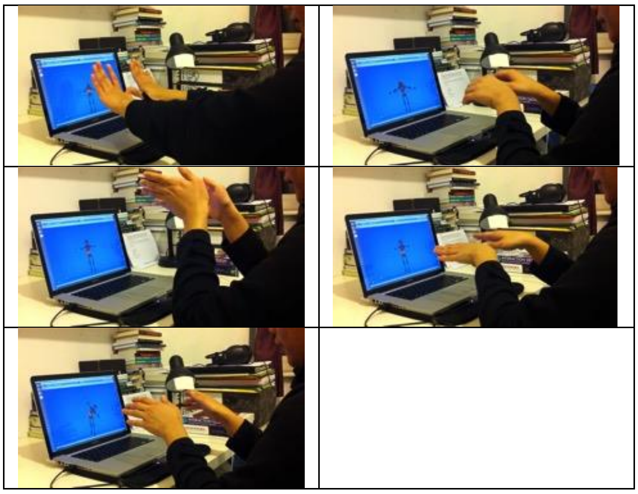
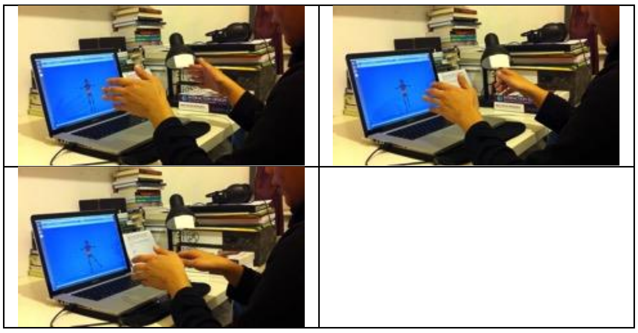
	2) User places her both hands above LM (Leap Motion) before animation takes place 3) User able to anticipate speed and timing of the character's movement 4) User's hand acceleration and placing in midair are confused by the different timing of character's hand movements. 5) User uses both hands: a) Upward/Downward- to move character's hands upwards/downwards b) Forward/Backward- to move character's hands forwards and backward	
Torso (Forward, Backward, Side Left, Side Right)	 1) User moves hands forward/backward as the character leans forward/backward 2) User (unconsciously) moves his body at the same time. **This is probably the term 'imitate' that I used to describe the task at the beginning of the test affected his movements. 3) User slides both hands sideways (left/right) as the character leans left and right	1) Moves Up/Down 2) Moves Forward/Backward 3) Slides Sideways (left/right)
Legs (Up, Down, Forward, Backward, Side Left, Side Right)		1) Moves Forward/Backward 2) Moves Sideways (left/right)

	1) User uses single hand at a time to control character's legs 2) User moves his hand forward/backward and sideways (left/right) 3) User able to anticipate the speed, timing and movement of his hands to the movement of the character's legs	

USER 5: Date: 5th April 2015 Duration of test: 1 min 25 secs (including transition time between 4 different exercises)		
When Pre-animated Character moves its…	**User Gesture Responses to the Character**	**Type of Hand Gestures Used by User**
Hands (Up, Down, Forward, Backward)		1) Moves Up/Down 2) Moves Forward/Backward
Torso (Forward, Backward, Side Left, Side Right)		1) Moves Forward/Backward 2) Flips Sideways (left/right)

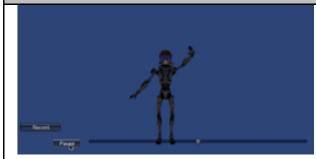
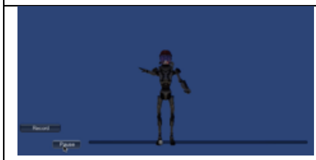
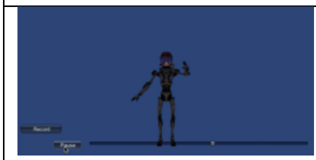
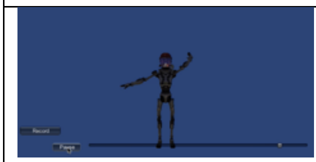
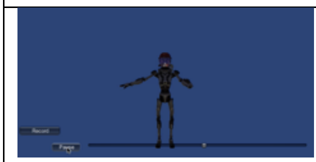
Legs (Up, Down, Forward, Backward, Side Left, Side Right)		1) Moves Forward/Backward

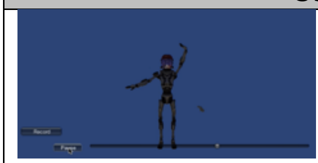
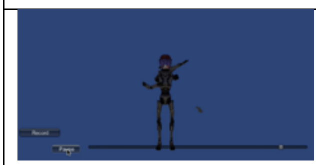
USER 6: Date: 5th April 2015 Duration of test: 1 min 15 secs (including transition time between 4 different exercises)		
When Pre-animated Character moves its…	**User Gesture Responses to the Character**	**Type of Hand Gestures Used by User**
Hands (Up, Down, Forward, Backward)	 1) User places her both hands above LM (Leap Motion) before animation takes place 2) User able to anticipate the speed and timing of his hand movements to match the speed and timing of the character's movements. 3) User moves both hands: a) Upward/Downward- to move character's hands upwards/downwards b) Forward/Backward- to move character's hands forwards and backward c) Sideways (left/right)- unsure	1) Move Up/Down 2) Moves Forward/Backward

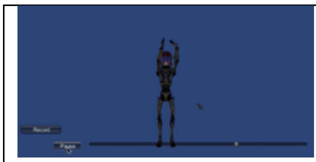
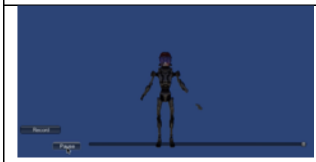
Torso (Forward, Backward, Side Left, Side Right)	 1) User moves hands forward/backward as the character leans forward/backward 2) User swipes both hands sideways (left/right) as the character leans left and right 3) At times user tilt his hand up 4) Small quantity of hand movements, speed and timing occur 5) When character leans sideways, user swipe his hands sideways but at times looking unsure	1) Moves Forward/Backward 2) Tilts Up/Down 3) Swipe Sideways (left/right)
Legs (Up, Down, Forward, Backward, Side Left, Side Right)	 1) User moves his hands forward/backward and swipe sideways 2) User unable to anticipate the speed and timing of the character's legs movements.	1) Up/Down 2) Forward/Backward 3) Swipe Sideways (left/right)

Appendix A-2: Interface Technical Feedback

This appendix describes analyses that we conducted with two users to briefly test the prototype and to attain opinions for improvement (see 3.5.2.2 in Chapter 3).

User 1		Feedbacks
		1) Feels intuitive, naturally controlled. 2) User finds that the second gesture (swinging character's hands as if he is walking) is less intuitive because of the hands are in lower position. This is also due to his sitting position, which makes his hands movement restricted. He attempted to swing his hands as if his hands are swinging while walking. He suggested that it is easier to lift the hands up/down, so that the gesturing is within the sensory range of the device. 3) User seems to expect some gestures learning rather than single hand gesture manipulation. 4) User attempts to stand up while controlling the character swinging hands. The result was not good as he unable to control his hands gesture within the Leap Motion's sensory radius.
		
		
		
		
		

User 2		Feedbacks
		1) User finds that the recording slider is too short and too fast to end when recording time is in progress. User was puzzled when animation suddenly stopped while he still in the middle of finishing his animation. 2) User feels strange between him and 3D character because of both
		

		are facing each other and movements are confusing. 3) While performing waving action, user twisting his wrist expecting characters to response the same action.
		

Appendix B

Appendix B-1: Usability Test Consent Form

A sample of participant's consent form used during Usability Test (see 4.2.4 in Chapter 4).

Goldsmiths
UNIVERSITY OF LONDON

Embodied AudioVisual Interaction Group

USABILITY TEST CONSENT FORM

Participant's Name:

Dear Participant,

Please read the following agreements. If you agreed, please sign this form.

During the experiment:

- You will be asked to execute certain tasks on a computer with additional tool to use.
- A short interview will be conducted with you which takes approximately 10 minutes after you have completed your tasks. The interview will be about the tasks you performed.

Participation in this experiment will be entirely voluntary. Your hand gestures will be recorded while performing the tasks. However, all information obtained in this experiment will remain anonymous and only for the purpose of this research. Your name or any form of your personal details will not be revealed other than for this research. The descriptions and findings of this experiment may be used to help improve the process of animation. This experiment will take a total maximum duration of 30 minutes followed by a 10 minutes of interview. You may stop participation at any time without giving a reason and withdraw your agreement of this experiment if you decided to discontinue.

If you have further questions, please ask.

Thank you for choosing to participate in this experiment. Your support is very much appreciated.

I have read and understood the information stipulated on this form and happy with all my questions answered.

Participant's Signature

____________________________________ Date __________________

Name:

Appendix B-2: Usability Test Task Instruction

A sample of task instruction sheet given to all participants before taking the Usability Test (see 4.3.4 in Chapter 4).

Goldsmiths
UNIVERSITY OF LONDON

Embodied AudioVisual Interaction Group

THE TASKS FOR USABILITY TEST

Thank you for choosing to participate in this experiment. Please read the instruction below before you begin.

1) In this experiment, you will need to animate a character animation in TWO different conditions:

   iii) **Using keyframe animation**
   - Software use: Autodesk Maya.
   - Additional device use: a computer mouse (optional to Trackpad).

   TASK 1: Animate the character's hand waving OR knocking (i.e. a door) neutrally.
   TASK 2: Animate the character's hand waving OR knocking with style/expression. Example: Happy/Angry/Sad/etc.
   **Note: Actions created in both tasks must not be similar.

   iv) **Using hand gesture animation system**
   - Software use: Hand-gesture Interface in Unity3D.
   - Additional device use: Leap Motion- a motion-sensing device.

   TASK 1: Animate the character's hand waving OR knocking (i.e. a door) neutrally.
   TASK 2: Animate the character's hand waving OR knocking with style/expression. Example: Happy/Angry/Sad/etc.
   **Note: Actions created in both tasks must not be similar.

2) You are required to create the character in action that can ONLY move the character's upper body.
3) A full-rigged IK-based character will be provided for you in both software.
4) You are free to choose how much time would you like to spend animating using both software. However, a maximum of 40 minutes of total duration of this test is restricted for you to complete both conditions.
5) Please be aware that there will be two ways of recordings happening:
   iii) Your animation will be screen captured.
   iv) Your hand gestures during the animation process will be recorded.
6) When you have completed the task, a 15-20 minutes of post-test questionnaires and short interview session will be conducted.

Thank you for your cooperation.

Appendix B-3: Usability Test Questionnaires

A sample of questionnaires sheet given to all participants during the Usability Test. It consists of 3 sections: 1) Demographic Information, 2) Experience of Using Keyframe Animation, 3) Experience of Using Hand Gesture Animation (see 4.4.1 in Chapter 4).

Usability Test for Hand Gesture-based Animation
Dear Participant,

Please read the following agreements. If you agreed, please sign this form.

During the experiment:
• You will be asked to execute certain tasks on a computer with additional tool to use.
• A short interview will be conducted with you which takes approximately 10 minutes after you have completed your tasks. The interview will be about the tasks you performed.

Participation in this experiment will be entirely voluntary. Your hand gestures will be recorded while performing the tasks. However, all information obtained in this experiment will remain anonymous and only for the purpose of this research. Your name or any form of your personal details will not be revealed other than for this research. The descriptions and findings of this experiment may be used to help improve the process of animation. This experiment will take a total maximum duration of 30 minutes followed by a 10 minutes of interview. You may stop participation at any time without giving a reason and withdraw your agreement of this experiment if you decided to discontinue.

If you have further questions, please ask.

Thank you for choosing to participate in this experiment. Your support is very much appreciated.

I have read and understood the information stipulated on this form and happy with all my questions answered.

SECTION 1: Demographic Information

1. What is your age group? *

- ☐ 18-23 years old
- ☐ 24-29 years old
- ☐ 30-35 years old
- ☐ 36 years old and above

2. What is your gender? *

- ☐ Male
- ☐ Female

3. Which of the following categories best describe your employment status? *

☐ Employed, full-time

☐ Employed, part-time

☐ Self-employed/Freelance

☐ Student (go to question 5)

4. How long have you been in your current job? *

☐ Less than 1 year

☐ 1 - 2 years

☐ 3 - 4 years

☐ More than 5 years

5. Which level of studies are you currently at? *

☐ Full-time (1st year undergraduate)

☐ Full-time (2nd year undergraduate)

☐ Full-time (3rd year undergraduate)

☐ Full-time/Part-time Postgraduate

☐ Others (Certificate/Diploma)

6. How many years have you been involved in producing animation? *

☐ Less than 1 year

☐ 1 - 2 years

☐ 3 - 4 years

☐ More than 4 years

7. What type of animation techniques are you familiar with? * (You may check more than one)

☐ 3D animation

☐ 2D animation

☐ Stop-motion (e.g: claymation, cutout, pixilation, sand animation)

8. Are you familiar with keyframe animation? *

☐ Yes

☐ No

9. Which level is best describe your experience in creating animation? *

☐ Beginner

☐ Intermediate

☐ Advanced

☐ Professional Animator

SECTION 2: Experience of Using Keyframe Animation

A. Usability Survey Keyframe Animation *

Scale:	1. Strongly Disagree	2. Disagree	3. Agree	4. Strongly Agree

	1	2	3	4
1. I think that I would like to use keyframe animation.				
2. I found keyframe animation is unnecessarily complex.				
3. I think that I would need the support of a technical person to be able to use keyframe animation.				
4. I found the various functions in keyframe animation were easy to use.				
5. I thought there was too much inconsistency in keyframe animation (i.e. difficult to create movement and timing).				
6. I would imagine that most people would learn to use keyframe animation very quickly.				
7. I found keyframe animation process is very tedious to use.				
8. I felt very confident using keyframe animation.				
9. I needed to learn a lot of things before I could get going with keyframe animation.				
10. I found keyframe animation able to provide a desirable timing control for 3D character.				
11. I think keyframe animation is more natural to control movement and timing.				
12. I think keyframe animation is an interesting approach to animate.				

B. Satisfaction Survey Keyframe Animation *

Scale:	1. Strongly Disagree	2. Disagree	3. Agree	4. Strongly Agree

	1	2	3	4
1. It was simple to use keyframe animation.				

	1	2	3	4
2. I was able to complete the tasks quickly using keyframe animation.				
3. I felt comfortable using keyframe animation.				
4. It was easy to learn to use keyframe animation.				
5. I believe I could become productive quickly using keyframe animation.				
6. Whenever I made a mistake using keyframe animation, I could recover easily and quickly.				
7. The interface was effective in helping me complete the task.				
8. The organisation of the interface on keyframe animation screen was clear.				
9. The interface of keyframe animation was pleasant.				
10. I liked using the interface of keyframe animation.				
11. Keyframe animation has all the functions and capabilities I expect it to have.				
12. Overall, I am satisfied with keyframe animation system.				

SECTION 3: Experience of Using Hand Gesture-based Animation

A. Usability Survey Hand Gesture-based Animation *

Scale:	1. Strongly Disagree	2. Disagree	3. Agree	4. Strongly Agree

	1	2	3	4
1. I think that I would like to use hand gesture animation.				
2. I found hand gesture animation is unnecessarily complex.				
3. I think that I would need the support of a technical person to be able to use hand gesture animation.				
4. I found the various functions in hand gesture animation were well integrated.				
5. I thought there was too much inconsistency in hand gesture animation.				
6. I would imagine that most people would learn to use hand gesture animation very quickly.				

	1	2	3	4
7. I found hand gesture animation process is very tedious to use.				
8. I felt very confident using hand gesture animation.				
9. I needed to learn a lot of things before I could get going with hand gesture animation.				
10. I found hand gesture e animation able to provide a desirable timing control for 3D character.				
11. I think hand gesture animation is more natural to control movement and timing.				
12. I think hand gesture animation is an interesting approach to animate.				

B. Satisfaction Survey Hand Gesture-based Animation *

Scale:	1. Strongly Disagree	2. Disagree	3. Agree	4. Strongly Agree

	1	2	3	4
1. It was simple to use hand gesture animation.				
2. I was able to complete the tasks quickly using hand gesture animation.				
3. I felt comfortable using hand gesture animation.				
4. It was easy to learn to use hand gesture animation.				
5. I believe I could become productive quickly using hand gesture animation.				
6. Whenever I made a mistake using hand gesture animation, I could recover easily and quickly.				
7. The interface was effective in helping me complete the task.				
8. The organisation of the interface on hand gesture animation screen was clear.				
9. The interface of hand gesture animation was pleasant.				
10. I liked using the interface of hand gesture animation.				
11. Hand gesture animation has all the functions and capabilities I expect it to have.				
12. Overall, I am satisfied with hand gesture animation system.				

Additional comments:

Appendix B-4: Coded Indicators for Usability Study

This appendix was only used as a method of reference during statistical data analysis for results in Chapter 4.

Coded	Description
UK1	I think I would like to use key-frame animation.
UK2	I found key-frame animation is unnecessary complex.
UK3	I think that I would need the support of a technical person to be able to use key-frame animation. (Reversed Coded)
UK4	I found the various functions in key-frame animation were well integrated.
UK5	I thought there was too much inconsistency in key-frame animation. (Reversed Coded)
UK6	I would imagine that most people would learn to use key-frame animation very quickly.
UK7	I found key-frame animation process is very tedious to use. (Reversed Coded)
UK8	I felt very confident using key-frame animation.
UK9	I needed to learn a lot of things before I could get going with key-frame animation. (Reversed Coded)
UK10	I found key-frame animation able to provide a desirable timing control for 3D character.
UK11	I think key-frame animation is more natural to control movement and timing.
UK12	I think key-frame animation is an interesting approach to animate.
SK1	It was simple to use key-frame animation.
SK2	I was able to complete the tasks quickly using key-frame animation.
SK3	I felt comfortable using key-frame animation.
SK4	It was easy to learn to use key-frame animation.
SK5	I believe I could become productive quickly using key-frame animation.
SK6	Whenever I made mistake using key-frame animation, I could recover easily and quickly.
SK7	The interface was effective in helping me complete the task.
SK8	The organization of the interface on key-frame animation screen was clear.
SK9	The interface of key-frame animation was pleasant.
SK10	I liked using the interface of key-frame animation.
SK11	Key-frame animation has all the functions and capabilities I expect it to have.
SK12	Overall, I am satisfied with key-frame animation system.
UH1	I think I would like to use hand-gesture animation.
UH2	I found hand-gesture animation is unnecessary complex.
UH3	I think that I would need the support of a technical person to be able to use hand-gesture animation. (Reversed Coded)
UH4	I found the various functions in hand-gesture animation were well integrated.
UH5	I thought there was too much inconsistency in hand-gesture animation. (Reversed Coded)
UH6	I would imagine that most people would learn to use hand-gesture animation very quickly.
UH7	I found hand-gesture animation process is very tedious to use. (Reversed Coded)
UH8	I felt very confident using hand-gesture animation.
UH9	I needed to learn a lot of things before I could get going with hand-gesture animation. (Reversed Coded)
UH10	I found hand-gesture animation able to provide a desirable timing control for 3D character.
UH11	I think hand-gesture animation is more natural to control movement and timing.
UH12	I think hand-gesture animation is an interesting approach to animate.
SH1	It was simple to use hand-gesture animation.
SH2	I was able to complete the tasks quickly using hand-gesture animation.

SH3	I felt comfortable using hand-gesture animation.
SH4	It was easy to learn to use hand-gesture animation.
SH5	I believe I could become productive quickly using hand-gesture animation.
SH6	Whenever I made mistake using hand-gesture animation, I could recover easily and quickly.
SH7	The interface was effective in helping me complete the task.
SH8	The organization of the interface on hand-gesture animation screen was clear.
SH9	The interface of hand-gesture animation was pleasant.
SH10	I liked using the interface of hand-gesture animation.
SH11	Hand-gesture animation has all the functions and capabilities I expect it to have.
SH12	Overall, I am satisfied with hand-gesture animation system.

Indication:
UK = Usability Keyframe Animation
SK = Satisfaction Keyframe Animation
UH = Usability Hand Gesture Animation
SH = Satisfaction Hand Gesture Animation

Appendix B-5: CRONBACH'S ALPHA RELIABILITY ANALYSIS

A supporting data of detailed statistical information for the Usability and Satisfaction Test results in Chapter 4 (see section 4.6 Results).

Usability Keyframe Animation

Case Processing Summary

		N	%
Cases	Valid	23	100.0
	Excluded[a]	0	.0
	Total	23	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.556	.574	12

Item Statistics

	Mean	Std. Deviation	N
UK1	3.43	.507	23
UK2	2.57	.507	23
UK3	2.83	.834	23
UK4	3.22	.518	23
UK5	2.52	.730	23
UK6	3.04	.825	23
UK7	2.74	.689	23
UK8	3.13	.694	23
UK9	3.39	.656	23
UK10	3.17	.650	23
UK11	2.91	.733	23
UK12	3.39	.499	23

Summary Item Statistics

	Mean	Minimum	Maximum	Range	Maximum / Minimum	Variance	N of Items
Inter-Item Correlations	.211	-.489	.497	.985	-1.016	.047	12

Satisfaction Keyframe Animation

Case Processing Summary

		N	%
Cases	Valid	23	100.0
	Excluded[a]	0	.0
	Total	23	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.777	.781	12

Item Statistics

	Mean	Std. Deviation	N
SK1	3.09	.668	23
SK2	2.74	.810	23
SK3	3.04	.638	23
SK4	3.09	.668	23
SK5	3.22	.600	23
SK6	2.96	.767	23
SK7	3.30	.470	23
SK8	3.22	.671	23
SK9	3.17	.491	23
SK10	3.17	.491	23
SK11	3.22	.518	23
SK12	3.35	.573	23

Summary Item Statistics

	Mean	Minimum	Maximum	Range	Maximum / Minimum	Variance	N of Items
Inter-Item Correlations	.229	-.349	.745	1.094	-2.135	.058	12

Usability Hand Gesture Animation

Case Processing Summary

		N	%
Cases	Valid	23	100.0
	Excluded[a]	0	.0
	Total	23	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.624	.633	12

Item Statistics

	Mean	Std. Deviation	N
UH1	3.52	.593	23
UH2	2.52	.730	23
UH3	3.17	.778	23
UH4	3.04	.562	23
UH5	2.78	.518	23
UH6	3.17	.778	23
UH7	2.48	.790	23
UH8	2.87	.626	23
UH9	3.48	.730	23
UH10	3.26	.619	23
UH11	3.26	.689	23
UH12	3.65	.487	23

Summary Item Statistics

	Mean	Minimum	Maximum	Range	Maximum / Minimum	Variance	N of Items
Inter-Item Correlations	.225	-.375	.681	1.056	-1.817	.052	12

Satisfaction Hand Gesture Animation

Case Processing Summary

		N	%
Cases	Valid	23	100.0
	Excluded[a]	0	.0
	Total	23	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.895	.899	12

Item Statistics

	Mean	Std. Deviation	N
SH1	3.13	.694	23
SH2	3.04	.767	23
SH3	3.00	.739	23
SH4	2.96	.706	23
SH5	3.09	.596	23
SH6	3.04	.638	23
SH7	3.04	.475	23
SH8	3.22	.600	23
SH9	3.22	.518	23
SH10	3.22	.600	23
SH11	3.00	.739	23
SH12	3.26	.449	23

Summary Item Statistics

	Mean	Minimum	Maximum	Range	Maximum / Minimum	Variance	N of Items
Inter-Item Correlations	.426	-.055	.785	.840	-14.207	.029	12

Appendix B-6: COHEN-KAPPA'S RELIABILITY ANALYSIS

A supporting data of detailed statistical information for the Usability and Satisfaction Test results in Chapter 4.

Usability Variable Pairing

UK1 * UH1 Crosstabulation

Count

		UH1			
		Disagree	Agree	Strongly Agree	Total
UK1	Agree	0	5	8	13
	Strongly Agree	1	4	5	10
Total		1	9	13	23

Symmetric Measures

		Value	Asymp. Std. Error[a]	Approx. T[b]	Approx. Sig.
Measure of Agreement	Kappa	-.060	.185	-.323	.747
N of Valid Cases		23			

a. Not assuming the null hypothesis.
b. Using the asymptotic standard error assuming the null hypothesis.

UK2 * UH2 Crosstabulation

Count

		UH2				
		Strongly Disagree	Disagree	Agree	Strongly Agree	Total
UK2	Disagree	1	8	1	0	10
	Agree	0	3	8	2	13
Total		1	11	9	2	23

Symmetric Measures

		Value	Asymp. Std. Error[a]	Approx. T[b]	Approx. Sig.
Measure of Agreement	Kappa	.467	.148	2.777	.005
N of Valid Cases		23			

a. Not assuming the null hypothesis.
b. Using the asymptotic standard error assuming the null hypothesis.

UK3 * UH3 Crosstabulation

Count

		UH3				
		Strongly Disagree	Disagree	Agree	Strongly Agree	Total
UK3	Strongly Disagree	1	1	0	0	2
	Disagree	0	0	3	1	4
	Agree	0	1	7	5	13
	Strongly Agree	0	0	2	2	4
Total		1	2	12	8	23

Symmetric Measures

		Value	Asymp. Std. Error[a]	Approx. T[b]	Approx. Sig.
Measure of Agreement	Kappa	.097	.153	.730	.465
N of Valid Cases		23			

a. Not assuming the null hypothesis.
b. Using the asymptotic standard error assuming the null hypothesis.

UK4 * UH4 Crosstabulation

Count

		UH4			Total
		Disagree	Agree	Strongly Agree	
UK4	Disagree	1	0	0	1
	Agree	2	11	3	16
	Strongly Agree	0	5	1	6
Total		3	16	4	23

Symmetric Measures

		Value	Asymp. Std. Error[a]	Approx. T[b]	Approx. Sig.
Measure of Agreement	Kappa	.065	.195	.407	.684
N of Valid Cases		23			

a. Not assuming the null hypothesis.
b. Using the asymptotic standard error assuming the null hypothesis.

UK5 * UH5 Crosstabulation

Count

		UH5			Total
		Disagree	Agree	Strongly Agree	
UK5	Strongly Disagree	0	1	0	1
	Disagree	4	6	1	11
	Agree	2	7	0	9
	Strongly Agree	0	2	0	2
Total		6	16	1	23

Symmetric Measures

		Value	Asymp. Std. Error[a]	Approx. T[b]	Approx. Sig.
Measure of Agreement	Kappa	.129	.144	.894	.371
N of Valid Cases		23			

a. Not assuming the null hypothesis.
b. Using the asymptotic standard error assuming the null hypothesis.

UK6 * UH6 Crosstabulation

Count

		UH6			Total
		Disagree	Agree	Strongly Agree	
UK6	Strongly Disagree	1	0	0	1
	Disagree	0	4	0	4
	Agree	2	4	5	11
	Strongly Agree	2	1	4	7
Total		5	9	9	23

Symmetric Measures

		Value	Asymp. Std. Error[a]	Approx. T[b]	Approx. Sig.
Measure of Agreement	Kappa	.006	.136	.040	.968
N of Valid Cases		23			

a. Not assuming the null hypothesis.
b. Using the asymptotic standard error assuming the null hypothesis.

UK7 * UH7 Crosstabulation

Count

		UH7				Total
		Strongly Disagree	Disagree	Agree	Strongly Agree	
UK7	Strongly Disagree	1	0	0	0	1
	Disagree	1	0	5	0	6
	Agree	1	5	7	1	14
	Strongly Agree	0	2	0	0	2
Total		3	7	12	1	23

Symmetric Measures

		Value	Asymp. Std. Error[a]	Approx. T[b]	Approx. Sig.
Measure of Agreement	Kappa	-.099	.149	-.689	.491
N of Valid Cases		23			

a. Not assuming the null hypothesis.
b. Using the asymptotic standard error assuming the null hypothesis.

UK8 * UH8 Crosstabulation

Count

		UH8			Total
		Disagree	Agree	Strongly Agree	
UK8	Disagree	1	2	1	4
	Agree	2	9	1	12
	Strongly Agree	3	3	1	7
Total		6	14	3	23

Symmetric Measures

		Value	Asymp. Std. Error[a]	Approx. T[b]	Approx. Sig.
Measure of Agreement	Kappa	.127	.137	.883	.377
N of Valid Cases		23			

a. Not assuming the null hypothesis.
b. Using the asymptotic standard error assuming the null hypothesis.

UK9 * UH9 Crosstabulation

Count

		UH9			Total
		Disagree	Agree	Strongly Agree	
UK9	Disagree	1	0	1	2
	Agree	1	4	5	10
	Strongly Agree	1	2	8	11
Total		3	6	14	23

Symmetric Measures

		Value	Asymp. Std. Error[a]	Approx. T[b]	Approx. Sig.
Measure of Agreement	Kappa	.256	.168	1.639	.101
N of Valid Cases		23			

a. Not assuming the null hypothesis.
b. Using the asymptotic standard error assuming the null hypothesis.

UK10 * UH10 Crosstabulation

Count

		UH10			Total
		Disagree	Agree	Strongly Agree	
UK10	Disagree	0	3	0	3
	Agree	1	6	6	13
	Strongly Agree	1	4	2	7
Total		2	13	8	23

Symmetric Measures

		Value	Asymp. Std. Error[a]	Approx. T[b]	Approx. Sig.
Measure of Agreement	Kappa	-.158	.150	-.966	.334
N of Valid Cases		23			

a. Not assuming the null hypothesis.
b. Using the asymptotic standard error assuming the null hypothesis.

UK11 * UH11 Crosstabulation

Count

		UH11			Total
		Disagree	Agree	Strongly Agree	
UK11	Disagree	2	3	2	7
	Agree	1	6	4	11
	Strongly Agree	0	2	3	5
Total		3	11	9	23

Symmetric Measures

		Value	Asymp. Std. Error[a]	Approx. T[b]	Approx. Sig.
Measure of Agreement	Kappa	.193	.154	1.370	.171
N of Valid Cases		23			

a. Not assuming the null hypothesis.
b. Using the asymptotic standard error assuming the null hypothesis.

UK12 * UH12 Crosstabulation

Count

		UH12		Total
		Agree	Strongly Agree	
UK12	Agree	5	9	14
	Strongly Agree	3	6	9
Total		8	15	23

Symmetric Measures

		Value	Asymp. Std. Error[a]	Approx. T[b]	Approx. Sig.
Measure of Agreement	Kappa	.021	.181	.117	.907
N of Valid Cases		23			

a. Not assuming the null hypothesis.
b. Using the asymptotic standard error assuming the null hypothesis.

Satisfaction Variable Pairing

SK1 * SH1 Crosstabulation

Count

		SH1			Total
		Disagree	Agree	Strongly Agree	
SK1	Disagree	0	3	1	4
	Agree	3	7	3	13
	Strongly Agree	1	2	3	6
Total		4	12	7	23

Symmetric Measures

		Value	Asymp. Std. Error[a]	Approx. T[b]	Approx. Sig.
Measure of Agreement	Kappa	.051	.151	.331	.741
N of Valid Cases		23			

a. Not assuming the null hypothesis.
b. Using the asymptotic standard error assuming the null hypothesis.

SK2 * SH2 Crosstabulation

Count

		SH2			Total
		Disagree	Agree	Strongly Agree	
SK2	Strongly Disagree	1	0	0	1
	Disagree	1	4	3	8
	Agree	3	3	4	10
	Strongly Agree	1	3	0	4
Total		6	10	7	23

Symmetric Measures

		Value	Asymp. Std. Error[a]	Approx. T[b]	Approx. Sig.
Measure of Agreement	Kappa	-.238	.106	-1.709	.087
N of Valid Cases		23			

a. Not assuming the null hypothesis.
b. Using the asymptotic standard error assuming the null hypothesis.

SK3 * SH3 Crosstabulation

Count

		SH3			Total
		Disagree	Agree	Strongly Agree	
SK3	Disagree	0	2	2	4
	Agree	3	7	4	14
	Strongly Agree	3	2	0	5
Total		6	11	6	23

Symmetric Measures

		Value	Asymp. Std. Error[a]	Approx. T[b]	Approx. Sig.
Measure of Agreement	Kappa	-.146	.095	-.992	.321
N of Valid Cases		23			

a. Not assuming the null hypothesis.
b. Using the asymptotic standard error assuming the null hypothesis.

SK4 * SH4 Crosstabulation

Count

		SH4			Total
		Disagree	Agree	Strongly Agree	
SK4	Disagree	1	3	0	4
	Agree	4	7	2	13
	Strongly Agree	1	2	3	6
Total		6	12	5	23

Symmetric Measures

		Value	Asymp. Std. Error[a]	Approx. T[b]	Approx. Sig.
Measure of Agreement	Kappa	.135	.167	.901	.368
N of Valid Cases		23			

a. Not assuming the null hypothesis.
b. Using the asymptotic standard error assuming the null hypothesis.

SK5 * SH5 Crosstabulation

Count

		SH5			Total
		Disagree	Agree	Strongly Agree	
SK5	Disagree	0	2	0	2
	Agree	2	10	2	14
	Strongly Agree	1	3	3	7
Total		3	15	5	23

Symmetric Measures

		Value	Asymp. Std. Error[a]	Approx. T[b]	Approx. Sig.
Measure of Agreement	Kappa	.173	.167	1.081	.280
N of Valid Cases		23			

a. Not assuming the null hypothesis.
b. Using the asymptotic standard error assuming the null hypothesis.

SK6 * SH6 Crosstabulation

Count

		SH6			Total
		Disagree	Agree	Strongly Agree	
SK6	Strongly Disagree	0	1	0	1
	Disagree	0	3	1	4
	Agree	2	9	2	13
	Strongly Agree	2	1	2	5
Total		4	14	5	23

Symmetric Measures

		Value	Asymp. Std. Error[a]	Approx. T[b]	Approx. Sig.
Measure of Agreement	Kappa	.098	.141	.671	.502
N of Valid Cases		23			

a. Not assuming the null hypothesis.
b. Using the asymptotic standard error assuming the null hypothesis.

SK7 * SH7 Crosstabulation

Count

		SH7			Total
		Disagree	Agree	Strongly Agree	
SK7	Agree	2	13	1	16
	Strongly Agree	0	5	2	7
Total		2	18	3	23

Symmetric Measures

		Value	Asymp. Std. Error[a]	Approx. T[b]	Approx. Sig.
Measure of Agreement	Kappa	.164	.186	1.016	.310
N of Valid Cases		23			

a. Not assuming the null hypothesis.
b. Using the asymptotic standard error assuming the null hypothesis.

SK8 * SH8 Crosstabulation

Count

		SH8			Total
		Disagree	Agree	Strongly Agree	
SK8	Disagree	0	2	1	3
	Agree	2	6	4	12
	Strongly Agree	0	6	2	8
Total		2	14	7	23

Symmetric Measures

		Value	Asymp. Std. Error[a]	Approx. T[b]	Approx. Sig.
Measure of Agreement	Kappa	-.154	.150	-.949	.343
N of Valid Cases		23			

a. Not assuming the null hypothesis.
b. Using the asymptotic standard error assuming the null hypothesis.

SK9 * SH9 Crosstabulation

Count

		SH9			Total
		Disagree	Agree	Strongly Agree	
SK9	Disagree	0	1	0	1
	Agree	0	13	4	17
	Strongly Agree	1	2	2	5
Total		1	16	6	23

Symmetric Measures

		Value	Asymp. Std. Error[a]	Approx. T[b]	Approx. Sig.
Measure of Agreement	Kappa	.186	.185	1.033	.302
N of Valid Cases		23			

a. Not assuming the null hypothesis.
b. Using the asymptotic standard error assuming the null hypothesis.

SK10 * SH10 Crosstabulation

Count

		SH10			Total
		Disagree	Agree	Strongly Agree	
SK10	Disagree	0	1	0	1
	Agree	2	12	3	17
	Strongly Agree	0	1	4	5
Total		2	14	7	23

Symmetric Measures

		Value	Asymp. Std. Error[a]	Approx. T[b]	Approx. Sig.
Measure of Agreement	Kappa	.366	.179	2.187	.029
N of Valid Cases		23			

a. Not assuming the null hypothesis.
b. Using the asymptotic standard error assuming the null hypothesis.

SK11 * SH11 Crosstabulation

Count

		SH11			Total
		Disagree	Agree	Strongly Agree	
SK11	Disagree	0	1	0	1
	Agree	5	7	4	16
	Strongly Agree	1	3	2	6
Total		6	11	6	23

Symmetric Measures

		Value	Asymp. Std. Error[a]	Approx. T[b]	Approx. Sig.
Measure of Agreement	Kappa	-.035	.142	-.255	.798
N of Valid Cases		23			

a. Not assuming the null hypothesis.
b. Using the asymptotic standard error assuming the null hypothesis.

SK12 * SH12 Crosstabulation

Count

		SH12		Total
		Agree	Strongly Agree	
SK12	Disagree	1	0	1
	Agree	10	3	13
	Strongly Agree	6	3	9
Total		17	6	23

Symmetric Measures

		Value	Asymp. Std. Error[a]	Approx. T[b]	Approx. Sig.
Measure of Agreement	Kappa	.094	.189	.515	.607
N of Valid Cases		23			

a. Not assuming the null hypothesis.
b. Using the asymptotic standard error assuming the null hypothesis.

Appendix B-7: INDEPENDENT T-TEST ANALYSIS

A supporting data of detailed statistical information for the Usability and Satisfaction Test results in Chapter 4 (see section 4.6 Results).

Group Statistics

	group	N	Mean	Std. Deviation	Std. Error Mean
Usability Keyframe	Degree	11	2.8939	.26376	.07953
	Diploma	12	3.1528	.22706	.06555
Satisfaction Keyframe	Degree	11	3.0530	.35799	.10794
	Diploma	12	3.2014	.31071	.08969
Usability Hand Gesture	Degree	11	2.9545	.22162	.06682
	Diploma	12	3.2361	.29481	.08510
Satisfaction Hand Gesture	Degree	11	2.9545	.26448	.07974
	Diploma	12	3.2361	.51839	.14965

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Usability Keyframe	Equal variances assumed	.225	.640	-2.529	21	.020	-.25884	.10236	-.47171	-.04596
	Equal variances not assumed			-2.512	19.867	.021	-.25884	.10306	-.47391	-.04377
Satisfaction Keyframe	Equal variances assumed	.043	.837	-1.064	21	.299	-.14836	.13944	-.43835	.14163
	Equal variances not assumed			-1.057	19.937	.303	-.14836	.14034	-.44116	.14445
Usability Hand Gesture	Equal variances assumed	.974	.335	-2.570	21	.018	-.28157	.10958	-.50945	-.05368
	Equal variances not assumed			-2.602	20.270	.017	-.28157	.10820	-.50708	-.05605
Satisfaction Hand Gesture	Equal variances assumed	4.985	.037	-1.617	21	.121	-.28157	.17416	-.64375	.08061
	Equal variances not assumed			-1.660	16.657	.116	-.28157	.16957	-.63988	.07675

Appendix B-8: MIXED-DESIGN ANALYSIS

A supporting data of detailed statistical information for the Usability and Satisfaction Test in Chapter 4 (see section 4.6 Results).

Usability Levels

Within-Subjects Factors

Measure:MEASURE_1

Usability	Dependent Variable
1	use_key
2	use_hand

Between-Subjects Factors

		Value Label	N
group	1	Degree	11
	2	Diploma	12

Descriptive Statistics

	group	Mean	Std. Deviation	N
Usability Key Frame	Degree	2.8939	.26376	11
	Diploma	3.1528	.22706	12
	Total	3.0290	.27364	23
Usability Hand Gesture	Degree	2.9545	.22162	11
	Diploma	3.2361	.29481	12
	Total	3.1014	.29404	23

Box's Test of Equality of Covariance Matrices[a]

Box's M	1.232
F	.368
df1	3
df2	111064.484
Sig.	.776

Tests the null hypothesis that the observed covariance matrices of the dependent variables are equal across groups.

a. Design: Intercept + group
Within Subjects Design: Usability

Multivariate Tests[b]

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared
Usability	Pillai's Trace	.062	1.382[a]	1.000	21.000	.253	.062
	Wilks' Lambda	.938	1.382[a]	1.000	21.000	.253	.062
	Hotelling's Trace	.066	1.382[a]	1.000	21.000	.253	.062
	Roy's Largest Root	.066	1.382[a]	1.000	21.000	.253	.062
Usability * group	Pillai's Trace	.002	.034[a]	1.000	21.000	.855	.002
	Wilks' Lambda	.998	.034[a]	1.000	21.000	.855	.002
	Hotelling's Trace	.002	.034[a]	1.000	21.000	.855	.002
	Roy's Largest Root	.002	.034[a]	1.000	21.000	.855	.002

a. Exact statistic
b. Design: Intercept + group
Within Subjects Design: Usability

Mauchly's Test of Sphericity[b]

Measure:MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[a]		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
Usability	1.000	.000	0	.	1.000	1.000	1.000

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.
a. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.
b. Design: Intercept + group
Within Subjects Design: Usability

Tests of Within-Subjects Effects

Measure:MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Usability	Sphericity Assumed	.059	1	.059	1.382	.253	.062
	Greenhouse-Geisser	.059	1.000	.059	1.382	.253	.062
	Huynh-Feldt	.059	1.000	.059	1.382	.253	.062
	Lower-bound	.059	1.000	.059	1.382	.253	.062
Usability * group	Sphericity Assumed	.001	1	.001	.034	.855	.002
	Greenhouse-Geisser	.001	1.000	.001	.034	.855	.002
	Huynh-Feldt	.001	1.000	.001	.034	.855	.002
	Lower-bound	.001	1.000	.001	.034	.855	.002
Error(Usability)	Sphericity Assumed	.903	21	.043			
	Greenhouse-Geisser	.903	21.000	.043			
	Huynh-Feldt	.903	21.000	.043			
	Lower-bound	.903	21.000	.043			

Tests of Between-Subjects Effects

Measure:MEASURE_1
Transformed Variable:Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	429.727	1	429.727	4995.144	.000	.996
group	.838	1	.838	9.741	.005	.317
Error	1.807	21	.086			

Satisfaction Levels

Within-Subjects Factors

Measure:MEASURE_1

Satisfaction	Dependent Variable
1	sat_key
2	sat_hand

Between-Subjects Factors

		Value Label	N
group	1	Degree	11
	2	Diploma	12

Descriptive Statistics

	group	Mean	Std. Deviation	N
Satisfaction Key Frame	Degree	3.0530	.35799	11
	Diploma	3.2014	.31071	12
	Total	3.1304	.33506	23
Satisfaction Hand Gesture	Degree	2.9545	.26448	11
	Diploma	3.2361	.51839	12
	Total	3.1014	.43225	23

Box's Test of Equality of Covariance Matrices[a]

Box's M	4.657
F	1.392
df1	3
df2	111064.484
Sig.	.243

Tests the null hypothesis that the observed covariance matrices of the dependent variables are equal across groups.

a. Design: Intercept + group
Within Subjects Design: Satisfaction

Multivariate Tests[b]

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared
Satisfaction	Pillai's Trace	.005	.103[a]	1.000	21.000	.751	.005
	Wilks' Lambda	.995	.103[a]	1.000	21.000	.751	.005
	Hotelling's Trace	.005	.103[a]	1.000	21.000	.751	.005
	Roy's Largest Root	.005	.103[a]	1.000	21.000	.751	.005
Satisfaction * group	Pillai's Trace	.021	.451[a]	1.000	21.000	.509	.021
	Wilks' Lambda	.979	.451[a]	1.000	21.000	.509	.021
	Hotelling's Trace	.021	.451[a]	1.000	21.000	.509	.021
	Roy's Largest Root	.021	.451[a]	1.000	21.000	.509	.021

a. Exact statistic
b. Design: Intercept + group
Within Subjects Design: Satisfaction

Mauchly's Test of Sphericity[b]

Measure:MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[a]		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
Satisfaction	1.000	.000	0	.	1.000	1.000	1.000

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.
a. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.
b. Design: Intercept + group
Within Subjects Design: Satisfaction

Tests of Within-Subjects Effects

Measure:MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Satisfaction	Sphericity Assumed	.012	1	.012	.103	.751	.005
	Greenhouse-Geisser	.012	1.000	.012	.103	.751	.005
	Huynh-Feldt	.012	1.000	.012	.103	.751	.005
	Lower-bound	.012	1.000	.012	.103	.751	.005
Satisfaction * group	Sphericity Assumed	.051	1	.051	.451	.509	.021
	Greenhouse-Geisser	.051	1.000	.051	.451	.509	.021
	Huynh-Feldt	.051	1.000	.051	.451	.509	.021
	Lower-bound	.051	1.000	.051	.451	.509	.021
Error(Satisfaction)	Sphericity Assumed	2.370	21	.113			
	Greenhouse-Geisser	2.370	21.000	.113			
	Huynh-Feldt	2.370	21.000	.113			
	Lower-bound	2.370	21.000	.113			

Tests of Between-Subjects Effects

Measure:MEASURE_1
Transformed Variable:Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	444.438	1	444.438	2571.820	.000	.992
group	.530	1	.530	3.069	.094	.128
Error	3.629	21	.173			

Appendix C

Appendix C-1: Quality of Animation Test Consent Form

A sample of participant's consent form used during Quality of Animation Test (see 5.2.4 in Chapter 5).

Goldsmiths
UNIVERSITY OF LONDON

Embodied AudioVisual Interaction Group

'QUALITY OF ANIMATION' TEST CONSENT FORM

Participant's Name:

Dear Participant,

Please read the following agreements. If you agreed, please sign this form.

During the experiment:

- You will be asked to execute certain tasks on a computer with additional tool to use.
- A short interview will be conducted with you which takes approximately 10 minutes after you have completed your tasks. The interview will be about the tasks you performed.

Participation in this experiment will be entirely voluntary. Your hand gestures will be recorded while performing the tasks. However, all information obtained in this experiment will remain anonymous and only for the purpose of this research. Your name or any form of your personal details will not be revealed other than for this research. The descriptions and findings of this experiment may be used to help improve the process of animation. This experiment will take a total maximum duration of 30 minutes followed by a 10 minutes of interview. You may stop participation at any time without giving a reason and withdraw your agreement of this experiment if you decided to discontinue.

If you have further questions, please ask.

Thank you for choosing to participate in this experiment. Your support is very much appreciated.

I have read and understood the information stipulated on this form and happy with all my questions answered.

Participant's Signature

_______________________________ Date _______________

Name:

Appendix C-2: Quality of Animation Survey

A sample of simple survey sheet was given to each participant during the test (see 5.4.1 in Chapter 5). In this survey, a detailed questionnaire was not required, as this is an extension study from the Usability Test.

Quality of Animation between Hand Gesture Animation and Keyframe Animation Survey

Please rate (✓) the quality of animation between hand gesture animation and keyframe animation from the experiments you have completed:

Hand Gesture Animation

	1 Strongly Disagree	2 Disagree	3 Neutral	4 Agree	5 Strongly Agree
1) I think the animation I created using hand gestures look good					
2) I think I have applied movement and timing of my hand gestures at the right time and place					
3) I think I able to express emotions (i.e happy/sad waving hard/soft punching) while animating using hand gestures					

Keyframe Animation

	1 Strongly Disagree	2 Disagree	3 Neutral	4 Agree	5 Strongly Agree
1) I think the animation I created using keyframe look good					
2) I think I have applied movement and timing of the keyframes at the right time and place					
3) I think I able to express emotions (i.e happy/sad waving hard/soft punching) while animating using keyframes					

Appendix C-3: SELECTED OUTPUT OF CRONBACH'S ALPHA RELIABILITY ANALYSIS

A supporting data of detailed statistical information for the Quality of Animation results in Chapter 5 (see section 5.6 Results).

Quality of Animation using Key Frame

Case Processing Summary

		N	%
Cases	Valid	20	100.0
	Excluded[a]	0	.0
	Total	20	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.774	.779	3

Item Statistics

	Mean	Std. Deviation	N
QK1	3.45	.759	20
QK2	3.55	.887	20
QK3	3.25	.786	20

Summary Item Statistics

	Mean	Minimum	Maximum	Range	Maximum / Minimum	Variance	N of Items
Inter-Item Correlations	.540	.396	.629	.233	1.588	.013	3

Quality of Animation using Hand Gesture

Case Processing Summary

		N	%
Cases	Valid	20	100.0
	Excluded[a]	0	.0
	Total	20	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.562	.553	3

Item Statistics

	Mean	Std. Deviation	N
QH1	4.15	.587	20
QH2	3.75	.639	20
QH3	4.35	.745	20

Summary Item Statistics

	Mean	Minimum	Maximum	Range	Maximum / Minimum	Variance	N of Items
Inter-Item Correlations	.292	.105	.415	.309	3.940	.022	3

Appendix C-4: SELECTED OUTPUT OF INDEPENDENT T-TEST ANALYSIS

A supporting data of detailed statistical information for the Quality of Animation results in Chapter 5 (see section 5.6 Results).

Group Statistics

	group	N	Mean	Std. Deviation	Std. Error Mean
Hand Gesture Quality	Beginner	10	4.0000	.49690	.15713
	Intermediate	10	4.1667	.47791	.15113
Keyframe Quality	Beginner	10	3.3000	.74453	.23544
	Intermediate	10	3.5333	.61262	.19373

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Hand Gesture Quality	Equal variances assumed	.255	.619	-.764	18	.454	-.16667	.21802	-.62470	.29137
	Equal variances not assumed			-.764	17.973	.455	-.16667	.21802	-.62475	.29142
Keyframe Quality	Equal variances assumed	1.148	.298	-.765	18	.454	-.23333	.30490	-.87390	.40723
	Equal variances not assumed			-.765	17.356	.454	-.23333	.30490	-.87561	.40894

Appendix C-5: SELECTED OUTPUT OF MIXED-DESIGN ANALYSIS

A supporting data of detailed statistical information for the Quality of Animation results in Chapter 5 (see section 5.6 Results).

Within-Subjects Factors

Measure:MEASURE_1

Quality	Dependent Variable
1	Quality_H
2	Quality_K

Between-Subjects Factors

		Value Label	N
group	1	Beginner	10
	2	Intermediate	10

Descriptive Statistics

	group	Mean	Std. Deviation	N
Hand Gesture Quality	Beginner	4.0000	.49690	10
	Intermediate	4.1667	.47791	10
	Total	4.0833	.48214	20
Keyframe Quality	Beginner	3.3000	.74453	10
	Intermediate	3.5333	.61262	10
	Total	3.4167	.67430	20

Box's Test of Equality of Covariance Matrices[a]

Box's M	5.173
F	1.517
df1	3
df2	58320.000
Sig.	.208

Tests the null hypothesis that the observed covariance matrices of the dependent variables are equal across groups.

a. Design: Intercept + group

Within Subjects Design: Quality

Multivariate Tests[b]

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared
Quality	Pillai's Trace	.431	13.611[a]	1.000	18.000	.002	.431
	Wilks' Lambda	.569	13.611[a]	1.000	18.000	.002	.431
	Hotelling's Trace	.756	13.611[a]	1.000	18.000	.002	.431
	Roy's Largest Root	.756	13.611[a]	1.000	18.000	.002	.431
Quality * group	Pillai's Trace	.002	.034[a]	1.000	18.000	.856	.002
	Wilks' Lambda	.998	.034[a]	1.000	18.000	.856	.002
	Hotelling's Trace	.002	.034[a]	1.000	18.000	.856	.002
	Roy's Largest Root	.002	.034[a]	1.000	18.000	.856	.002

a. Exact statistic
b. Design: Intercept + group
Within Subjects Design: Quality

Mauchly's Test of Sphericity[b]

Measure:MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[a]		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
Quality	1.000	.000	0	.	1.000	1.000	1.000

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.
a. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.
b. Design: Intercept + group
Within Subjects Design: Quality

Tests of Within-Subjects Effects

Measure:MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Quality	Sphericity Assumed	4.444	1	4.444	13.611	.002	.431
	Greenhouse-Geisser	4.444	1.000	4.444	13.611	.002	.431
	Huynh-Feldt	4.444	1.000	4.444	13.611	.002	.431
	Lower-bound	4.444	1.000	4.444	13.611	.002	.431
Quality * group	Sphericity Assumed	.011	1	.011	.034	.856	.002
	Greenhouse-Geisser	.011	1.000	.011	.034	.856	.002
	Huynh-Feldt	.011	1.000	.011	.034	.856	.002
	Lower-bound	.011	1.000	.011	.034	.856	.002
Error(Quality)	Sphericity Assumed	5.878	18	.327			
	Greenhouse-Geisser	5.878	18.000	.327			
	Huynh-Feldt	5.878	18.000	.327			
	Lower-bound	5.878	18.000	.327			

Tests of Between-Subjects Effects

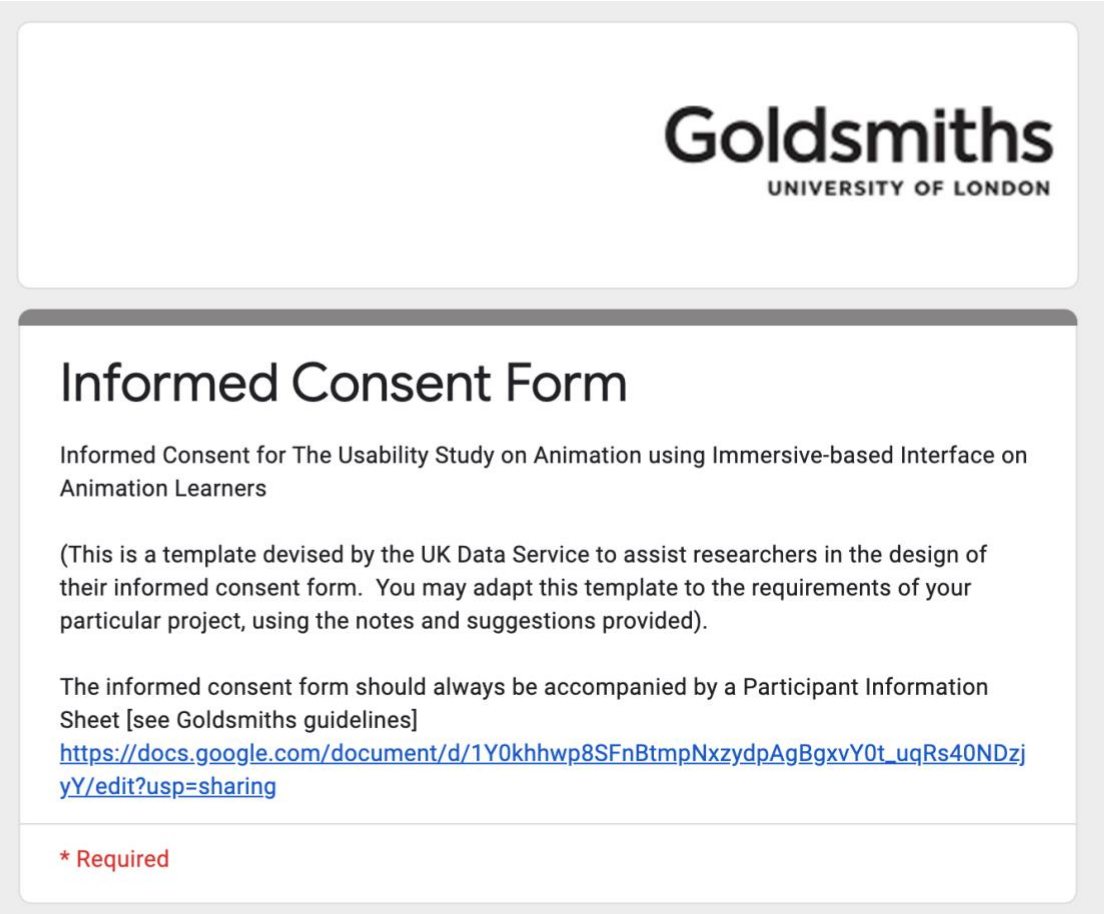
Measure:MEASURE_1
Transformed Variable:Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	562.500	1	562.500	1496.305	.000	.988
group	.400	1	.400	1.064	.316	.056
Error	6.767	18	.376			

Appendix D

Appendix D-1: Experiment Consent Form

Informed Consent Form is converted to online version for participants convenience during COVID-19 Regulations. The form can be retrieved at: https://docs.google.com/forms/d/1xedRU83MfhNeQN-eC-YmG_HkroxYeLY0DKnMwEYwvkY/prefill



Goldsmiths
UNIVERSITY OF LONDON

Informed Consent Form

Informed Consent for The Usability Study on Animation using Immersive-based Interface on Animation Learners

(This is a template devised by the UK Data Service to assist researchers in the design of their informed consent form. You may adapt this template to the requirements of your particular project, using the notes and suggestions provided).

The informed consent form should always be accompanied by a Participant Information Sheet [see Goldsmiths guidelines] https://docs.google.com/document/d/1Y0khhwp8SFnBtmpNxzydpAgBgxvY0t_uqRs40NDzjyY/edit?usp=sharing

* Required

Appendix D-2: UEQ Questionnaire

UEQ Questionnaire is converted to online version for participants convenience during COVID-19 Regulations. The survey form can be retrieved at:: https://docs.google.com/forms/d/1ZduA6-IhuFUYOG0pNA3Fr8JO78-BZfJL6SrsVtC1DRg/edit

Please make your evaluation now.

For the assessment of the product, please fill out the following questionnaire. The questionnaire consists of pairs of contrasting attributes that may apply to the product. The circles between the attributes represent gradations between the opposites. You can express your agreement with the attributes by ticking the circle that most closely reflects your impression.

Example:

attractive	○	⊗	○	○	○	○	○	unattractive

This response would mean that you rate the application as more attractive than unattractive.

Please decide spontaneously. Don’t think too long about your decision to make sure that you convey your original impression.

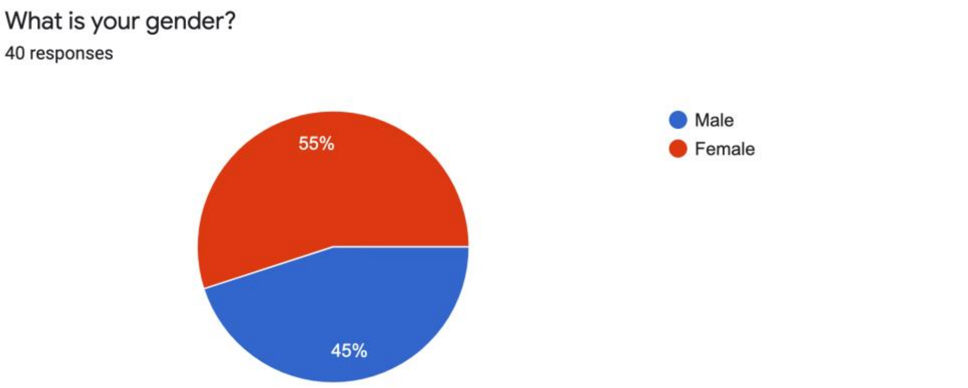
Sometimes you may not be completely sure about your agreement with a particular attribute or you may find that the attribute does not apply completely to the particular product. Nevertheless, please tick a circle in every line.

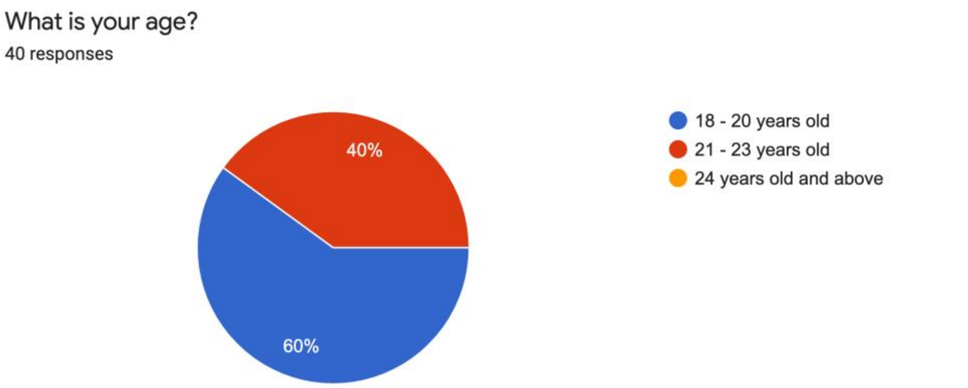
It is your personal opinion that counts. Please remember: there is no wrong or right answer!

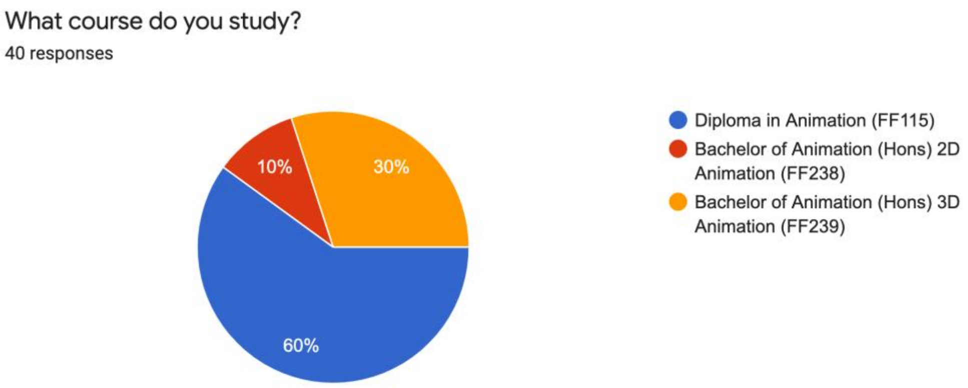
Please assess the product now by ticking one circle per line.

	1	2	3	4	5	6	7		
annoying	○	○	○	○	○	○	○	enjoyable	1
not understandable	○	○	○	○	○	○	○	understandable	2
creative	○	○	○	○	○	○	○	dull	3
easy to learn	○	○	○	○	○	○	○	difficult to learn	4
valuable	○	○	○	○	○	○	○	inferior	5
boring	○	○	○	○	○	○	○	exciting	6
not interesting	○	○	○	○	○	○	○	interesting	7
unpredictable	○	○	○	○	○	○	○	predictable	8
fast	○	○	○	○	○	○	○	slow	9
inventive	○	○	○	○	○	○	○	conventional	10
obstructive	○	○	○	○	○	○	○	supportive	11
good	○	○	○	○	○	○	○	bad	12
complicated	○	○	○	○	○	○	○	easy	13
unlikable	○	○	○	○	○	○	○	pleasing	14
usual	○	○	○	○	○	○	○	leading edge	15
unpleasant	○	○	○	○	○	○	○	pleasant	16
secure	○	○	○	○	○	○	○	not secure	17
motivating	○	○	○	○	○	○	○	demotivating	18
meets expectations	○	○	○	○	○	○	○	does not meet expectations	19
inefficient	○	○	○	○	○	○	○	efficient	20
clear	○	○	○	○	○	○	○	confusing	21
impractical	○	○	○	○	○	○	○	practical	22
organized	○	○	○	○	○	○	○	cluttered	23
attractive	○	○	○	○	○	○	○	unattractive	24
friendly	○	○	○	○	○	○	○	unfriendly	25
conservative	○	○	○	○	○	○	○	innovative	26

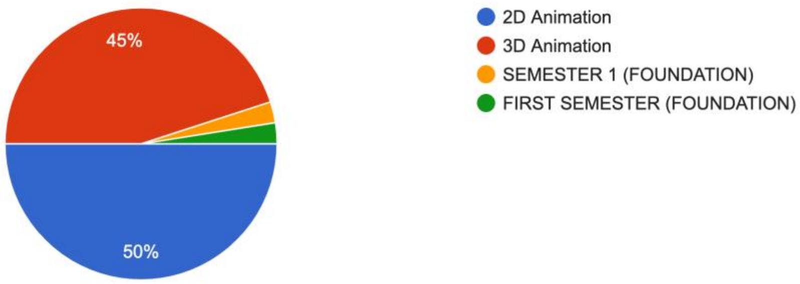
Appendix D-3: Demographics for Immersive-based Study



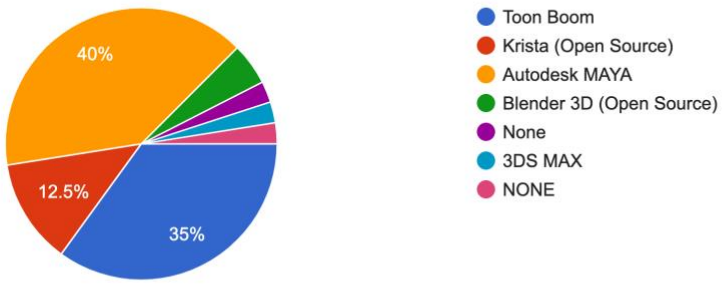




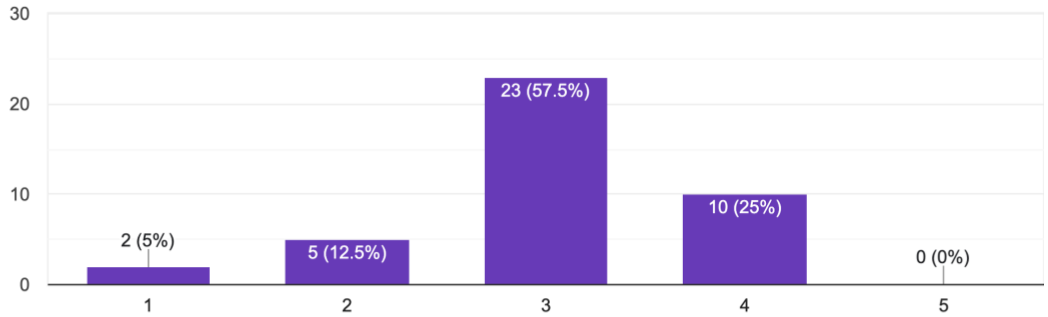
What is your preference to create animation?
40 responses



What software do you use to create animation?
40 responses



How would you rate your animation skills?
40 responses



Appendix D-4: UEQ T-test (Maya-Tvori)

Two sample T-Test assuming unequal variances (MAYA-TVORI)

This sheet shows a simple T-Test to check if the scale means of two measured products differ significantly. As default the Alpha-Level 0.05 is used, but you can simply change this value in this sheet if you want to use a different level.

Alpha level: **0.05**

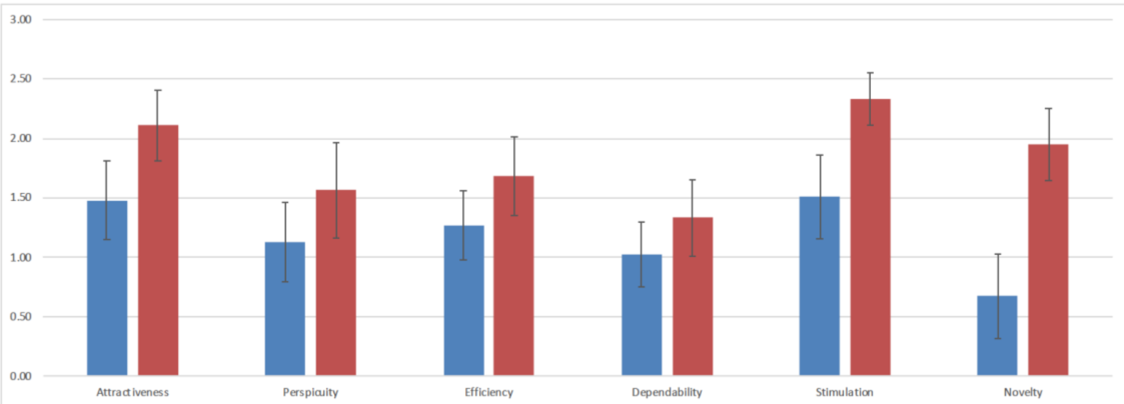
Attractiveness	0.0072	**Significant Difference**
Perspicuity	0.1037	**No Significant Difference**
Efficiency	0.0716	**No Significant Difference**
Dependability	0.1592	**No Significant Difference**
Stimulation	0.0002	**Significant Difference**
Novelty	0.0000	**Significant Difference**

Appendix D-5: UEQ Comparison Scale Means (Maya-Tvori)

Comparison of Scale Means (MAYA-TVORI)

Shows the scale means and the corresponding 5% confidence intervals.

Scale	Data Set 1 - for MAYA						Data Set 2 - for TVORI					
	Mean	STD	N	Confidence	Confidence Interval		Mean	STD	N	Confidence	Confidence Interval	
Attractiveness	1.48	1.07	40	0.33	1.15	1.81	2.11	0.96	40	0.30	1.81	2.41
Perspicuity	1.13	1.08	40	0.33	0.79	1.46	1.56	1.29	40	0.40	1.16	1.96
Efficiency	1.27	0.94	40	0.29	0.98	1.56	1.68	1.08	40	0.33	1.35	2.02
Dependability	1.03	0.88	40	0.27	0.75	1.30	1.33	1.04	40	0.32	1.01	1.65
Stimulation	1.51	1.14	40	0.35	1.15	1.86	2.33	0.71	40	0.22	2.11	2.55
Novelty	0.67	1.15	40	0.36	0.31	1.02	1.95	0.98	40	0.30	1.65	2.25



Appendix D-6: UEQ Transformed Data for Maya

Transformed Data (MAYA_UEQ Data Analysis)

The order of the positive and negative term for an item is randomized in the questionnaire. Per dimension half of the items start with the positive and half with the negative term.

Here you can find the transformed values per item. You can use these values for example for own statistical calculations. The +3 represent the most positive and the -3 the most negative value.

Items																									
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
3	3	3	2	3	3	3	0	3	2	3	3	3	3	3	3	3	3	3	3	3	3	2	3	2	2
0	2	2	2	2	2	2	-1	-1	0	0	2	0	1	-3	0	0	-3	0	0	-2	2	-2	1	-2	-3
2	2	3	2	3	3	3	1	2	3	3	3	3	3	3	3	2	3	2	2	3	2	2	3	2	2
2	1	0	1	2	2	3	1	2	0	2	2	2	1	0	1	3	2	1	2	2	2	3	3	3	1
0	1	1	1	1	1	1	0	-1	0	1	1	-1	1	1	1	1	1	1	2	2	2	2	2	2	0
1	1	0	-1	0	1	2	-1	0	-2	0	2	0	0	2	2	0	2	2	2	2	0	2	3	1	2
3	2	-2	-1	-1	2	2	1	-2	-2	2	-2	3	2	3	3	-2	-2	-3	3	-2	3	-1	-2	-2	2
2	2	-3	-2	-2	2	2	2	-2	-2	2	-3	2	2	1	3	-2	-2	-3	2	-1	2	-3	-2	-3	3
2	2	2	2	2	2	2	1	2	2	2	2	2	2	2	2	2	3	1	2	2	2	2	2	2	2
3	2	2	3	3	2	2	1	3	2	2	2	3	3	3	2	2	2	2	2	1	2	-1	3	3	2
3	3	3	3	3	3	3	2	3	3	3	3	3	3	2	3	3	3	2	3	3	3	3	3	3	3
1	0	1	0	1	0	0	0	0	0	0	2	-1	0	1	0	1	2	1	1	0	1	2	2	1	0
1	1	2	1	2	1	1	-2	1	1	1	2	-1	1	1	1	1	2	2	2	1	1	2	2	1	-1
2	1	2	2	2	2	2	0	0	2	2	2	2	2	2	3	2	2	2	1	1	1	2	2	2	0
2	2	-2	-2	-2	3	2	1	-2	-2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
2	1	2	2	2	2	3	0	1	1	2	3	1	2	3	1	2	2	2	1	2	2	3	3	3	2
-1	1	-1	0	1	-2	-1	0	-2	-3	-1	-1	-2	-1	-2	-1	0	1	-2	-1	-1	2	1	-1	0	-2
3	2	2	1	1	2	2	0	-1	-2	-2	2	-2	1	-1	1	1	1	2	2	-1	2	2	1	1	1
2	2	1	2	2	3	3	0	3	2	2	3	2	2	2	2	1	2	2	2	2	2	2	2	2	2
-1	2	-2	0	0	-1	1	1	-3	0	-1	2	-3	-1	2	-1	3	-1	-2	-2	-2	3	3	-1	-1	-1
-1	0	1	-1	-1	-2	-2	0	-3	0	0	0	-2	-2	0	-1	0	0	0	0	0	0	0	0	-2	0
2	1	-2	0	-1	2	1	2	2	2	0	2	-2	0	2	0	2	1	2	2	2	2	1	2	0	0
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3	2	3	2	3	3	3	2	3	2	2	3	2	2	2	2	3	3	2	3	3	3	3	3	3	2
3	3	3	3	3	3	3	0	2	3	3	3	3	3	3	3	0	3	2	2	2	1	2	3	3	3
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2	3	2	3	3	3	3	2	1	0	2	2	2	2	0	2	2	1	2	1	3	3	3	3	3	0
2	0	0	-1	1	3	2	0	-1	0	1	2	0	1	0	1	0	1	2	1	0	1	-1	1	1	-1
3	3	3	-1	3	2	3	1	1	1	3	3	2	2	2	1	2	3	2	3	3	3	2	2	1	2
1	2	0	2	1	1	1	0	0	-2	1	1	1	1	0	1	1	1	1	0	0	0	1	2	2	0
1	2	2	2	-1	1	2	1	1	-2	1	2	2	2	-1	1	1	1	2	2	1	1	1	2	2	0
3	3	-1	3	3	3	3	-1	3	0	2	3	0	3	0	0	0	3	0	1	1	2	-1	3	1	0
2	2	1	0	2	2	2	1	1	1	2	2	1	1	1	2	3	2	1	2	2	1	2	1	2	0
0	1	0	-1	0	0	1	-1	-2	-1	0	0	1	1	1	1	0	1	1	1	0	1	0	1	0	0
2	2	0	2	2	2	2	1	2	0	2	1	1	1	1	0	1	1	2	2	3	2	3	1	1	0
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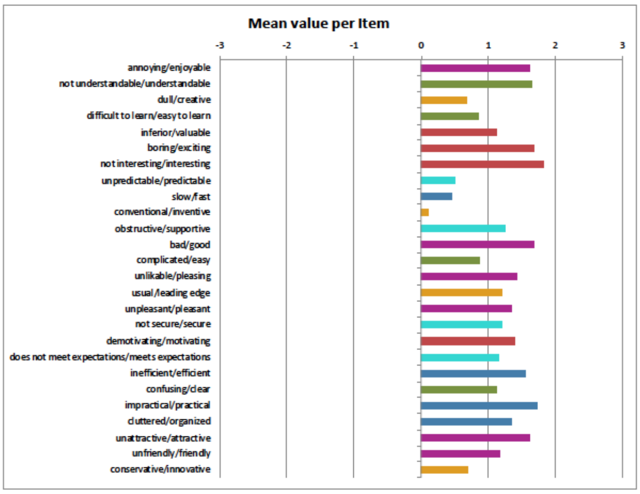
1	2	-1	-1	-1	0	0	0	0	-2	0	0	1	1	2	1	0	-1	0	2	0	2	1	0	0	-1
0	0	0	0	0	0	0	1	0	1	-1	0	-1	-1	1	-1	0	1	1	0	0	0	0	0	0	0
1	1	1	1	0	1	1	0	-1	-2	1	1	0	1	0	1	1	0	1	1	0	2	1	1	0	0

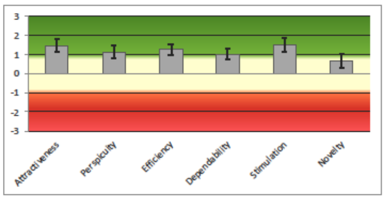
Scale means per person					
Attractiveness	Perspicuity	Efficiency	Dependability	Stimulation	Novelty
2.83	2.75	2.75	2.25	3.00	2.50
0.33	0.50	-0.25	-0.25	0.75	-1.00
2.67	2.50	2.00	2.00	3.00	2.75
2.00	1.50	2.25	1.75	2.25	0.25
1.17	0.75	1.25	0.75	1.00	0.50
1.50	0.50	1.00	0.25	1.25	0.50
0.33	0.50	0.75	-0.50	0.25	0.25
-0.17	0.25	-0.25	-0.25	0.00	-0.25
2.00	2.00	2.00	1.50	2.25	2.00
2.67	2.25	1.50	1.75	2.25	2.25
3.00	3.00	3.00	2.50	3.00	2.75
1.00	-0.25	1.00	0.50	0.75	0.50
1.33	0.50	1.50	0.50	1.50	0.75
2.17	1.50	1.00	1.50	2.00	1.50
2.00	1.00	1.00	1.75	1.25	0.00
2.33	1.50	1.75	1.50	2.25	2.00
-0.83	-0.50	0.00	-0.75	-0.25	-2.00
1.50	0.00	1.25	0.25	1.50	0.00
2.17	2.00	2.25	1.25	2.50	1.75
-0.50	-0.75	0.25	0.25	-0.25	-0.25
-1.00	-0.75	-0.75	0.00	-1.25	0.25
1.00	0.25	1.75	1.50	0.75	0.50
2.50	1.25	2.00	2.25	2.25	-0.50
1.83	0.50	1.25	0.75	1.25	1.25
2.67	2.25	3.00	2.25	3.00	2.25
3.00	2.75	1.75	1.25	3.00	3.00
2.83	3.00	2.25	2.25	3.00	0.50
2.33	2.75	2.00	2.00	2.50	0.50
1.33	-0.25	0.00	0.75	1.75	-0.25
2.00	1.75	2.25	2.00	2.75	2.00
1.33	1.25	0.25	0.75	1.00	-0.50
1.67	1.75	1.25	1.25	0.75	-0.25
2.17	1.75	1.25	0.25	3.00	-0.25
1.67	1.25	1.50	1.75	2.00	0.75
0.50	0.25	0.00	0.00	0.50	0.00
1.00	2.00	2.25	1.50	1.75	0.25
1.83	1.00	0.75	1.00	1.75	0.75
0.50	0.50	1.25	0.00	-0.50	-0.50
-0.33	-0.25	0.00	0.25	0.25	0.50
0.83	0.50	0.75	0.75	0.50	-0.25

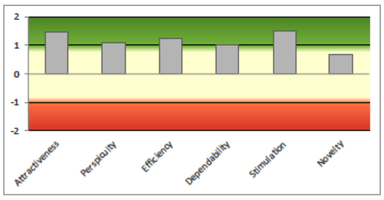
Appendix D-7: UEQ Results for Maya

Item	Mean	Variance	Std. Dev.	No.	Left	Right	Scale
1	1.6	1.4	1.2	40	annoying	enjoyable	Attractiveness
2	1.7	0.8	0.9	40	not understandable	understandable	Perspicuity
3	0.7	2.8	1.7	40	creative	dull	Novelty
4	0.9	2.3	1.5	40	easy to learn	difficult to learn	Perspicuity
5	1.1	2.5	1.6	40	valuable	inferior	Stimulation
6	1.7	1.8	1.3	40	boring	exciting	Stimulation
7	1.8	1.4	1.2	40	not interesting	interesting	Stimulation
8	0.5	1.0	1.0	40	unpredictable	predictable	Dependability
9	0.5	3.2	1.8	40	fast	slow	Efficiency
10	0.1	3.0	1.7	40	inventive	conventional	Novelty
11	1.3	1.7	1.3	40	obstructive	supportive	Dependability
12	1.7	2.0	1.4	40	good	bad	Attractiveness
13	0.9	2.9	1.7	40	complicated	easy	Perspicuity
14	1.4	1.6	1.3	40	unlikable	pleasing	Attractiveness
15	1.2	2.0	1.4	40	usual	leading edge	Novelty
16	1.4	1.5	1.2	40	unpleasant	pleasant	Attractiveness
17	1.2	1.9	1.4	40	secure	not secure	Dependability
18	1.4	2.3	1.5	40	motivating	demotivating	Stimulation
19	1.2	2.2	1.5	40	meets expectations	does not meet expectations	Dependability
20	1.6	1.2	1.1	40	inefficient	efficient	Efficiency
21	1.1	2.3	1.5	40	clear	confusing	Perspicuity
22	1.7	0.9	0.9	40	impractical	practical	Efficiency
23	1.4	2.2	1.5	40	organized	cluttered	Efficiency
24	1.6	1.9	1.4	40	attractive	unattractive	Attractiveness
25	1.2	2.5	1.6	40	friendly	unfriendly	Attractiveness
26	0.7	2.3	1.5	40	conservative	innovative	Novelty



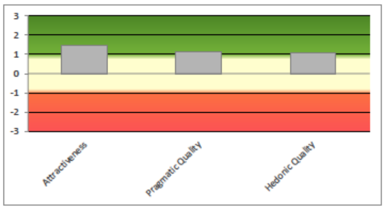
UEQ Scales (Mean and Variance)		
Attractiveness	1.479	1.16
Perspicuity	1.125	1.16
Efficiency	1.269	0.88
Dependability	1.025	0.78
Stimulation	1.506	1.30
Novelty	0.669	1.32





Pragmatic and Hedonic Quality	
Attractiveness	1.48
Pragmatic Quality	1.14
Hedonic Quality	1.09

The scales of the UEQ can be grouped into pragmatic quality (Perspicuity, Efficiency, Dependability) and hedonic quality (Stimulation, Originality). Pragmatic quality describes task related quality aspects, hedonic quality the non-task related quality aspects. Below the mean of the three pragmatic and hedonic quality aspects is calculated.

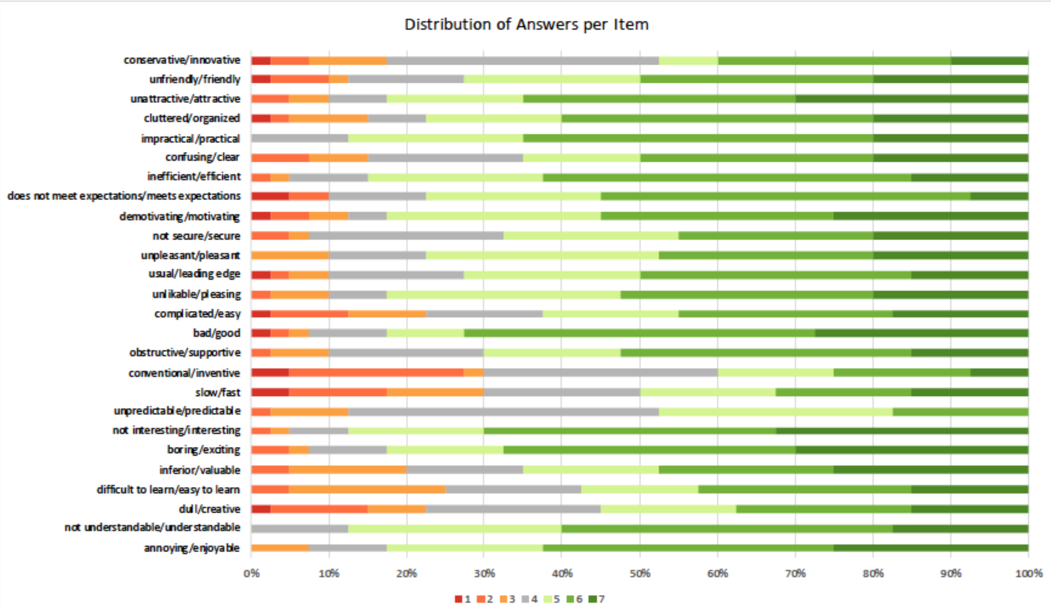


Appendix D-8: UEQ Distribution of Answers for Maya

Distribution of Answers per Item (MAYA_UEQ Data Analysis)

Here you can see the distribution of answers to the single items. If there are items that show a polarization in the answers (many negative and many positve judgements and not much neutral judgements) may help to get deeper insigths concerning aspects of the product that are experienced as quite positive by one subgroup of participants and quite negative by another subgroup.

Nr	Item	1	2	3	4	5	6	7	Scale
1	annoying/enjoyable	0	0	3	4	8	15	10	Attractiveness
2	not understandable/understandable	0	0	0	5	11	17	7	Perspicuity
3	dull/creative	1	5	3	9	7	9	6	Novelty
4	difficult to learn/easy to learn	0	2	8	7	6	11	6	Perspicuity
5	inferior/valuable	0	2	6	6	7	9	10	Stimulation
6	boring/exciting	0	2	1	4	6	15	12	Stimulation
7	not interesting/interesting	0	1	1	3	7	15	13	Stimulation
8	unpredictable/predictable	0	1	4	16	12	7	0	Dependability
9	slow/fast	2	5	5	8	7	7	6	Efficiency
10	conventional/inventive	2	9	1	12	6	7	3	Novelty
11	obstructive/supportive	0	1	3	8	7	15	6	Dependability
12	bad/good	1	1	1	4	4	18	11	Attractiveness
13	complicated/easy	1	4	4	6	7	11	7	Perspicuity
14	unlikable/pleasing	0	1	3	3	12	13	8	Attractiveness
15	usual/leading edge	1	1	2	7	9	14	6	Novelty
16	unpleasant/pleasant	0	0	4	5	12	11	8	Attractiveness
17	not secure/secure	0	2	1	10	9	10	8	Dependability
18	demotivating/motivating	1	2	2	2	11	12	10	Stimulation
19	does not meet expectations/meets expectations	2	2	0	5	9	19	3	Dependability
20	inefficient/efficient	0	1	1	4	9	19	6	Efficiency
21	confusing/clear	0	3	3	8	6	12	8	Perspicuity
22	impractical/practical	0	0	0	5	9	18	8	Efficiency
23	cluttered/organized	1	1	4	3	7	16	8	Efficiency
24	unattractive/attractive	0	2	2	3	7	14	12	Attractiveness
25	unfriendly/friendly	1	3	1	6	9	12	8	Attractiveness
26	conservative/innovative	1	2	4	14	3	12	4	Novelty



Appendix D-9: UEQ Cronbachs Alpha for Maya

Correlations of the items per scale and reliability coefficients (MAYA_UEQ Data Analysis)

Items that belong to the same scale should show in general a high correaltion.
Here you can find the correaltions of the items in a scale and some common coefficients, Cronbachs Alpha and Guttmans Lambda2, that are typically used to estimate reliability of a scale.

Cronbachs Alpha-Coefficient

The Alpha-Coefficient (Cronbach, 1951) is a measure for the consistency of a scale. There is no generally accepted rule how big the value of the coefficient should be. Many authors assume that a scale should show an alpha value > 0.7 to be considered as sufficiently consistent, but these suggestions are more rules-of-thumb and not based on some sound statistical facts. Thus, from an methodological standpoint such a use of a cut-off criterium is not really well-founded (see for example Schmitt, N., 1996). Especially if you have only a small sample (for example less than 50 answers) the value of the Alpha-Coefficient should be interpreted very carefully. In such cases a low Alpha can result from sampling errors and may not be an indicator for a problem with the scale.
If the value of the Alpha-Coefficient for a scale shows a massive deviation from a reasonable target value, for example 0.6 or 0.7, this can be a hint that some items of the scale are in the given context interpreted by several participants in an unexpected way. In such cases please check the single item scores and correlations between the items. This can give a hint if there is maybe a common misinterpretation of an item due to the context of the evaluation. In such cases the corresponding scale should be interpreted very carefully. The 5% confidence interval for the Alpha coefficient is calculated accordingly to Bonett, D.B. (2002), Sample Size Requirements for Testing and Estimating Coefficient Alpha, Journal of Educational and Behavioral Statistics, 27(4), 335-340.

Attractiveness	
Items	Correlation
1, 12	0.42
1, 14	0.79
1, 16	0.67
1, 24	0.45
1, 25	0.48
12, 14	0.44
12, 16	0.20
12, 24	0.84
12, 25	0.73
14, 16	0.80
14, 24	0.53
14, 25	0.55
16, 24	0.35
16, 25	0.42
24, 25	0.84
Average	0.57
Alpha	**0.89**
Conf. Int.	0.82
Alpha (5%)	0.93

Perspicuity	
Items	Correlation
2, 4	0.45
2, 13	0.58
2, 21	0.32
4, 13	0.34
4 , 21	0.38
13, 21	0.50
Average	0.43
Alpha	**0.75**
Conf. Int.	0.58
Alpha (5%)	0.85

Efficiency	
Items	Correlation
9, 20	0.52
9, 22	0.20
9, 23	0.33
20, 22	0.35
20, 23	0.21
22, 23	0.24
Average	0.31
Alpha	**0.64**
Conf. Int.	0.39
Alpha (5%)	0.79

Dependability	
Items	Correlation
8, 11	0.28
8, 17	0.25
8, 19	-0.05
11, 17	0.26
11, 19	0.29
17, 19	0.61
Average	0.27
Alpha	**0.60**
Conf. Int.	0.33
Alpha (5%)	0.76

Stimulation	
Items	Correlation
5, 6	0.44
5, 7	0.53
5, 18	0.56
6, 7	0.90
6, 18	0.43
7, 18	0.45
Average	0.55
Alpha	**0.83**
Conf. Int.	0.72
Alpha (5%)	0.90

Novelty	
Items	Correlation
3, 10	0.56
3, 15	0.06
3, 26	0.24
10, 15	0.47
10, 26	0.25
15, 26	0.64
Average	0.37
Alpha	**0.70**
Conf. Int.	0.50
Alpha (5%)	0.82

Guttmans Lambda2 coefficient

Another coefficient often reported as a measure of reliability of a scale is Guttmans Lambda2 coefficient. Lambda2 is a better approximation of reliability than Cronbach's Alpha (both are a lower bound for the real reliability of a scale). The coefficient Lambda1 also computed here is mainly needed for computing Lambda2.
NOTE: Theoretically, Lambda2 is higher than Alpha, but due to some rounding errors in the computation, it can happen that the Excel-Sheet shows some violations of this!

Attractiveness	
Lambda1	0.73854688

Items	Covar^2
1, 12	0.46
1, 14	1.34
1, 16	0.91
1, 24	0.54
1, 25	0.75
12, 14	0.58
12, 16	0.11
12, 24	2.57
12, 25	2.42
14, 16	1.44
14, 24	0.83
14, 25	1.10
16, 24	0.34
16, 25	0.62
24, 25	3.21
Sum	17.24
Lambda2	**0.89**

Perspicuity	
Lambda1	0.54716066

Items	Covar^2
2, 4	0.41
2, 13	0.82
2, 21	0.21
4, 13	0.77
4 , 21	0.79
13, 21	1.69
Sum	4.68
Lambda2	**0.74**

Efficiency	
Lambda1	0.46631133

Items	Covar^2
9, 20	1.01
9, 22	0.10
9, 23	0.75
20, 22	0.12
20, 23	0.11
22, 23	0.10
Sum	2.20
Lambda2	**0.64**

Dependability	
Lambda1	0.4602978

Items	Covar^2
8, 11	0.12
8, 17	0.11
8, 19	0.01
11, 17	0.20
11, 19	0.29
17, 19	1.43
Sum	2.15
Lambda2	**0.65**

Stimulation	
Lambda1	0.6155786

Items	Covar^2
5, 6	0.84
5, 7	0.94
5, 18	1.69
6, 7	2.01
6, 18	0.73
7, 18	0.63
Sum	6.85
Lambda2	**0.82**

Novelty	
Lambda1	0.5234078

Items	Covar^2
3, 10	2.50
3, 15	0.02
3, 26	0.36
10, 15	1.22
10, 26	0.40
15, 26	1.72
Sum	6.22
Lambda2	**0.72**

Appendix D-10: UEQ Benchmark Analysis for Maya

Benchmark (MAYA_UEQ Data Analysis)

The measured scale means are set in relation to existing values from a benchmark data set. This data set contains data from 21175 persons from 468 studies concerning different products (business software, web pages, web shops, social networks).

The comparison of the results for the evaluated product with the data in the benchmark allows conclusions about the relative quality of the evaluated product compared to other products.

Please help to increase the data basis for the benchmark! If you use the UEQ to evaluate products it would be quite helpful for us if you will share information concerning the type of product, the number of participants in your study and the scale means. We will of course handle these information absolutely confidential and will use it solely to improve the benchmark.

Scale	Mean	Comparisson to benchmark	Interpretation
Attractiveness	1.48	**Above average**	25% of results better, 50% of results worse
Perspicuity	1.13	**Below Average**	50% of results better, 25% of results worse
Efficiency	1.27	**Above Average**	25% of results better, 50% of results worse
Dependability	1.03	**Below Average**	50% of results better, 25% of results worse
Stimulation	1.51	**Good**	10% of results better, 75% of results worse
Novelty	0.67	**Below Average**	50% of results better, 25% of results worse

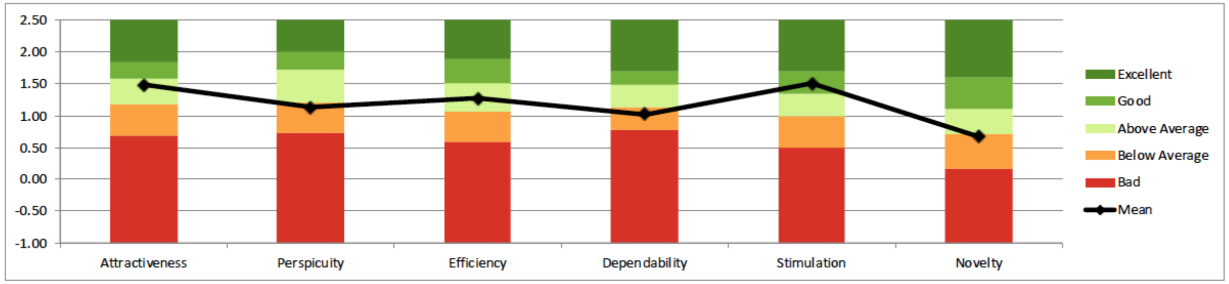


Table to create the benchmark graph (purely technical, please ignore)

Scale	**Lower Border**	**Bad**	**Below Average**	**Above Average**	**Good**	**Excellent**	**Mean**
Attractiveness	-1.00	0.69	0.49	0.4	0.26	0.66	1.48
Perspicuity	-1.00	0.72	0.48	0.53	0.27	0.5	1.13
Efficiency	-1.00	0.6	0.45	0.45	0.38	0.62	1.27
Dependability	-1.00	0.78	0.36	0.34	0.22	0.8	1.03
Stimulation	-1.00	0.5	0.5	0.35	0.35	0.8	1.51
Novelty	-1.00	0.16	0.54	0.42	0.48	0.9	0.67

Benchmark borders (purely technical, please ignore and do not change)

Scale	**25%**	**50%**	**75%**	**90%**
Attractiveness	0.69	1.18	1.58	1.84
Perspicuity	0.72	1.2	1.73	2
Efficiency	0.6	1.05	1.5	1.88
Dependability	0.78	1.14	1.48	1.7
Stimulation	0.5	1	1.35	1.7
Novelty	0.16	0.7	1.12	1.6

Appendix D-11: UEQ Transformed Data for Tvori

Transformed Data (TVORI_UEQ Data Analysis)

The order of the positive and negative term for an item is randomized in the questionnaire. Per dimension half of the items start with the positive and half with the negative term.

Here you can find the transformed values per item. You can use these values for example for own statistical calculations. The +3 represent the most positive and the -3 the most negative value.

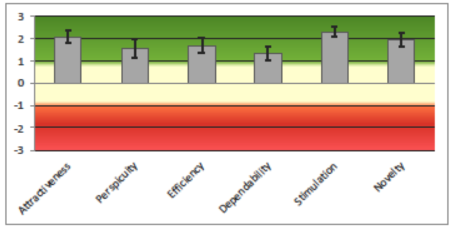
Items																									
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
3	2	3	3	3	3	3	3	3	3	3	3	2	3	3	3	3	3	3	3	2	3	3	3	2	3
3	2	3	3	3	3	3	2	3	3	3	3	3	3	3	3	3	3	3	3	2	3	3	3	2	-3
3	2	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
3	1	3	2	3	2	3	2	2	3	3	2	0	2	1	2	2	2	2	2	1	1	1	3	2	1
-1	0	2	1	2	3	2	-1	0	3	0	1	-2	1	0	0	1	1	1	1	1	0	-1	1	0	2
3	3	3	3	2	3	3	2	2	3	3	3	2	3	3	3	0	3	2	2	3	2	2	3	3	3
3	3	-2	-3	-2	3	3	1	-2	-3	3	-3	2	3	3	3	-2	-2	-1	3	-2	2	-2	-2	-2	3
1	2	-3	-2	-1	3	3	2	-1	-3	0	3	3	3	3	3	2	3	2	2	-2	3	-2	3	1	3
3	3	3	2	2	3	3	0	1	3	2	3	3	2	3	3	2	3	3	3	3	3	3	3	3	3
2	2	3	3	3	3	3	1	3	3	3	3	3	3	3	3	2	3	3	3	2	2	-1	2	3	2
3	3	2	3	3	3	3	0	3	2	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
3	2	3	3	3	2	2	2	2	3	3	3	3	2	2	2	2	2	2	2	2	2	2	3	3	-3
-1	1	2	0	2	2	2	-2	2	2	1	2	-2	1	2	2	0	1	1	1	1	1	0	2	1	-1
0	0	3	0	3	3	3	-2	0	0	2	3	-2	2	2	1	0	1	2	1	2	0	1	3	1	0
3	3	2	3	3	3	3	3	3	3	3	2	2	2	3	2	2	2	3	3	2	2	2	3	3	3
3	2	3	1	2	3	3	2	2	3	2	2	0	2	2	0	0	1	0	0	0	2	0	3	0	3
3	3	3	3	1	3	3	-2	3	3	2	2	3	3	3	3	-1	2	1	1	2	-2	0	3	3	3
3	3	2	3	3	3	3	2	2	2	2	2	-2	3	3	3	1	2	2	2	2	2	2	3	2	0
3	3	3	3	3	3	3	0	3	3	3	3	2	2	3	3	2	3	3	3	3	3	3	3	3	3
3	3	3	3	2	3	3	-1	2	2	2	2	3	3	3	3	0	3	2	3	3	3	3	3	3	2
2	2	2	3	2	3	3	-1	3	3	2	3	0	2	2	2	1	2	1	1	2	2	2	3	3	0
3	2	-3	-2	2	3	3	0	1	2	1	2	1	2	2	1	1	2	1	2	2	2	2	3	2	-1
-2	-2	-1	-3	0	3	3	0	-3	1	-1	1	-3	2	2	0	0	2	1	1	0	0	0	0	-1	1
2	2	2	1	2	3	3	1	2	2	3	2	1	3	3	3	2	2	-1	3	3	3	2	2	1	2
3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
3	3	3	3	3	3	3	0	2	3	3	3	3	3	3	3	0	3	3	3	3	3	3	3	3	3
3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
3	1	3	2	3	3	3	0	0	3	2	3	-1	2	2	0	0	1	0	2	-1	2	1	3	2	3
3	2	2	2	2	3	3	1	2	1	2	2	2	2	2	2	2	2	2	2	2	2	2	3	2	-1
3	3	3	2	3	3	3	1	3	3	3	3	3	3	3	3	3	3	3	3	2	2	3	3	3	3
0	-1	0	1	1	2	1	-1	-1	2	1	2	-1	1	0	0	1	1	0	0	-1	1	2	2	1	0
1	0	1	1	1	2	1	0	1	2	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	0
3	3	3	2	3	3	3	-1	3	3	3	3	0	1	1	1	1	1	1	1	3	3	3	3	3	3
1	2	2	2	2	3	2	1	1	2	2	3	0	2	2	2	0	3	2	2	1	1	0	2	2	2
0	1	0	-1	1	1	-2	-1	-2	0	0	1	-1	-1	1	0	-1	0	-2	0	-2	0	-1	1	-1	0
3	3	3	3	2	3	3	-1	3	3	2	2	3	3	3	3	2	2	3	2	3	3	0	3	3	2
3	2	2	3	2	2	3	2	2	0	2	3	2	3	2	2	0	2	0	2	2	2	2	2	2	2
-1	1	0	1	0	2	2	-1	0	2	-1	0	-1	0	-1	-1	-1	1	1	0	1	0	0	1	1	2
1	1	2	1	0	2	2	0	2	2	2	1	1	1	2	1	0	2	1	1	0	2	0	1	1	2
2	2	2	2	2	2	2	0	2	2	2	2	2	2	2	2	1	2	2	2	1	0	2	3	2	2

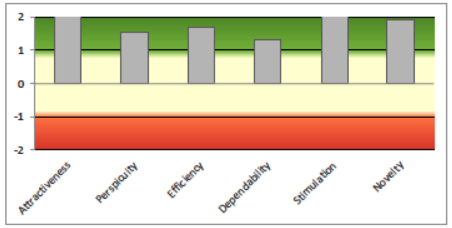
Scale means per person					
Attractiveness	Perspicuity	Efficiency	Dependability	Stimulation	Novelty
2.83	2.25	3.00	3.00	3.00	3.00
2.83	2.50	3.00	2.75	3.00	1.50
3.00	2.75	3.00	3.00	3.00	3.00
2.33	1.00	1.50	2.25	2.50	2.00
0.33	0.00	0.00	0.25	2.00	1.75
3.00	2.75	2.00	1.75	2.75	3.00
0.33	0.00	0.25	0.25	0.50	0.25
2.33	0.25	0.50	1.50	2.00	0.00
2.83	2.75	2.50	1.75	2.75	3.00
2.67	2.50	1.75	2.25	3.00	2.75
3.00	3.00	3.00	2.25	3.00	2.50
2.67	2.50	2.00	2.25	2.25	1.25
1.17	0.00	1.00	0.00	1.75	1.25
1.67	0.00	0.50	0.50	2.50	1.25
2.50	2.50	2.50	2.75	2.75	2.75
1.67	0.75	1.00	1.00	2.25	2.75
2.83	2.75	0.50	0.00	2.25	3.00
2.67	1.50	2.00	1.75	2.75	1.75
2.83	2.75	3.00	2.00	3.00	3.00
2.83	3.00	2.75	0.75	2.75	2.50
2.50	1.75	2.00	0.75	2.50	1.75
2.17	0.75	1.75	0.75	2.50	0.00
0.00	-2.00	-0.50	0.00	2.00	0.75
2.17	1.75	2.50	1.25	2.50	2.25
3.00	3.00	3.00	3.00	3.00	3.00
3.00	3.00	2.75	1.50	3.00	3.00
3.00	3.00	3.00	3.00	3.00	3.00
2.17	0.25	1.25	0.50	2.50	2.75
2.33	2.00	2.00	1.75	2.50	1.00
3.00	2.50	2.75	2.50	3.00	3.00
1.00	-0.50	0.50	0.25	1.25	0.50
0.83	0.75	1.00	0.75	1.25	1.00
2.33	2.00	2.50	1.00	2.50	2.50
2.00	1.25	1.00	1.25	2.50	2.00
0.00	-0.75	-0.75	-1.00	0.00	0.25
2.83	3.00	2.00	1.50	2.50	2.75
2.50	2.25	2.00	1.00	2.25	1.50
0.00	0.50	0.00	-0.50	1.25	0.75
1.00	0.75	1.25	0.75	1.50	2.00
2.17	1.75	1.50	1.25	2.00	2.00

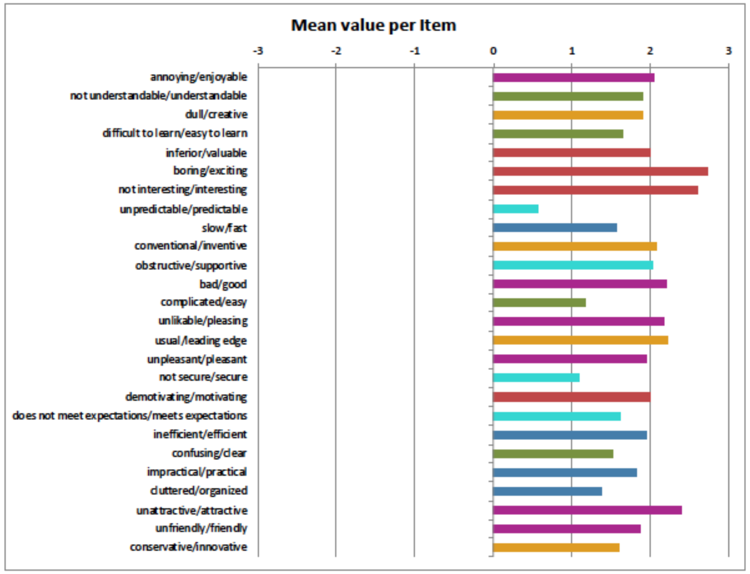
Appendix D-12: UEQ Results for Tvori

Item	Mean	Variance	Std. Dev.	No.	Left	Right	Scale
1	2.1	2.2	1.5	40	annoying	enjoyable	Attractiveness
2	1.9	1.5	1.2	40	not understandable	understandable	Perspicuity
3	1.9	2.8	1.7	40	creative	dull	Novelty
4	1.7	3.1	1.7	40	easy to learn	difficult to learn	Perspicuity
5	2.0	1.5	1.2	40	valuable	inferior	Stimulation
6	2.7	0.3	0.5	40	boring	exciting	Stimulation
7	2.6	0.9	0.9	40	not interesting	interesting	Stimulation
8	0.6	2.3	1.5	40	unpredictable	predictable	Dependability
9	1.6	2.6	1.6	40	fast	slow	Efficiency
10	2.1	2.2	1.5	40	inventive	conventional	Novelty
11	2.0	1.3	1.1	40	obstructive	supportive	Dependability
12	2.2	1.3	1.2	40	good	bad	Attractiveness
13	1.2	3.5	1.9	40	complicated	easy	Perspicuity
14	2.2	0.9	1.0	40	unlikable	pleasing	Attractiveness
15	2.2	1.0	1.0	40	usual	leading edge	Novelty
16	2.0	1.5	1.2	40	unpleasant	pleasant	Attractiveness
17	1.1	1.8	1.3	40	secure	not secure	Dependability
18	2.0	1.1	1.1	40	motivating	demotivating	Stimulation
19	1.6	1.7	1.3	40	meets expectations	does not meet expectations	Dependability
20	2.0	1.0	1.0	40	inefficient	efficient	Efficiency
21	1.5	2.3	1.5	40	clear	confusing	Perspicuity
22	1.8	1.5	1.2	40	impractical	practical	Efficiency
23	1.4	2.3	1.5	40	organized	cluttered	Efficiency
24	2.4	1.2	1.1	40	attractive	unattractive	Attractiveness
25	1.9	1.7	1.3	40	friendly	unfriendly	Attractiveness
26	1.6	2.9	1.7	40	conservative	innovative	Novelty

UEQ Scales (Mean and Variance)		
Attractiveness	2.108	0.92
Perspicuity	1.563	1.67
Efficiency	1.681	1.16
Dependability	1.331	1.08
Stimulation	2.331	0.50
Novelty	1.950	0.96

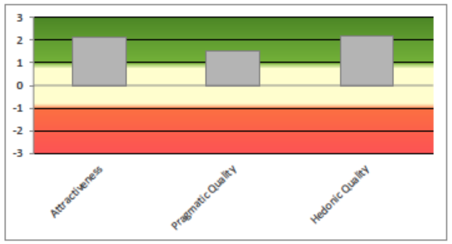






Pragmatic and Hedonic Quality	
Attractiveness	2.11
Pragmatic Quality	1.53
Hedonic Quality	2.14

The scales of the UEQ can be grouped into pragmatic quality (Perspicuity, Efficiency, Dependability) and hedonic quality (Stimulation, Originality). Pragmatic quality describes task related quality aspects, hedonic quality the non-task related quality aspects. Below the mean of the three pragmatic and hedonic quality aspects is calculated.

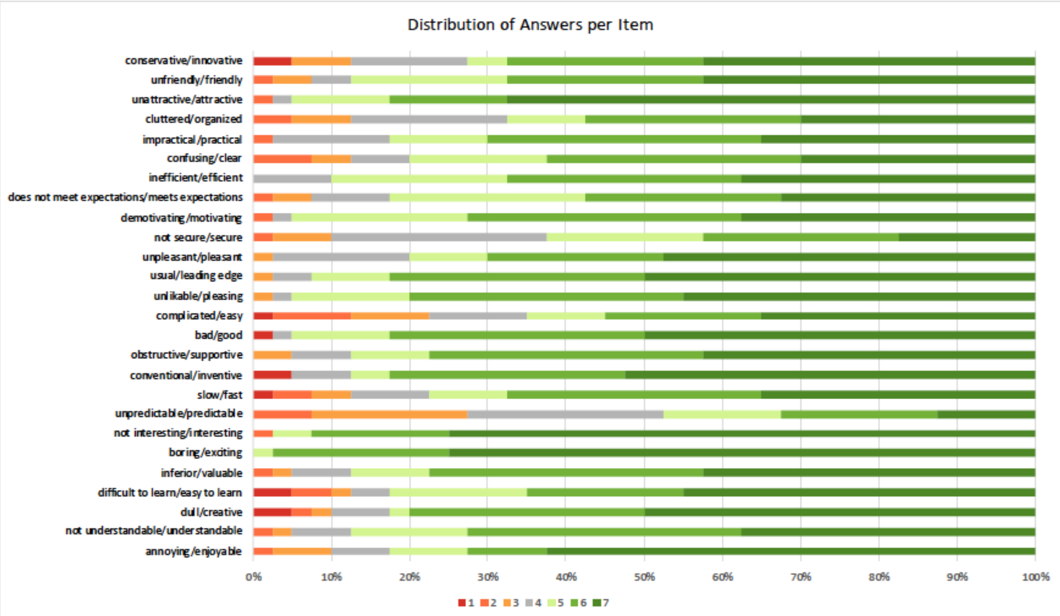


Appendix D-13: UEQ Distribution of Answers for Tvori

Distribution of Answers per Item (TVORI_UEQ Data Analysis)

Here you can see the distribution of answers to the single items. If there are items that show a polarization in the answers (many negative and many positve judgements and not much neutral judgements) may help to get deeper insigths concerning aspects of the product that are experienced as quite positive by one subgroup of participants and quite negative by another subgroup.

Nr	Item	1	2	3	4	5	6	7	Scale
1	annoying/enjoyable	0	1	3	3	4	4	25	Attractiveness
2	not understandable/understandable	0	1	1	3	6	14	15	Perspicuity
3	dull/creative	2	1	1	3	1	12	20	Novelty
4	difficult to learn/easy to learn	2	2	1	2	7	8	18	Perspicuity
5	inferior/valuable	0	1	1	3	4	14	17	Stimulation
6	boring/exciting	0	0	0	0	1	9	30	Stimulation
7	not interesting/interesting	0	1	0	0	2	7	30	Stimulation
8	unpredictable/predictable	0	3	8	10	6	8	5	Dependability
9	slow/fast	1	2	2	4	4	13	14	Efficiency
10	conventional/inventive	2	0	0	3	2	12	21	Novelty
11	obstructive/supportive	0	0	2	3	4	14	17	Dependability
12	bad/good	1	0	0	1	5	13	20	Attractiveness
13	complicated/easy	1	4	4	5	4	8	14	Perspicuity
14	unlikable/pleasing	0	0	1	1	6	14	18	Attractiveness
15	usual/leading edge	0	0	1	2	4	13	20	Novelty
16	unpleasant/pleasant	0	0	1	7	4	9	19	Attractiveness
17	not secure/secure	0	1	3	11	8	10	7	Dependability
18	demotivating/motivating	0	1	0	1	9	14	15	Stimulation
19	does not meet expectations/meets expectations	0	1	2	4	10	10	13	Dependability
20	inefficient/efficient	0	0	0	4	9	12	15	Efficiency
21	confusing/clear	0	3	2	3	7	13	12	Perspicuity
22	impractical/practical	0	1	0	6	5	14	14	Efficiency
23	cluttered/organized	0	2	3	8	4	11	12	Efficiency
24	unattractive/attractive	0	1	0	1	5	6	27	Attractiveness
25	unfriendly/friendly	0	1	2	2	8	10	17	Attractiveness
26	conservative/innovative	2	0	3	6	2	10	17	Novelty



Appendix D-14: UEQ Cronbachs Alpha for Tvori

Correlations of the items per scale and reliability coefficients (TVORI_UEQ Data Analysis)

Items that belong to the same scale should show in general a high correaltion.

Here you can find the correaltions of the items in a scale and some common coefficients, Cronbachs Alpha and Guttmans Lambda2, that are typically used to estimate reliability of a scale.

Cronbachs Alpha-Coefficient

The Alpha-Coefficient (Cronbach, 1951) is a measure for the consistency of a scale. There is no generally accepted rule how big the value of the coefficient should be. Many authors assume that a scale should show an alpha value > 0.7 to be considered as sufficiently consistent, but these suggestions are more rules-of-thumb and not based on some sound statistical facts. Thus, from an methodological standpoint such a use of a cut-off criterium is not really well-founded (see for example Schmitt, N., 1996). Especially if you have only a small sample (for example less than 50 answers) the value of the Alpha-Coefficient should be interpreted very carefully. In such cases a low Alpha can result from sampling errors and may not be an indicator for a problem with the scale.

If the value of the Alpha-Coefficient for a scale shows a massive deviation from a reasonable target value, for example 0.6 or 0.7, this can be a hint that some items of the scale are in the given context interpreted by several participants in an unexpected way. In such cases please check the single item scores and correlations between the items. This can give a hint if there is maybe a common misinterpretation of an item due to the context of the evaluation. In such cases the corresponding scale should be interpreted very carefully. The 5% confidence interval for the Alpha coefficient is calculated accordingly to Bonett, D.B. (2002), Sample Size Requirements for Testing and Estimating Coefficient Alpha, Journal of Educational and Behavioral Statistics, 27(4), 335-340.

Attractiveness	
Items	Correlation
1, 12	0.34
1, 14	0.63
1, 16	0.64
1, 24	0.54
1, 25	0.62
12, 14	0.34
12, 16	0.35
12, 24	0.86
12, 25	0.75
14, 16	0.81
14, 24	0.35
14, 25	0.45
16, 24	0.38
16, 25	0.55
24, 25	0.80
Average	0.56
Alpha	**0.88**
Conf. Int.	0.81
Alpha (5%)	0.93

Perspicuity	
Items	Correlation
2, 4	0.51
2, 13	0.71
2, 21	0.52
4, 13	0.46
4 , 21	0.70
13, 21	0.43
Average	0.56
Alpha	**0.83**
Conf. Int.	0.72
Alpha (5%)	0.90

Efficiency	
Items	Correlation
9, 20	0.46
9, 22	0.43
9, 23	0.59
20, 22	0.66
20, 23	0.48
22, 23	0.50
Average	0.52
Alpha	**0.81**
Conf. Int.	0.69
Alpha (5%)	0.89

Dependability	
Items	Correlation
8, 11	0.46
8, 17	0.53
8, 19	0.34
11, 17	0.45
11, 19	0.43
17, 19	0.68
Average	0.48
Alpha	**0.79**
Conf. Int.	0.65
Alpha (5%)	0.87

Stimulation	
Items	Correlation
5, 6	0.25
5, 7	0.27
5, 18	0.51
6, 7	0.80
6, 18	0.38
7, 18	0.42
Average	0.44
Alpha	**0.76**
Conf. Int.	0.59
Alpha (5%)	0.86

Novelty	
Items	Correlation
3, 10	0.72
3, 15	0.26
3, 26	0.16
10, 15	0.02
10, 26	0.04
15, 26	0.28
Average	0.25
Alpha	**0.57**
Conf. Int.	0.27
Alpha (5%)	0.74

Guttmans Lambda2 coefficient

Another coefficient often reported as a measure of reliability of a scale is Guttmans Lambda2 coefficient. Lambda2 is a better approximation of reliability than Cronbach's Alpha (both are a lower bound for the real reliability of a scale). The coefficient Lambda1 also computed here is mainly needed for computing Lambda2.

NOTE: Theoretically, Lambda2 is higher than Alpha, but due to some rounding errors in the computation, it can happen that the Excel-Sheet shows some violations of this!

Attractiveness	
Lambda1	0.73359926
Items	Covar^2
1, 12	0.32
1, 14	0.75
1, 16	1.27
1, 24	0.69
1, 25	1.34
12, 14	0.13
12, 16	0.24
12, 24	1.09
12, 25	1.21
14, 16	0.87
14, 24	0.13
14, 25	0.30
16, 24	0.25
16, 25	0.75
24, 25	1.21
Sum	10.54
Lambda2	**0.89**

Perspicuity	
Lambda1	0.61476671
Items	Covar^2
2, 4	1.19
2, 13	2.58
2, 21	0.90
4, 13	2.25
4 , 21	3.35
13, 21	1.47
Sum	11.75
Lambda2	**0.82**

Efficiency	
Lambda1	0.59829414
Items	Covar^2
9, 20	0.53
9, 22	0.68
9, 23	2.06
20, 22	0.63
20, 23	0.52
22, 23	0.84
Sum	5.25
Lambda2	**0.80**

Dependability	
Lambda1	0.5884184
Items	Covar^2
8, 11	0.62
8, 17	1.09
8, 19	0.44
11, 17	0.45
11, 19	0.40
17, 19	1.35
Sum	4.35
Lambda2	**0.79**

Stimulation	
Lambda1	0.5315743
Items	Covar^2
5, 6	0.02
5, 7	0.09
5, 18	0.42
6, 7	0.13
6, 18	0.04
7, 18	0.16
Sum	0.87
Lambda2	**0.72**

Novelty	
Lambda1	0.4235461
Items	Covar^2
3, 10	2.92
3, 15	0.18
3, 26	0.19
10, 15	0.00
10, 26	0.01
15, 26	0.22
Sum	3.51
Lambda2	**0.62**

Appendix D-15: UEQ Benchmark Analysis for Tvori

Benchmark (TVORI_UEQ Data Analysis)

The measured scale means are set in relation to existing values from a benchmark data set. This data set contains data from 21175 persons from 468 studies concerning different products (business software, web pages, web shops, social networks).

The comparison of the results for the evaluated product with the data in the benchmark allows conclusions about the relative quality of the evaluated product compared to other products.

Please help to increase the data basis for the benchmark! If you use the UEQ to evaluate products it would be quite helpful for us if you will share information concerning the type of product, the number of participants in your study and the scale means. We will of course handle these information absolutely confidential and will use it solely to improve the benchmark.

Scale	Mean	Comparisson to benchmark	Interpretation
Attractiveness	2.11	**Excellent**	In the range of the 10% best results
Perspicuity	1.56	**Above Average**	25% of results better, 50% of results worse
Efficiency	1.68	**Good**	10% of results better, 75% of results worse
Dependability	1.33	**Above Average**	25% of results better, 50% of results worse
Stimulation	2.33	**Excellent**	In the range of the 10% best results
Novelty	1.95	**Excellent**	In the range of the 10% best results

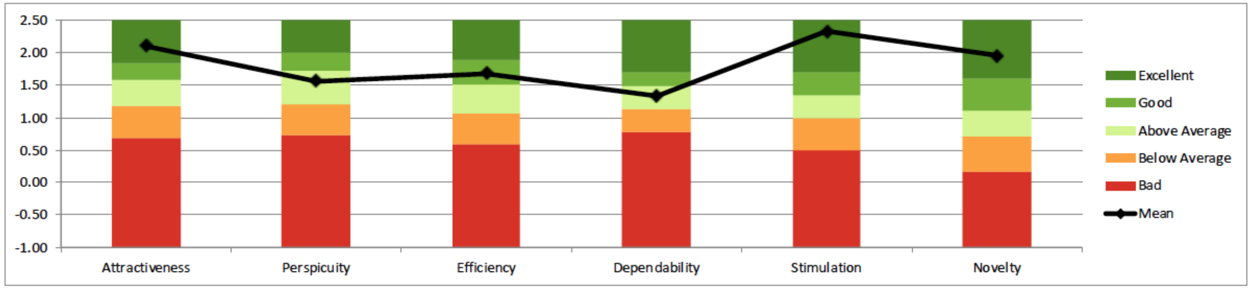


Table to create the benchmark graph (purely technical, please ignore)

Scale	Lower Border	Bad	Below Average	Above Average	Good	Excellent	Mean
Attractiveness	-1.00	0.69	0.49	0.4	0.26	0.66	2.11
Perspicuity	-1.00	0.72	0.48	0.53	0.27	0.5	1.56
Efficiency	-1.00	0.6	0.45	0.45	0.38	0.62	1.68
Dependability	-1.00	0.78	0.36	0.34	0.22	0.8	1.33
Stimulation	-1.00	0.5	0.5	0.35	0.35	0.8	2.33
Novelty	-1.00	0.16	0.54	0.42	0.48	0.9	1.95

Benchmark borders (purely technical, please ignore and do not change)

Scale	25%	50%	75%	90%
Attractiveness	0.69	1.18	1.58	1.84
Perspicuity	0.72	1.2	1.73	2
Efficiency	0.6	1.05	1.5	1.88
Dependability	0.78	1.14	1.48	1.7
Stimulation	0.5	1	1.35	1.7
Novelty	0.16	0.7	1.12	1.6

8 Bibliography

Adrian, B., 2008. Actor Training the Laban Way: An Integrated Approach to Voice, Speech, and Movement, 1 edition. ed. Allworth Press.

Aigner, R., Wigdor, D., Benko, H., Haller, M., Lindbauer, D., Ion, A., Zhao, S., Koh, J.T.K.V., 2012. Understanding Mid-Air Hand Gestures: A Study of Human Preferences in Usage of Gesture Types for HCI [WWW Document]. Microsoft Res. URL https://www.microsoft.com/en-us/research/publication/understanding-mid-air-hand-gestures-a-study-of-human-preferences-in-usage-of-gesture-types-for-hci/

Bernhardt, D., Robinson, P., 2008. Interactive Control of Music Using Emotional Body Expressions, in: CHI ’08 Extended Abstracts on Human Factors in Computing Systems, CHI EA ’08. ACM, New York, NY, USA, pp. 3117–3122. doi:10.1145/1358628.1358817

Bishko, L., 2007. The Uses and Abuses of Cartoon Style in Animation. J. Animat. Stud. 2, 24–35.

Cairns, P., Cox, A.L., 2008. Research Methods for Human-Computer Interaction. Cambridge University Press.

Chang, S.H.-H., Stuart, L., Plimmer, B., Wünsche, B., 2009. Origami Simulator: A Multi-touch Experience, in: CHI ’09 Extended Abstracts on Human Factors in Computing Systems, CHI EA ’09. ACM, New York, NY, USA, pp. 3889–3894. doi:10.1145/1520340.1520589

Chen, J., Izadi, S., Fitzgibbon, A., 2012. KinEtre: Animating the World with the Human Body, in: Proceedings of the 25th Annual ACM Symposium on User Interface Software and Technology, UIST ’12. ACM, New York, NY, USA, pp. 435–444. doi:10.1145/2380116.2380171

Chua, Y.P., 2012. Mastering research methods. Mcgraw-Hill Education, Shah Alam.

Clark, L.A., Watson, D., 1995. Constructing validity: Basic issues in objective scale development. Psychol. Assess. 7, 309–319. doi:10.1037/1040-3590.7.3.309

Coolican, H., 2014. Research Methods and Statistics in Psychology. Psychology Press.

De Beer, A., 2009. Kinesic Construction: An Aesthetic Analysis of Movement and Performance in 3D Animation. J. Animat. Stud. 4, 44–52.

Dong, H., Figueroa, N., El Saddik, A., 2015. An Elicitation Study on Gesture Attitudes and Preferences Towards an Interactive Hand-Gesture Vocabulary, in: Proceedings of the 23rd ACM International Conference on Multimedia, MM ’15. ACM, New York, NY, USA, pp. 999–1002. doi:10.1145/2733373.2806385

Ebert, D.S., Bailey, D., 2000. A collaborative and interdisciplinary computer animation course. ACM SIGGRAPH Comput. Graph. 34, 22–26. doi:10.1145/359293.359325

Furniss, M., 2007. Art in Motion: Animation Aesthetics. JOHN LIBBEY & Company Limited.

Fiebrink, R., Trueman, D., Britt, N.C., Nagai, M., Kaczmarek, K., Early, M., Daniel, M.R., Hege, A. and Cook, P.R., 2010. Toward Understanding Human-Computer Interaction In Composing The Instrument. In *Proceedings of the International Computer Music Conference (ICMC).*

Garcia, A.L., 2012. Principles of Animation Physics, in: ACM SIGGRAPH 2012 Courses, SIGGRAPH ’12. ACM, New York, NY, USA, p. 13:1–13:20. doi:10.1145/2343483.2343496

Gerling, K., Livingston, I., Nacke, L., Mandryk, R., 2012. Full-body Motion-based Game Interaction for Older Adults, in: Proceedings of the SIGCHI Conference on Human Factors in Computing Systems, CHI ’12. ACM, New York, NY, USA, pp. 1873–1882. doi:10.1145/2207676.2208324

Gillies, M., Kleinsmith, A., 2014. Non-representational Interaction Design, in: Bishop, J.M., Martin, A.O. (Eds.), Contemporary Sensorimotor Theory, Studies in Applied Philosophy, Epistemology and Rational Ethics. Springer International Publishing, pp. 201–208.

Goh, W.B., Yang, L., Ong, K.L., 2016. MuSeeCol: A See-through Multi-touch Surface for Face-to-face Musical Collaboration, in: Proceedings of the 13th International Conference on Advances in Computer Entertainment Technology, ACE2016. ACM, New York, NY, USA, p. 15:1–15:6. doi:10.1145/3001773.3001788

Gray, C., Malins, J., 2004. Visualizing Research: A Guide to the Research Process in Art and Design, 1 edition. ed. Routledge, Aldershot.

Held, R., Gupta, A., Curless, B., Agrawala, M., 2012. 3D puppetry: A Kinect based Interface for 3D Animation. ACM Press, p. 423. doi:10.1145/2380116.2380170

Heloir, A., Nunnari, F., 2013. Towards an intuitive sign language animation authoring environment for the deaf, in: Third International Symposium on Sign Language Translation and Avatar Technology.

Hess, R., 2011. Tradigital Blender: A CG Animator's Guide to Applying the Classic Principles of Animation. Focal Press, Waltham, MA.

Hinderks, A., Schrepp, M., Domínguez Mayo, F., Escalona, M. and Thomaschewski, J., 2019. Developing a UX KPI based on the user experience questionnaire. *Computer Standards & Interfaces*, [online] 65, pp.38- 44. Available at: <https://doi.org/10.1016/j.csi.2019.01.007> [Accessed 17 May 2022].

Hooks, E., 2003. *Acting for animators: a complete guide to performance animation* (Vol. 1). Heinemann Drama.

Igarashi, T., Moscovich, T. and Hughes, J.F., 2005. Spatial keyframing for performance-driven animation. In *Proceedings of the 2005 ACM SIGGRAPH/Eurographics symposium on Computer animation* (pp. 107-115). ACM.

Joel, W., Echevarria, A., 2005. A Kinesthetic Exercise for Teaching Computer Animation, in: ACM SIGGRAPH 2005 Posters, SIGGRAPH '05. ACM, New York, NY, USA. doi:10.1145/1186954.1187055

Jones, A., & Oliff, J., 2008. Thinking animation: bridging the gap between 2D and CG. Boston, MA, Thomson Course Technology.

Kang, S.P., Rodnay, G., Tordon, M., Katupitiya, J., 2003. A hand gesture based virtual interface for wheelchair control, in: Proceedings 2003 IEEE/ASME International Conference on Advanced Intelligent Mechatronics (AIM 2003). Presented at the Proceedings 2003 IEEE/ASME International Conference on Advanced Intelligent Mechatronics (AIM 2003), pp. 778–783 vol.2. doi:10.1109/AIM.2003.1225441

Koutsabasis, P., Domouzis, C.K., 2016. Mid-Air Browsing and Selection in Image Collections. Presented at the Proceedings of the International Working Conference on Advanced Visual Interfaces, ACM, pp. 21–27. doi:10.1145/2909132.2909248

Kundert-Gibbs, J.,, Kundert-Gibbs, K., 2009. Action: Acting Lessons for CG Animators. Wiley Publishing, Indiana.

Lapidus, R., 2011. Tradigital 3DS Max: A CG Animator's Guide to Applying the Classic Principles of Animation. Focal Press, Waltham, MA.

Laugwitz, B., Held, T., & Schrepp, M. (2008). Construction and evaluation of A user experience questionnaire. *Lecture Notes in Computer Science*, 63–76. https://doi.org/10.1007/978-3-540-89350-9_6

Lasseter, J., 1987. Principles of Traditional Animation Applied to 3D Computer Animation, in: Proceedings of the 14th Annual Conference on Computer Graphics and Interactive Techniques, SIGGRAPH '87. ACM, New York, NY, USA, pp. 35–44. doi:10.1145/37401.37407

Laszlo, J., van de Panne, M., Fiume, E., 2000. Interactive control for physically-based animation. ACM Press, pp. 201–208. doi:10.1145/344779.344876

Lazar, D.J., Feng, D.J.H., Hochheiser, D.H., 2010. Research Methods in Human-Computer Interaction. John Wiley & Sons.

Leite, L., 2012. Virtual marionette. ACM Press, p. 363. doi:10.1145/2166966.2167049

Leite, L., Orvalho, V., 2011. Anim-actor: Understanding Interaction with Digital Puppetry Using Low-cost Motion Capture, in: Proceedings of the 8th International Conference on Advances in Computer Entertainment Technology, ACE '11. ACM, New York, NY, USA, p. 65:1–65:2. doi:10.1145/2071423.2071505

Lewis, J.R., 1992. Psychometric Evaluation of the Post-Study System Usability Questionnaire: The PSSUQ. Proc. Hum. Factors Ergon. Soc. Annu. Meet. 36, 1259–1260. doi:10.1177/154193129203601617

Lewis, J.R., Sauro, J., 2009. The Factor Structure of the System Usability Scale, in: Kurosu, M. (Ed.), Human Centered Design, Lecture Notes in Computer Science. Springer Berlin Heidelberg, pp. 94–103.

Liu, S., Lu, K., Seifeselassie, N., Grote, C., Francisco, N., Lin, V., Ding, L., Valdes, C., Kincaid, R., Shaer, O., 2012. MoClo Planner: Supporting Innovation in Bio-design Through Multi-touch Interaction, in: Proceedings of the 2012 ACM International Conference on Interactive Tabletops and Surfaces, ITS '12. ACM, New York, NY, USA, pp. 307–310. doi:10.1145/2396636.2396686

MacKenzie, I.S., 2012. Human-Computer Interaction: An Empirical Research Perspective. Newnes.

May, K.R., Gable, T.M., Walker, B.N., 2014. A Multimodal Air Gesture Interface for In Vehicle Menu Navigation, in: Adjunct Proceedings of the 6th International Conference on Automotive User Interfaces and Interactive Vehicular Applications, AutomotiveUI ’14. ACM, New York, NY, USA, pp. 1–6. doi:10.1145/2667239.2667280

McCracken, C.R., 2006. Issues in computer graphics education. ACM Press, p. 29. doi:10.1145/1179295.1179325

Misumi, H., Fujimura, W., Kosaka, T., Hattori, M., Shirai, A., 2011. GAMIC: Exaggerated Real Time Character Animation Control Method for Full-body Gesture Interaction Systems, in: ACM SIGGRAPH 2011 Posters, SIGGRAPH ’11. ACM, New York, NY, USA, p. 5:1–5:1. doi:10.1145/2037715.2037721

Montgomery, L., 2012. Tradigital Maya: A CG Animator’s Guide to Applying the Classic Principles of Animation. Focal Press, Waltham, MA.

Mora-Guiard, J., Crowell, C., Pares, N., Heaton, P., 2016. Lands of Fog: Helping Children with Autism in Social Interaction Through a Full-Body Interactive Experience, in: Proceedings of the The 15th International Conference on Interaction Design and Children, IDC ’16. ACM, New York, NY, USA, pp. 262–274. doi:10.1145/2930674.2930695

Morris, M.R., Wobbrock, J.O., Wilson, A.D., 2010. Understanding users’ preferences for surface gestures. Presented at the Proceedings of Graphics Interface 2010, Canadian Information Processing Society, pp. 261–268.

Nestorov, N., Hughes, P., Healy, N., Sheehy, N. and OHare, N., 2016. Application of Natural User I nterface Devices for Touch-Free Control of Radiological Images During Surgery. In *Computer-Based Medical Systems (CBMS), 2016 IEEE 29th International Symposium on* (pp. 229-234). IEEE.

Orr, Genevieve B., Nord, Michael, 2005. A new collaborative teaching model applied to digital music and 3D computer animation 21, 246--253.

Oshita, M., Senju, Y., Morishige, S., 2013. Character Motion Control Interface with Hand Manipulation Inspired by Puppet Mechanism, in: Proceedings of the 12th ACM SIGGRAPH International Conference on Virtual-Reality Continuum and Its Applications in Industry, VRCAI ’13. ACM, New York, NY, USA, pp. 131–138. doi:10.1145/2534329.2534360

Paul, F.C., Goh, C., Yap, K., 2015. Get Creative With Learning: Word Out! A Full Body Interactive Game, in: Proceedings of the 33rd Annual ACM Conference Extended Abstracts on Human Factors in Computing Systems, CHI EA ’15. ACM, New York, NY, USA, pp. 81–84. doi:10.1145/2702613.2728657

Peter, H., 2008. Designing And Reporting Experiments In Psychology. McGraw-Hill Education (UK).

Pfeiffer, M., Kern, D., Schöning, J., Döring, T., Krüger, A., Schmidt, A., 2010. A Multi-touch Enabled Steering Wheel: Exploring the Design Space, in: CHI ’10 Extended Abstracts on Human Factors in Computing Systems, CHI EA ’10. ACM, New York, NY, USA, pp. 3355–3360. doi:10.1145/1753846.1753984

Pfeuffer, K., Alexander, J., Chong, M.K., Gellersen, H., 2014. Gaze-touch: Combining Gaze with Multi-touch for Interaction on the Same Surface, in: Proceedings of the 27th Annual ACM Symposium on User Interface Software and Technology, UIST ’14. ACM, New York, NY, USA, pp. 509–518. doi:10.1145/2642918.2647397

Popović, J., Seitz, S.M., Erdmann, M., 2003. Motion sketching for control of rigid-body simulations. ACM Trans. Graph. 22, 1034–1054. doi:10.1145/944020.944025

Rogers, Y., Sharp, H., Preece, J., 2011. Interaction design: beyond human-computer interaction, 3rd ed. ed. Wiley, Chichester, West Sussex, U.K.

Saffer, D., 2008. Designing Gestural Interfaces: Touchscreens and Interactive Devices. O’Reilly Media, Inc.

Sampath, J., 1999. NUKE.

Shiratori, T.,, Hodgins, J.K., 2008. Accelerometer-based User Interfaces for the Control of a Physically Simulated Character. ACM Trans. Graph., Article 123 27, 1–9.

Schmidt, F., Jagger, J., McCambell, J. and Slagel, C., 2004, August. 3D animation: difficult or impossible to teach and learn?. In *ACM SIGGRAPH 2004 Panels* (p. 3). ACM.

Schrepp, M. (2019, December 31). *User Experience Questionnaire (UEQ) Handbook*. Https://Www.Ueq-Online.Org/. Retrieved April 2, 2022, from https://www.ueq-online.org/

Schrepp, M., Hinderks, A., & Thomaschewski, J. (2017). Construction of a Benchmark for the User Experience Questionnaire (UEQ). *International*

Journal of Interactive Multimedia and Artificial Intelligence, 4(4), 40. Available at: https://doi.org/10.9781/ijimai.2017.445

Terra, S.C.L., Metoyer, R.A., 2007. A performance-based technique for timing keyframe animations. Graph. Models 69, 89–105. doi:10.1016/j.gmod.2006.09.002

Terra, S.C.L., Metoyer, R.A., 2004. Performance Timing for Keyframe Animation, in: Proceedings of the 2004 ACM SIGGRAPH/Eurographics Symposium on Computer Animation, SCA '04. Eurographics Association, Aire-la-Ville, Switzerland, Switzerland, pp. 253–258. doi:10.1145/1028523.1028556

Thomas, F.,, Johnston, O., 1981. The Illusion of Life: Disney Animation. Disney Editions, New York, NY.

Thorne, M., Burke, D., van de Panne, M., 2004. Motion doodles: an interface for sketching character motion. ACM Trans Graph 23, 424–431. doi:10.1145/1015706.1015740

Vatavu, R.-D., Wobbrock, J.O., 2015. Formalizing Agreement Analysis for Elicitation Studies: New Measures, Significance Test, and Toolkit, in: Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems, CHI '15. ACM, New York, NY, USA, pp. 1325–1334. doi:10.1145/2702123.2702223

Vatavu, R.-D., Zaiti, I.-A., 2014. Leap Gestures for TV: Insights from an Elicitation Study, in: Proceedings of the 2014 ACM International Conference on Interactive Experiences for TV and Online Video, TVX '14. ACM, New York, NY, USA, pp. 131–138. doi:10.1145/2602299.2602316

Walther-Franks, B., Herrlich, M., Karrer, T., Wittenhagen, M., Schröder-Kroll, R., Malaka, R., Borchers, J., 2012. Dragimation: Direct Manipulation Keyframe Timing for Performance-based Animation, in: Proceedings of Graphics Interface 2012, GI '12. Canadian Information Processing Society, Toronto, Ont., Canada, Canada, pp. 101–108.

Webster, C., 2005. *Animation: The mechanics of motion* (Vol. 1). Taylor & Francis.

Wells, P., 1998. Understanding Animation. Routledge, London.

Wells, P., 2011. "Picture by Picture, Movement by Movement": Melbourne-Cooper, Shiryaev and the Symbolic Body. Animation 6, 149–162. doi:10.1177/1746847711407406

Whitaker, H.,, Halas, J., 1981. Timing for Animation. Focal Press, Oxford.

Wigdor, D., Wixon, D., 2011. Brave NUI World: Designing Natural User Interfaces for Touch and Gesture. Elsevier.

Williams, R., 2009. The Animator's Survival Kit–Revised Edition: A Manual of Methods, Principles and Formulas for Classical, Computer, Games, Stop Motion and Internet Animators. Faber & Faber, Inc.

Wobbrock, J.O., Aung, H.H., Rothrock, B., Myers, B.A., 2005. Maximizing the Guessability of Symbolic Input, in: CHI '05 Extended Abstracts on Human Factors in Computing Systems, CHI EA '05. ACM, New York, NY, USA, pp. 1869–1872. doi:10.1145/1056808.1057043

Wobbrock, J.O., Myers, B.A., Kembel, J.A., 2003. EdgeWrite: A Stylus-based Text Entry Method Designed for High Accuracy and Stability of Motion, in: Proceedings of the 16th Annual ACM Symposium on User Interface Software and Technology, UIST '03. ACM, New York, NY, USA, pp. 61–70. doi:10.1145/964696.964703

Zaiţi, I.-A., Pentiuc, Ş.-G., Vatavu, R.-D., 2015. On free-hand TV control: experimental results on user-elicited gestures with Leap Motion. Pers. Ubiquitous Comput. 19, 821–838. doi:10.1007/s00779-015-0863-y

Zaporah, R., 1995. Action Theater: The Improvisation of Presence. North Atlantic Books.

Zeng, J., Sun, Y., Wang, F., 2012. A Natural Hand Gesture System for Intelligent Human-Computer Interaction and Medical Assistance, in: 2012 Third Global Congress on Intelligent Systems. Presented at the 2012 Third Global Congress on Intelligent Systems, pp. 382–385. doi:10.1109/GCIS.2012.60