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**INTEGRATED MULTIMODAL INTERACTION FRAMEWORK FOR  
VIRTUAL REALITY FOOT REFLEXOLOGY STRESS THERAPY**

**OKERE PRINCE-HECTOR CHIMEREMEZE**



**DOCTOR OF PHILOSOPHY  
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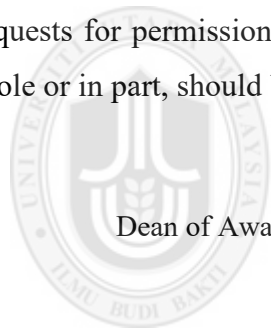
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## Abstrak

Kerangka dalam penyelidikan interaksi telah menyaksikan pelbagai komposisi daripada ramai penyelidik, dan telah digunakan untuk tujuan tertentu atau umum dalam beberapa domain. Kajian terdahulu telah menonjolkan realiti maya (VR) dalam terapi tekanan, dan mendedahkan terapi refleksologi kaki menggunakan teknologi VR. Walau bagaimanapun, kerangka interaksi untuk refleksologi kaki melalui realiti maya memerlukan kajian lanjut. Kajian ini membentangkan reka bentuk dan penilaian kerangka interaksi multimodal bersepadu untuk terapi tekanan refleksologi kaki realiti maya. Komponen kerangka yang dicadangkan telah dikenalpasti daripada sorotan karya dan kajian sebelumnya yang merangkumi prinsip reka bentuk, teknologi, komponen struktur, seni bina interaksi multimodal, dan komposisi segmen. Ini membentuk kerangka interaksi multimodal terintegrasi untuk terapi tekanan refleksologi kaki realiti maya. Kerangka yang dicadangkan kemudiannya telah disahkan melalui ulasan pakar. Ini diikuti dengan pembangunan prototaip yang meneroka keberkesanan aplikasi terapi refleksologi kaki realiti maya ke atas pengenduran dan pelepasan tekanan menggunakan Smith Relaxation States Inventory (SRSI-3). Eksperimen kuasi intervensi pra dan pasca ujian digunakan dalam kajian untuk tujuan penilaian. Penemuan ini mendedahkan bahawa Terapi Tekanan Refleksologi Kaki Realiti Maya (VR-FRST) secara berkesan membangkitkan kategori keadaan pengenduran yang melampau, kesungguhan, tenaga positif, dan pengenduran asas, dan juga mengurangkan keadaan tekanan pengguna. Kajian ini menyediakan kerangka interaksi multimodal yang bersepadu, teratur, praktikal dan disahkan untuk reka bentuk dan perkembangan terapi refleksologi kaki dalam persekitaran maya. Ini menyumbang kepada bidang reka bentuk interaksi bagi pembangun realiti maya dan terapi pelengkap untuk pengamal perubatan alternatif.

**Kata kunci:** Kerangka interaksi multimodal bersepadu, Terapi tekanan refleksologi kaki realiti maya, Smith Relaxation States Inventory, Pengenduran, Melepaskan tekanan.

## Abstract

Frameworks in interaction research have seen varying compositions from numerous researchers, and have been applied for either a specific or general purposes in several domains. Previous studies have highlighted virtual reality (VR) in stress therapy, and revealed the potential of foot reflexology therapy using VR technology. However, the interaction framework for foot reflexology through virtual reality requires further investigation. This study presents the design and evaluation of an integrated multimodal interaction framework for virtual reality foot reflexology stress therapy. The components of the proposed framework were identified from the literature review and previous research, which included design principles, technology, structural components, multimodal interaction architecture, and segment composition. This formed the proposed integrated multimodal interaction framework for virtual reality foot reflexology stress therapy. The proposed framework was then validated using expert reviews. This was followed by prototype development, which explored the effectiveness of the virtual reality foot reflexology therapy application on relaxation and stress relief using Smith Relaxation States Inventory (SRSI-3). A pre and post-test intervention quasi experiment was employed in the study for the evaluation. The findings revealed that Virtual Reality Foot Reflexology Stress Therapy (VR-FRST) effectively evokes the relaxation state categories of transcendence, mindfulness, positive energy, and basic relaxation, and also reduces users stress state. This research provides a concise, organized, practical and validated integrated multimodal interaction framework for the design and development of foot reflexology therapy in a virtual environment. This contributes to the field of interaction design for virtual reality developers and complementary therapy for the alternative medical practitioners.

**Keywords:** Integrated multimodal interaction framework, Virtual reality foot reflexology stress therapy, Smith Relaxation States Inventory, Relaxation, Stress Relief.

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## List of Abbreviations

AI	Artificial Intelligence
AHP	Analytical Hierarchical Process
EPs	Exploratory Procedures
ET	Exposure Therapy
FR	Foot Reflexology
RA	Reflexology Artifact
SRSI-3	Smith Relaxation States Inventory 3
UUM	Universiti Utara Malaysia
VE	Virtual Environment
VR	Virtual Reality
VRET	Virtual Reality Exposure Therapy
VRST	Virtual Reality Stress Therapy
VR-FRST	Virtual Reality Foot Reflexology Stress Therapy
VR-Foot-ReST	Virtual Reality Foot Reflexology Stress Therapy Application



# CHAPTER ONE

## INTRODUCTION

### 1.1 Overview

This is the first introductory chapter of the thesis, which presents the research background, motivation, and purpose behind the execution of the research. The chapter also highlighted research objectives, problems and challenges the research aims to address. It also presents the research scope, limitations, as well as the research contributions.

### 1.2 Background of Research

Virtual reality is an immersive technology which blurs the boundaries between our physical environments and our virtual environments, enabling users' sense of immersive experience (Suh & Prophet, 2018). Research in several domains like education (Johnston et al., 2017; Solak & Erdem, 2015), entertainment (Liszio & Masuch, 2016), and healthcare (Khan et al., 2017; Wiederhold, Miller, & Wiederhold, 2018), underlines that VR technologies augments learning experiences (Ng & Lam, 2018), fosters participation in collaborative activity (Fu & Hwang, 2018), and increases creativity and engagement (Yang et al., 2018).

The advancement of VR technologies or applications have encouraged researchers on the utilization of VR technologies and applications to support, improve, or complement life, in the treatment of phobias (Maples-Keller, Yasinski, Manjin, & Rothbaum, 2017; Morina, Ijntema, Meyerbröker, & Emmelkamp, 2015a; Parsons, 2015; Peperkorn, Diemer, & Mühlberger, 2015; Zinzow et al., 2017), for relaxation

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## Appendix A

### Prototype Demonstration with Medical Experts

Dear Sir/Madam,

I am Prince-Hector C. Okere (900725), currently pursuing a PhD program in Multimedia at University Utara Malaysia (UUM), under the Supervision of Dr. Juliana Aida Abu Bakar and Dr. Ruzinoor Che Mat. I am interested in your expertise which is either in Complementary Therapy, Massage Therapy, Stress Therapy, Nursing Care, Foot Reflexology and/or related areas. And have been practicing in said area for at least five (5) years.

With the expertise you possess, I would be honoured to have you review the prototype **VIRTUAL REALITY FOOT REFLEXOLOGY STRESS THERAPY (VR-Foot-ReST)**. The application is aimed at offering a complimentary application for foot reflexology using VR and as an alternative for Traditional foot reflexology in relaxation, stress relief and complementary therapy.

Every sensitive information supplied will be treated as confidential and will be used for research purposes, which will be reported anonymously in academic publications.

Please feel free to contact me by email (okerejunior@yahoo.com) in regards to any queries or my supervisor suziah@petronas.com.my

Thanking you for your time and assistance.

#### EXPERT/REVIEWER DETAILS

Name: \_\_\_\_\_

Age: \_\_\_\_\_ Gender: \_\_\_\_\_

**Highest Education Level** \_\_\_\_\_

Occupation: \_\_\_\_\_

Working Experience (years): \_\_\_\_\_

I consented to participate in this research.

Signature: \_\_\_\_\_

<b>1. What do you think of the application?</b>	
R1	It is quite relaxing. Like we can simply go into the forest scenery and relax relax relax relax.
R2	For relaxation therapy, it is very good. I'm just worried that the finished product will be too expensive for low income earners. But for those who can afford it, it is very good for relaxation and stress relief. The pebbles found at the parks or recreational areas are free for people to use which is very good. But as you know, everything needs money. So I hope your application will be affordable.
<b>2. What recommendations will you give to better improve the prototype?</b>	
R1	<ul style="list-style-type: none"> <li>The GPR instructional activity session may be improved upon. Maybe include lower limbs relaxation activities.</li> <li>The time duration maybe increased (give patients the choice to choose).</li> <li>Let the patients using the VR application be able to sit. Perhaps design Two (2) types one sitting and the other standing and compare or see what users prefer (give patients the choice to choose)</li> </ul>
R2	<ul style="list-style-type: none"> <li>The HMD should also be as light as possible especially for aged patients. They would not want to carry around the burden of the extra head weight.</li> <li>Also the posture, you should consider also designing one for sitting. Especially for the elderly or those with hypertension, it may make them dizzy and fall. But the sitting posture will help them relax better.</li> <li>Give users the choice to choose preferred language. As in Malaysia, not everyone can understand English. So include Bahasa Melayu and other languages for people's convenience.</li> </ul>
<b>3. Are you familiar with some of the reflexology artifacts like slipper, pebbles, mats, or electronic reflexology massage devices?</b>	
R1	Yes
R2	Yes
<b>4. How will you compare having the Traditional therapy to Reflexology Artifacts?</b>	
R1	Actually, they are almost the same. The differences may just include the person applying the therapy, how much energy they use, and so on.
R2	They are quite similar
<b>5. In your opinion, does the visual component of the application contribute to the relaxation and stress relief users will perceive? (The nature background, Animated, instructions, and so on)</b>	
R1	The jungle, the waterfall, the visual environment was quite relaxing and quite clear.
R2	The nature environment of the waterfall, the forest and so on is very good for the eyes and the mind. That is why people love to go to the forest to experience nature, it makes our mind cool down.
<b>6. In your opinion, does the Sound component of the application contribute to the relaxation and stress relief users will perceive? (background nature sounds, instructional voice component, background music and so on) ?</b>	
R1	It was quite relaxing. It is not depressing as at all. Especially the natural stream and the waterfall, because I love swimming. So when I see the stream and the waterfall, I really love it. The entire sound of the environment was very relaxing. The voice of

	the VR instructor was clear and audible enough. But you may want to increase the volume a little bit more.
R2	The volume should be increased as I feel as though it was not loud enough. But the sound of nature in the application is quite relaxing. You know more people get sick in the urban areas than the rural areas. So the sounds are very relaxing.
<b>7. In your opinion, does the haptic component of the application contribute to the relaxation and stress relief users will perceive? (Reflexology slipper and room temperature)?</b>	
R1	From the starting the pain was a bit unbearable and quite irritating, perhaps because I am not used to such pressure and my body was adjusting to it. But after a while I felt better. It became okay
R2	The slipper is quite painful especially from the beginning (reflexology pebbles are not as painful as these slippers). And when the slipper is connected to an area of the body that is sick, the pain will be unbearable. Most of our attention will be on the slipper and the pain. So the pain should be bearable. Because this pressure and pain benefits the body for blood circulation from our heart to the legs and other parts of the body to improve health (no pain, no gain yes).
<b>8. Are there any risk or safety concerns you will attribute to the usage of this application?</b>	
R1	The slipper that provides the pressure to the reflex points was a bit too sharp especially from the start but becomes bearable after a while. Perhaps you may want to regulate the pressure from the beginning and ease in slowly. To allow people to adjust to the pain.
R2	The application is safe. But if your application is also meant for elderly or for the weak, then the HMD should be much lighter and not heavy. As light as wearing a pair of eyeglasses. And the pressure should be regulated so the pain can be bearable.
<b>9. How will you compare having the therapy using RA to VR-Foot-ReST</b>	
R1	You know most people are very busy and don't have time to go to the outdoors and relax. But with your VR application, it allows people to explore clear, realistic and relaxing outdoors to relax. And with the VR instructor, instructing Users on how to walk, stretch, breath in and out deeply, with the soft sounds which calm their minds and so on, allows the people to fully relax.
R2	The pebbles found at the parks or recreational areas are free for people to use which is very good. But as you know, everything needs money. So I hope your application will be affordable.
<b>10. Are there any distracting, unnecessary or irrelevant component of the application that should be avoided that may alter the users' relaxation and stress relief?</b>	
R1	I don't think so. It was very clear and relaxing.
R2	You may want to do without the visual aid which shows people how to perform the activities and just use voice instructions. As the visual aid may obstruct the natural view people see. But also people may not be able to understand and properly perform the activities needed, hence the visual aid. So people should be able to choose.
<b>11. In your opinion, does the product achieve its objective for relaxation and stress relief?</b>	

R1	Yes it does. Especially with the VR instructor guiding people towards relaxation. Feels a little bit like hypnosis. Not in the sense of going to space or something imaginary; more like asking you to consciously clear your mind, breath in and out deeply, walk slowly and so on. And also with the colourful/serene environment, it is very good for relaxation.
R2	Yes the application is relaxing and reduces stress.

**12. Have you seen or used any similar application?**

R1	Not at all. This was my 1 <sup>st</sup> time.
R2	No. It is my first time.

**13. How does the application measure up to your expectations before and after usage?**

R1	It is quite marvellous. You know from the onset, I had no idea what the prototype was all about, but after usage, wow! It is quite marvellous. At first glance, it looked very expensive. And as people are not aware of this form of therapy, the price may scare them away.
R2	Yes, it is said to be for reflexology therapy stress therapy. So yes I experienced all of that. But due to the pain, the relaxation process comes in after using it for some time.

**14. How likely are you to recommend the finished product to a friend or patient needing relaxation and stress relief?**

R1	It can be introduced. As you know, many patients in the world nowadays are experiencing a lot of stress due to standard of living and so on. So applications like these are needed.
R2	

## Appendix B

### Smith Relaxation States Inventory 3 Instrument

<b>R-STATES</b>	<b>(A) Transcendence</b>		
	<i>Timeless/Boundless</i>	<b>A1</b>	Things seem TIMELESS, BOUNDLESS, or INFINITE?
	<i>Mystery</i>	<b>A2</b>	I sense the DEEP MYSTERY of things beyond my understanding?
	<i>Prayerful</i>	<b>A3</b>	I feel PRAYERFUL or REVERENT?
	<i>Awe and Wonder</i>	<b>A4</b>	Things seem AMAZING, AWESOME, and EXTRAORDINARY?
	<b>(B) Mindfulness</b>		
	<i>Quiet</i>	<b>B1.</b>	My mind is SILENT and calm (I am not thinking about anything)?
		<b>B2.</b>	My mind is QUIET and STILL?
	<i>Aware / Focused</i>	<b>B3.</b>	I feel AWARE, FOCUSED, and CLEAR?
	<i>Accepting</i>	<b>B4.</b>	Right now I recognize the wisdom of sometimes ACCEPTING things as they are?
		<b>B5.</b>	Presently I feel there's no need to try to change things that simply can't be changed?
	<i>Innocent</i>	<b>B6.</b>	I feel INNOCENT and CHILDLIKE?
	<i>Centering</i>	<b>B7.</b>	I feel like I am living fully and SIMPLY in the PRESENT, not distracted by past or future concerns?
		<b>B8.</b>	I feel fully focused and ABSORBED in what I am doing?
	<i>Awakening</i>	<b>B9.</b>	Things seem FRESH and NEW, as if I am seeing them for the first time?
	<b>(C) Positive Energy</b>		
	<i>Joyful (Happy)</i>	<b>C1.</b>	I am HAPPY?
<b>C2.</b>		I feel JOYFUL?	
<i>Optimistic</i>	<b>C3</b>	I feel trusting; I feel I can rely on someone or something?	
<i>Energized</i>	<b>C4</b>	I feel ENERGIZED, CONFIDENT, and STRENGTHENED?	
<i>Thankful / Loving</i>	<b>C5.</b>	I feel THANKFUL?	
	<b>C6.</b>	I feel LOVING?	
<b>(D) Basic Relaxation</b>			
<i>Mentally Relaxed (At ease)</i>	<b>D1.</b>	I feel AT PEACE?	
	<b>D2.</b>	I feel AT EASE?	
	<b>D3.</b>	I feel CAREFREE?	
<i>Physically Relaxed</i>	<b>D4.</b>	My muscles are SO RELAXED that they feel LIMP?	
	<b>D5.</b>	My hands, arms, or legs are SO RELAXED that they feel WARM and HEAVY?	
	<b>D6.</b>	My body is PHYSICALLY RELAXED	
<i>Disengaged</i>	<b>D7.</b>	I feel DISTANT and FAR AWAY from my cares and concerns?	
	<b>D8.</b>	I feel INDIFFERENT and DETACHED from my cares and concerns?	
<i>Sleepy</i>	<b>D9.</b>	I feel DROWSY and SLEEPY?	
	<b>D10.</b>	I am DOZING OFF or NAPPING?	
<i>Rested/Refreshed</i>	<b>D11.</b>	I feel RESTED and REFRESHED	
<b>(E) Stress</b>			
<b>Stress-States</b>	<i>Somatic Stress</i>	<b>E1.</b>	My muscles feel TIGHT and TENSE (clenched fist or jaws; furrowed brow)?
		<b>E2.</b>	My BREATHING is NERVOUS and UNEVEN (Or shallow and hurried)?
		<b>E3.</b>	I feel PHYSICAL DISCOMFORT or PAIN (backaches, headaches, fatigue)?
<i>Emotional Stress</i>	<b>E4.</b>	I feel IRRITATED or ANGRY?	
	<b>E5.</b>	I feel SAD, DEPRESSED, or BLUE?	
	<b>E6.</b>	I feel ANXIOUS?	
<i>Cognitive Stress</i>	<b>E7.</b>	I am WORRYING?	
	<b>E8.</b>	TROUBLESOME THOUGHTS are going through my mind?	

## Appendix C

### Experts Review Feedbacks, Analysis & Modifications


Review Section	Review rating	Review critiques or/and recommendation	Analysis & review modification
Technology	3 of the experts expressed that the technology element is relevant. 1 expressed that some may not be relevant and the remaining 3 expressed that some are definitely not relevant, and presented their review feedbacks, critiques and recommendations to address their concerns	<ul style="list-style-type: none"> <li>- The haptic foot massaging device, is it also under the integrated or console platform? if no, please make provision for it in the technology section.</li> <li>- Desktop as in Windows? How about Mac's environment? What does console refer to? Gaming console or...?</li> <li>- Can consider including "Standalone" technology.</li> <li>- Options for technology are divided into Integrated or mobile? But there's also integrated platform for mobile.</li> <li>- Desktop is the targeted platform?</li> <li>Define console</li> <li>- The haptic foot massaging device, is it also under the integrated or console platform? if no, please make provision for it in the technology section.</li> </ul>	The experts demonstrated the unclear presentation of the technology element. Hence the technology element was re-categorized and restructured following the recommendations of (Angkananon et al., 2013b, 2013c; Burden, 2016). Hence, addressing all the concerns raised by the expert reviewers.
Content composition	Majority of the experts expressed that the content composition element is easy to understand, and presented 1 review feedbacks, critiques, concerns or recommendations to address.	<ul style="list-style-type: none"> <li>- A bit difficult to differentiate as recognizers and synthesizers are inline</li> <li>- Fussion or Fusion</li> </ul>	<ul style="list-style-type: none"> <li>- The experts demonstrated the unclear difference of the multimodal recognizers and synthesizers in the framework. This was addressed by distinguishing the synthesizers and recognizers through grouping each category in a dotted white rounded square.</li> <li>- Experts also recommended that the appropriate spelling for the terminology "Fusion" be verified. This was addressed consistent to Dumas et al.'s (2009) multimodal interaction</li> </ul>

			architecture.
Segment composition	6 of the experts expressed that the segment composition element is relevant. none expressed that some may not be relevant and only 1 expressed that some are definitely not relevant, and presented their review feedbacks, critiques and recommendations to address their concerns	- What about "Gamified Elements" in Presentation styles, which is largely the beauty of incorporating VR.	Smith et al. (2000) expressed that all forms of relaxation involve sustaining passive simple focus; the opposite of discursive effort. In everyday life, we strive, and our attention moves discursively and digressing from complex topic to topic; However in relaxation, we let go, and we focus on just one simple thing (relaxation stimuli). Gamification entails increasing brain activity which may include cognitive process, working memory and so on (Howard-Jones, Jay, Mason, & Jones, 2016). This contradicts the overall target of the therapy which aims at sustaining attention while diminishing overt behaviour and covert or cognitive activity (Smith et al., 2000). Hence, Gamification is excluded from the framework.
Design Principles	3 of the experts expressed that the design principles element is relevant. 1 expressed that some may not be relevant and the remaining 3 expressed that some are definitely not relevant, and presented their review feedbacks, critiques and recommendations to address their concerns	- Is graphics a multimedia element? Do you mean image? Please confirm. - All are relevant, but they should be captured under one (or more) known design principle -to which the elements (like text, graphics, etc) can lay claim to. For example, is Shneiderman's user interface design principle applicable, or is it Cooper's interaction framework for the multimedia element design. - The MMEDP's details could be more specific.	The design principles outlined in the framework was motivated by several prominent researchers like Norman, Nielson and Molich, Shneiderman and Plaisant amongst others with justifications. However, Alan Cooper deals with the interaction design between people technology and business and the development approaches and development team. This is not the focus of the framework; hence Alan Cooper's "About face interaction design" was excluded.
Multimedia Elements Design Principles	6 of the experts expressed that the multimedia element design principles is easy to understand. None expressed that the MMEDP needs some explanation, except for 1 who expressed that the MMEDP needs very detail explanation, and presenting their review feedbacks, critiques and recommendations to address their concerns.	- Suggestion: include Interaction element since it's a core binding element for interactive multimedia product. - Is graphics a multimedia element? Do you mean image? Please confirm.	Interactivity was included in the design principle as a binding component of multimedia products. Graphic is an established multimedia element. Though sometimes referred to as graphical images (Rawi et al., 2015).

i.	Texts	5 of the experts expressed that the text multimedia element is easy to understand. None expressed that the text needs some explanation, except for 2 who expressed that the text multimedia element needs very detail explanation, and presented their review feedbacks, critiques and recommendations to address their concerns.	<ul style="list-style-type: none"> <li>- Suggested to add maximum number of prominent colour usage in one design.</li> <li>- Easy terms like what?; consistent colour without any reckon to colour type and class?; and how is important content is expected to be highlighted: with colour or text font size or alignment.</li> </ul>	
ii.	Graphic	5 of the experts expressed that the graphic multimedia element is easy to understand. None expressed that the graphic needs some explanation, except for 2 who expressed that the graphic multimedia element needs very detail explanation, and presented their review feedbacks, critiques and recommendations to address their concerns.	<ul style="list-style-type: none"> <li>- What do you mean by consistency in graphic? Probably you can mention the two major categories: bitmap vs. vector</li> <li>- Good quality in range of what and what pixels, or frame size;</li> </ul>	
iii.	Animation	4 of the experts expressed that the animation multimedia element is easy to understand. 1 expressed that the animation needs some explanation, except for 2 who expressed that the animation multimedia element needs very detail explanation, and presented their review feedbacks, critiques and recommendations to address their concerns.	<ul style="list-style-type: none"> <li>- What is an appropriate movement for an animation? Could be clarified.</li> <li>- What is the appropriate movement, per second, etc.</li> </ul>	Experts requested the clarification of “appropriate movement of animation”. The principle was paraphrased for clarity purpose to “Animation actions must match audio output corresponding to user goals”
iv.	Audio	6 of the experts expressed that the audio multimedia element is easy to understand. None expressed that the audio needs some explanation, except for 1 who expressed that the audio multimedia element needs very detail explanation, and presented their review feedbacks, critiques and recommendations to address their concerns.	<ul style="list-style-type: none"> <li>- Small size of what size range</li> </ul>	Experts raised the concern of “use small size of what size range”. The principle “use small sized audio file” was removed as focus is allocated to the file codec and compatibility (MP3). MP3 files are generally compatible and have small file sizes.
v.	Video	5 of the experts expressed that the video	<ul style="list-style-type: none"> <li>- Size of video? Format of video which is</li> </ul>	In addressing this concern raised by the experts. The



	multimedia element is easy to understand. 1 expressed that the video needs some explanation, except for 1 who expressed that the video multimedia element needs very detail explanation, and presented their review feedbacks, critiques and recommendations to address their concerns.	appropriate for the said purpose?	principle “Use common video codec (MP4)” was added to the design principles for video. The Mp4 video format is an ISO Base Media File Format (Amon, Rathgen, & Singer, 2007)
Information Architecture Principles and Theories	Majority of the experts expressed that the Information Architecture Principles and Theories element is easy to understand, and presented no review feedbacks, critiques, concerns or recommendations to address.	---	
User Interface & Layout	5 of the experts expressed that the user interface & layout element is easy to understand. 1 expressed that the user interface & layout needs some explanation, except for 1 who expressed that the user interface & layout element needs very detail explanation, and presented their review feedbacks, critiques and recommendations to address their concerns.	- Why is the 1st guideline a replica of TFR user requirements' 1st guideline? I think it should be excluded from this segment	This principle “provide multiple relaxing scenery” was excluded from the User interface and Layout segment as it is a replica of the 1 <sup>st</sup> principle in the TFR User requirement segment.
TFR User Requirements	5 of the experts expressed that the TFR user requirements element is easy to understand. 1 expressed that the user interface & layout needs some explanation, except for 1 who expressed that the user interface & layout element needs very detail explanation, and presented their review feedbacks, critiques and recommendations to address their concerns.	- What is TFR? please write in full or include in Legend	TFR is an acronym for the terminology Traditional Foot Reflexology. The acronym was removed from the framework and replaced by the full terminology “Traditional Foot Reflexology”
Overall Framework	Majority of the experts expressed that the overall framework is easy to understand, and presented no review feedbacks, critiques, concerns or recommendations to address.	- The connections are OK, but the sentences don't show clear relation to any component - I want to see the relation for the definitions in sentences describing the	- Relation definition was outlined in the legend, highlighting each relation and its interpretation or meaning. - Detailed description of each framework composition and

		<p>terms use relation to any component</p> <ul style="list-style-type: none"> <li>- For a framework, it is readable but the details of the MME Design Principles could be more specific.</li> <li>- Basic Framework Hierarchy is good, but provides the relation or where Definition of Terms is used, so that is easier to understand</li> <li>- It is good if the researcher can provide more details for the introduction. For example, is the app is a web-based type of app? Is the framework will be generalized or more specified to certain platform/device? If it will be generalized, the UI &amp; layout segment should provide more info on the approach that will be used for managing multiple layout settings. How is this VR-FRST works? As a tutorial app or presentation layer installed to a foot reflexology machine? BTW, what is TFR ?</li> <li>- The arrow lines in the framework have different thickness levels and this is not captured in the legend.</li> <li>- Dotted arrows that connect the multimedia elements with the design principles are not captured in the legend.</li> </ul>	<p>justification is outlined in the Thesis Table 4.5.</p> <ul style="list-style-type: none"> <li>- As is outlined within the framework, the domain is VR, and the technology may include, mobile, integrated or standalone.</li> </ul>
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## Appendix D

### Systematic Literature Review

Author & Year	Subject matter	Framework components	Remarks
(Larson et al., 2003)	W3C Multimodal Interaction Framework	<ul style="list-style-type: none"> <li>- Human user</li> <li>- Input</li> <li>- Output</li> <li>- Interaction manager</li> <li>- Interaction Architecture</li> <li>- session component</li> <li>- System and Environment component</li> </ul>	Introduces the W3C Multimodal Interaction Framework, and identifies the major components for multimodal systems. Each component represents a set of related functions.
(Beaudouin-lafon, 2004)	Improving user interfaces through designing interaction	<ul style="list-style-type: none"> <li>- Users</li> <li>- Environments</li> <li>- Artifacts</li> <li>- Computer system</li> <li>- Action/command</li> <li>- Feedback/response</li> </ul>	The researcher claimed that the only way to significantly improve user interfaces is to shift the research focus from designing interfaces to designing interaction. This requires powerful interaction models, a better understanding of both the sensory-motor details of interaction and a broader view of interaction in the context of use. It also requires novel interaction architectures that address reinterpretability, resilience and scalability.
(Foulger, 2004)	Models of the Communication Process	<ul style="list-style-type: none"> <li>- Information source</li> <li>- Transmitter</li> <li>- Receiver</li> <li>- Message</li> <li>- Destination</li> <li>- Feedback</li> </ul>	This paper presents the classic communication models that are taught in introducing students to interpersonal communication and mass communication, including Shannon's information theory model (the active model), a cybernetic model that includes feedback (the interactive model, an intermediary model (sometimes referred to as a gatekeeper model of the two-step flow), and the transactive model
(Karam, 2006)	A Framework For Researching and Designing Gesture-	<ul style="list-style-type: none"> <li>- User</li> <li>- Application Domain (User-task, interaction context, user goals),</li> </ul>	Framework to support a systematic approach for designing freehand gesture-based interactions. The authors designed and evaluated (analytically and empirically) gestural interaction techniques for two broad

	based human computer Interactions	<ul style="list-style-type: none"> <li>- Enabling technology (Input device, System performance)</li> <li>- Response system/ output (resulting artifact, feedback),</li> <li>- Gesture (gesture style, and gesture set)</li> </ul>	categories of freehand gestures we specified – spatial gestures, and surface gestures. In the design activity, they discovered and proposed the core design principles and guidelines, and validated them via user studies.
(Klink, 2006)	The use of interaction methods in a blended	<ul style="list-style-type: none"> <li>- direct communication in the same time and at the same place</li> <li>- people-technology interaction</li> <li>- technology to mediate people-people interaction</li> </ul>	The use of interaction methods in a blended learning environment: evaluating methods in blended learning environment in two courses of a Masters program at the university of south Australia, unit systems engineering & evaluation centre.
(O'Brien et al., 2008)	Developing a framework for intuitive human-computer interaction.	<ul style="list-style-type: none"> <li>- Seeking user goals / task as User behaviours are oriented toward achieving goals</li> <li>- Performing well-learned behaviour</li> <li>- Determining what to do next / transition</li> <li>- Metacognition is the cognitive mechanism through which humans evaluate and monitor their own thinking processes and knowledge content</li> </ul>	Based on synthesis of the reviews, the author reorganized key themes into an organizational framework for intuitive HCI and developed a working definition and framework that allow the human to use a combination of prior experience and feedforward methods to achieve an individual's functional and abstract goals.
(Chorianopoulos, 2008)	User Interface Design Principles for Interactive Television Applications	<ul style="list-style-type: none"> <li>- Design Principles (interactivity, navigation, content delivery, group viewing, multiple level of attention, TV grammar and aesthetics, infotainment)</li> <li>- Entities (User &amp; system)</li> <li>- Technology</li> </ul>	In this research, the UI principles were explicitly addressed in an ITV prototype that has been tested with users. The proposed set of ITV UI principles was presented as a list of high-level and generic design factors, which describe the design space of feasible ITV applications. Overall, the proposed principles facilitate the design process of early interactive prototypes. In
(Rukzio et al., 2008)	The Physical Mobile Interaction Framework (PMIF)	<ul style="list-style-type: none"> <li>- Requirement</li> <li>- Interaction architecture / interaction component</li> <li>- Direct manipulation (touching, pointing, scanning)</li> <li>- Smart object</li> <li>- Technology (mobile device)</li> <li>- Segment composition</li> <li>- Interaction entities (user, mobile tourist guide,</li> </ul>	The author presented a physical mobile interaction framework for using mobile devices as mediator for the interaction with a physical object and discussed purpose, need, training, information overload, item headings, initial items, and activity. Klink

		server, smart object)	
(Vyas et al., 2008)	Role of artifacts in mediated communication.	<ul style="list-style-type: none"> <li>- Entities (user, organisation, culture/society)</li> <li>- Segment</li> <li>- interaction</li> </ul>	Based on our ethnographic fieldwork on understanding cooperative design practices of industrial design students and researchers, the researchers described several experiential practices that are supported by design-related artefacts such as sketches, drawings, physical models and explorative prototypes – used and developed in designers’ everyday work. This is aimed at developing technologies to support designers’ everyday practices.
(Dumas et al., 2009)	Multimodal system architecture	<ul style="list-style-type: none"> <li>- Input modalities</li> <li>- Modality recognizers and processors</li> <li>- Output modalities</li> <li>- Modality synthesizers</li> <li>- Integration committee (Input modality fusion</li> <li>- Context user model history</li> <li>- Output modality fission</li> <li>- Dialog management)</li> <li>- application</li> </ul>	The author presents the features and advantages associated with multimodal interaction, with a focus on particular findings and guidelines, as well as cognitive foundations underlying multimodal interaction. Consequently, focus was given to driving the theoretical principles, time-sensitive software architectures and multimodal fusion and fission issues. And then presented the modeling of multimodal interaction and tools to allow rapid creation of multimodal interfaces.
( Lee, Armitage, Groves, & Stephens, 2009)	Systems for supporting group learning	<ul style="list-style-type: none"> <li>- Entities (User, system)</li> <li>- Interaction architecture</li> <li>- Technology</li> </ul>	This study is amongst the several publications in human computer interaction (HCI) that focus on using technologies as a tool to enhance experiences: in the same place but at a different time (for instance, using systems for supporting group learning such as notice boards, questions and answers, electronic debates and collaborative learning)
(Petrie & Bevan, 2009)	The evaluation of accessibility, usability and user experience	<ul style="list-style-type: none"> <li>- Design principles and guidelines</li> <li>- Content</li> <li>- Structure</li> <li>- Evaluation</li> </ul>	Research introduces a range of evaluation methods that assist developers in the creation of interactive electronic products, services and environments (eSystems) that are both easy and pleasant to use for the target audience. The
(Sung et al., 2010)	Designing an electronic guidebook for learning	<ul style="list-style-type: none"> <li>- Entities (peer, computer, visitor, object)</li> <li>- Content composition (background story, mission, hypothesis, evidence search, notebook)</li> </ul>	This study proposed a human–computer–context interaction (HCCI) framework as a guide for designing a mobile electronic guidebook for a history museum

	engagement in a museum of history	<ul style="list-style-type: none"> <li>- Architecture/Segment</li> <li>- Interaction</li> <li>- Technology</li> </ul>	
(Ni, 2011)	A Framework of Freehand Gesture Interaction : Techniques , Guidelines , and Applications A Framework of Freehand Gesture Interaction : Techniques , Guidelines , And Applications	<ul style="list-style-type: none"> <li>- user</li> <li>- input device,</li> <li>- Theories and Interaction Architecture Theories</li> <li>- interaction techniques,</li> <li>- fundamental design principles</li> <li>- Practical design guidelines.</li> </ul>	The goal of the research is to construct a framework to support a systematic approach for designing freehand gesture-based interactions. Toward
(Martens & Antonenko, 2012)	Narrowing gender-based performance gaps in virtual environment navigation	<ul style="list-style-type: none"> <li>- User</li> <li>- Spatial knowledge representation</li> <li>- Navigation</li> </ul>	In order to utilize virtual environments to their fullest potential, users with different individual characteristics must be able to effectively navigate in these environments even though navigation or associated spatial tasks may not be the user's primary concern.
(Sandino, 2012)	A generic therapist Graphical User Interface design of the Virtual Reality Exposure Therapy system	<ul style="list-style-type: none"> <li>- Entities (Therapist, system, user)</li> <li>- Multimodality (visual, audio, other)</li> <li>- Navigation</li> <li>- User control</li> <li>- Actions</li> <li>- Measurement</li> </ul>	The researcher focused on the analysis and improvement of the therapist GUI in order to decrease the task load for the therapist.
(Angkananon et al., 2013b, 2013c)	Technology Enhanced	<ul style="list-style-type: none"> <li>- People (role, ability/disability)</li> <li>- Objects (dimension, property, content)</li> </ul>	The Technology Enhanced Interaction Framework supports developers and designers design and develop technology

	Interaction Framework	<ul style="list-style-type: none"> <li>- Technology (Electronic, Non-electronic, User - Interface, Application or Service, Cost)</li> <li>- Interactions &amp; Communication (People-People, People-Objects, People-Technology, People-Technology -People, People-Technology -Objects)</li> <li>- Time/Place (Location, Weather Condition, Signal Type and Quality, Background Noise, Lighting)</li> <li>- Interaction Layer (Culture, Intentionality, Knowledge, Action, Expression, Physical)</li> </ul>	enhanced interactions involving people, technology and objects and has seven main components
(Y. Lu et al., 2014)	Promote physical activity among college students: Using media richness and interactivity in web design	<ul style="list-style-type: none"> <li>- Navigability (browsing, elaboration, scaffolding, play, prominence, similarity)</li> <li>- Interactivity (interaction, activity, responsiveness, choice, control, tele-presence, flow, contingency, ownness).</li> <li>- Agency (machine, bandwagon, authority, social presence, helper, identity)</li> <li>- Rich modality (realism, media, being there, distraction, bells and whistles, coolness, novelty, intrusiveness)</li> </ul>	media richness and interactivity as design characteristics in 3d virtual environment are significant cues for users' attitude towards a multimedia technology.
(Shneiderman et al., 2016, 2009; Shneiderman & Plaisant, 1987)	Shneiderman's "Eight Golden Rules of Interface Design". Designing the user interface: strategies for effective human-computer interaction.	<ul style="list-style-type: none"> <li>- Strive for consistency.</li> <li>- Enable frequent users to use shortcuts.</li> <li>- Offer informative feedback.</li> <li>- Design dialog to yield closure.</li> <li>- Offer simple error handling.</li> <li>- Permit easy reversal of actions.</li> <li>- Support internal locus of control.</li> <li>- Reduce short-term memory load.</li> </ul>	Shneiderman's "Eight Golden Rules of Interface Design" for designing the user interface: strategies for effective human-computer interaction.
(Al-Aidaroos, 2017)	Conceptual model for usable	<ul style="list-style-type: none"> <li>- Human entities</li> <li>- Technology</li> </ul>	Proposed a conceptual model for usable multimodal mobile assistance during umrah called the personal digital mutawwif (PDM)

	multimodal mobile assistance during Umrah	<ul style="list-style-type: none"> <li>- Structural component (opening, content, closing)</li> <li>- Content composition (interaction design, modalities, presentation, instruction modes, flow patterns)</li> <li>- Design principles (multimodal principles, information architecture, user interface layout)</li> <li>- Development approach (pre-production, production, and post production).</li> </ul>	
(Lindner et al., 2017)	Design considerations and future directions for creating state of the art, next-generation Virtual Reality exposure therapies for anxiety disorders using consumer hardware platforms.	<ul style="list-style-type: none"> <li>- Platform (stationary integrated or mobile)</li> <li>- Therapist-led or unguided self help (seen or unseen therapist)</li> <li>- User input</li> <li>- Interaction techniques</li> <li>- Domain knowledge</li> <li>- Gamification</li> <li>- User control</li> <li>- Stimuli intensity control or tailoring</li> </ul>	The authors highlighted the current state of VR technology and discuss important therapeutic considerations in designing self-help and clinician-led VRETs, such as platform choice, exposure progression design, inhibitory learning strategies, stimuli tailoring, gamification, virtual social learning and more
(Apple_Developer, 2018b)	Human Interface Guidelines	<ul style="list-style-type: none"> <li>- Aesthetic Integrity</li> <li>- Consistency</li> <li>- Direct Manipulation</li> <li>- Feedback</li> <li>- Metaphors</li> <li>- User Control</li> </ul>	High expectations for quality and functionality for delivering extraordinary products that rises to the top of the App Store charts



## Appendix E

### **Instrument for Expert Review: Multimodal Interaction Framework For Virtual Reality Foot Reflexology Stress Therapy (VR-FRST)**

Dear Prof / Dr. / Sir / Mdm,

I am Prince-Hector C. Okere and currently pursuing a PhD program in Multimedia at Universiti Utara Malaysia (UUM). It is great pleasure to inform you that you have been selected to participate in this research on the reason as follows:

1. Your qualifications either in Human Computer Interaction (HCI) or Multimedia or Mobile Applications or Virtual Reality (VR) or Information Systems (IS) or Computer Science (CS) and/or related areas.
2. You have been teaching / researching in VR or Multimedia or HCI or instructional designs or IT and/or CS areas for at least five (5) years.

My research proposes A MULTIMODAL INTERACTION FRAMEWORK FOR VIRTUAL REALITY FOOT REFLEXOLOGY STRESS THERAPY. As part of this research, a multimodal interaction framework named VR-FRST has being designed. It is aimed at providing an alternative substitute for TFR application in relaxation, stress relief and complementary therapy.

One part of this research is to evaluate the proposed framework in a few dimensions as listed in the review form. You will see the review questions give you ample opportunity to use your expertise, experiences, interests, and creativity. It would be greatly appreciated if you could complete this evaluation form.

The information supplied will be treated as confidential and will be used for research purposes, which will be reported anonymously in academic publications.

Please feel free to contact me by email ([okerejunior@yahoo.com](mailto:okerejunior@yahoo.com)) in regards to any queries or my supervisor Dr. Juliana Aida Abu Bakar ([liana@uum.edu.my](mailto:liana@uum.edu.my))

Thanking you for your time and assistance.

Instructions: Please read and go through the Document and Framework emailed to you carefully. Once this is done, with the expertise you possess, please provide feedback for all questions in the provided spaces.

Name	
Gender	
Highest Education	
Level	
Occupation	
Affiliation	
Field of Expertise	
Years of Experience	

### ITEMS TO REVIEW

Based on the proposed Interaction Framework (as depicted in the given handout).	Please select where you feel appropriate		
	All are relevant	Some may be not relevant	Some are definitely not relevant / Please comment
1. The following Components in the proposed Interaction Framework are relevant.  Technology Content Compositions Segment Composition Design Principles.			
2. The following design principles in the proposed Multimodal Interaction Framework for VR-FRST are understood. Multimedia Elements Design Principles Information Architecture Principles and Theories User Interface & Layout TFR User Requirements	It's easy to understand	Need some explanation	Needs very detail explanation / Please comment
3. The proposed elements in the design principles are understood Texts Graphic Animation Audio Video Organization Labelling Navigation System Transitions	It's easy to understand	Need some explanation	Needs very detail explanation / Please comment

<p>4. The following terminologies in the entire interaction Framework are easy to understand.</p> <p>Multimodal interaction</p> <p>Integrated Platform / Console</p> <p>Multimodal recognizers</p> <p>Multimodal Synthesizers</p> <p>Fussion</p> <p>Fission</p> <p>Labelling</p>	<p>It's easy to understand</p>	<p>Need some explanation</p>	<p>Needs very detail explanation / Please comment</p>
<p>5. Please select (Yes / No) where you feel appropriate.</p> <p>The connections and flows of all components are logical</p> <p>Overall, the multimodal interaction framework is readable</p>	<p>Yes</p>	<p>No /leave your comment</p>	
<p>6. Please leave any further comments</p>			

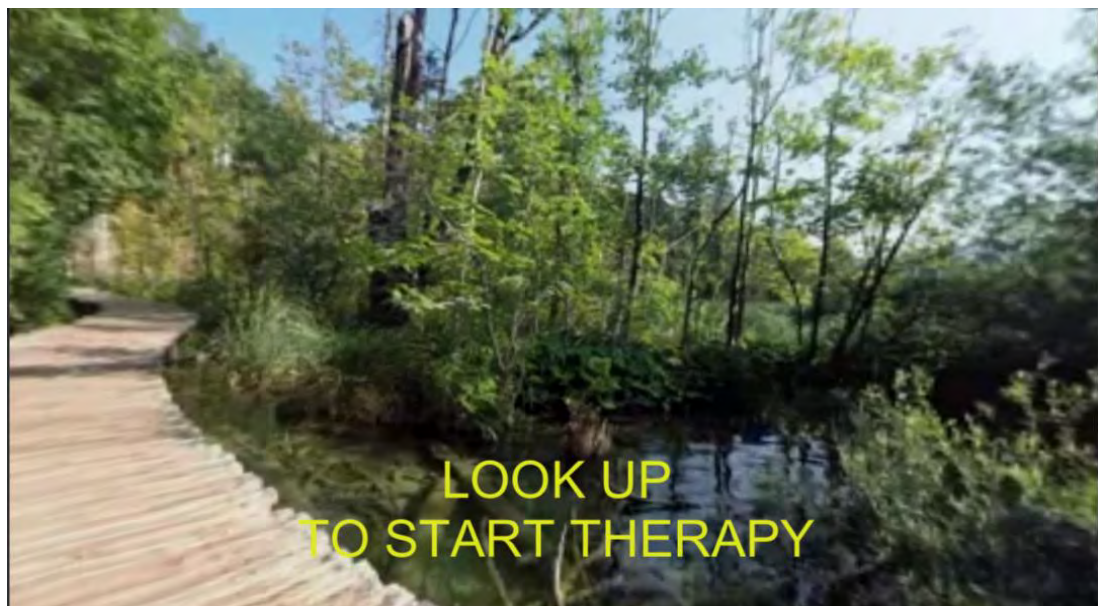


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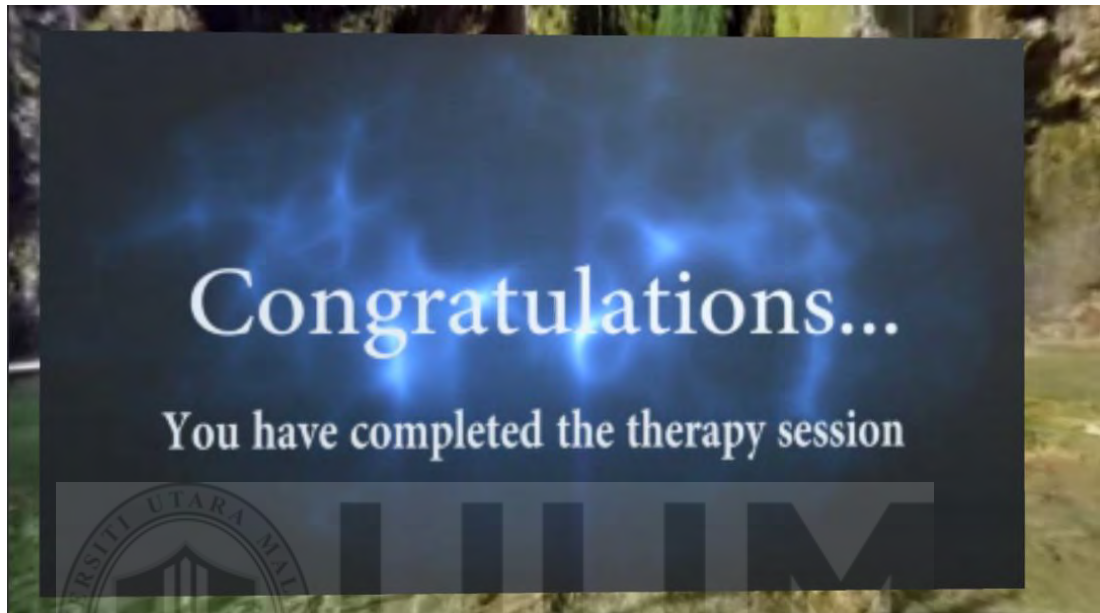
**Appendix F**  
**VR-Foot-ReST Application Screenshots and Unity3D Game**  
**development Environment**



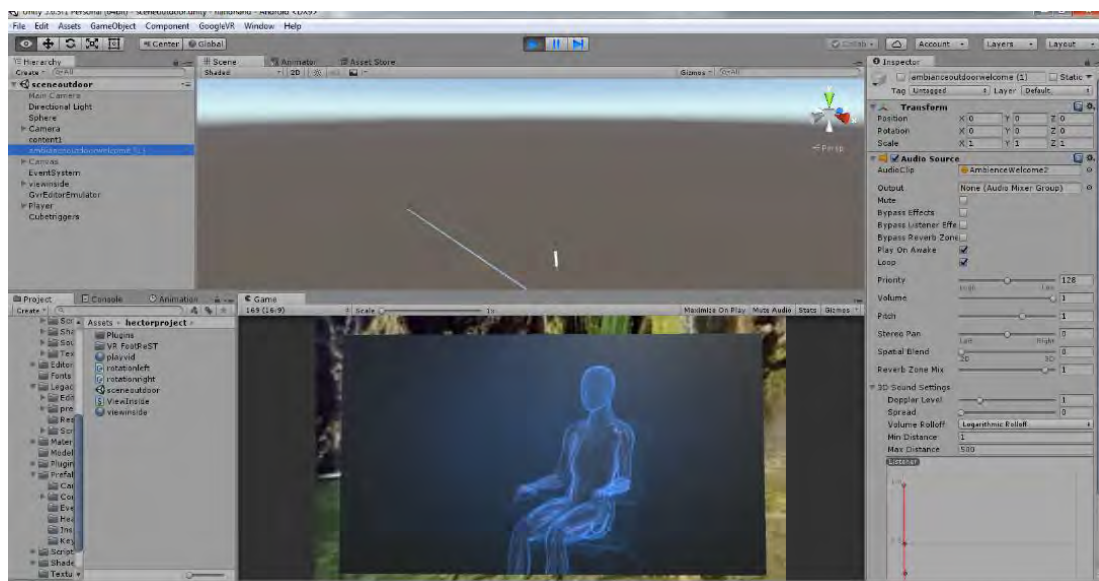
Waterfall Outdoor relaxing VR environment Front view



## Waterfall Outdoor relaxing VR environment Rear view



## After Therapy Congratulatory Message



## Unity3D Game Development Environment

## Appendix G

### List of Publications

- Okere, H. C., Bakar, J. A. A., & Mat, R. C. (2018a). Design Features of Virtual Reality Foot Reflexology Stress Therapy. *Journal of Advanced Research in Dynamical and Control Systems*, 10(Special Issue 10), 1472–1479. Retrieved from <http://www.jarcds.org/backissues/abstract.php?archiveid=5049>
- Okere, H. C., Bakar, J. A. A., & Mat, R. C. (2018b). Virtual Reality and Its Potential for Stress Therapy. *SMMTC Postgraduate Symposium 2018*, 244. Retrieved from [https://28536699-376730838878981982.preview.editmysite.com/uploads/2/8/5/3/28536699/proceedings\\_final\\_version.pdf#page=244](https://28536699-376730838878981982.preview.editmysite.com/uploads/2/8/5/3/28536699/proceedings_final_version.pdf#page=244)
- Okere, H. C., Bakar, J. A. A., & Mat, R. C. (2018c). Virtual Reality Foot Reflexology (VRST): A New Alternative in Foot Reflexology. *International Journal of Engineering & Technology*, 7(3.7), 383–387.



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