Teach Me Drums: 
Learning Rhythms through the 
Embodiment of a Drumming Teacher in 
Virtual Reality

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Preface

The project of this master thesis was conducted at the EPICentre (Expanded Perception and Interaction Centre) at the University of New South Wales, Art & Design, in Sydney Australia. The EPICentre facilitated the project from February 1st to the 31st of May 2018. The author was still enrolled at Aalborg University of Copenhagen, while conducting the project’s research abroad at UNSW.

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Teach Me Drums: Learning Rhythms through the Embodiment of a Drumming Teacher in Virtual Reality

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Abstract: Learning new skills through embodied interaction in virtual reality (VR), has been fuelled by the advances in sensor technologies, including VR display technology. Moreover, by the fact that VR can render scenarios not possible in real life. This has created a vast field of application areas in VR, exploiting the medium as an alternative training platform. It has been shown that an embodied perspective of a mentor can stimulate creativity and learning while training skills and physical movements. Learning a new skill such as music, requires time and dedication which can prevent people to engage with the art and miss the benefits of music learning. Learning music, has been shown to increase learning in other areas such as mathematic thinking and verbal memory. This project investigates how to design an embodied learning experience of a drumming teacher playing hand drums, to aid higher rhythm understanding and accuracy. Essentially by providing novices the first-person perspective of a drumming teacher, while learning to play a West-African djembe drum. A stereoscopic video of a drum lesson was developed, capturing the first-person perspective of a drumming teacher.

Participants learning was measured objectively by their ability to follow the drumming teacher’s rhythms compared to the rhythm of the metronome, with the teachers. Participants subjective learning was assessed through a self-assessment questionnaire measuring aspects of Flow, User-experience, Ownership, and Presence. Two test iterations were conducted. In both there was found no significance difference in participants ability to follow the drumming teacher’s temps for the experimental group exposed to the first-person perspective of the teacher in a VR drum lesson, than for the control group exposed to a 2D version of the stereoscopic drum lesson. There was found a significance difference in the experimental group’s presence scores in the first test iteration, and a significance difference in experimental group’s presence scores in the second test iteration. Participants subjective feelings indicated enjoyment and motivation to the presented learning technique in both groups.

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Learning new skills through embodied interaction in virtual reality (VR), has been fuelled by the advances in sensor technologies, including VR display technology. Moreover, by the fact that VR can render scenarios not possible in real life. This has situated a vast field of application areas in VR, exploiting the medium as an alternative training platform. It has been shown that an embodied perspective of a mentor can stimulate creativity and learning while training skills and physical movements. Learning a new skill such as music, requires time and dedication which can prevent people to engage with the art and miss the benefits of music learning. Learning music, has been shown to increase learning in other areas such as mathematic thinking and verbal memory. This project investigates how to design an embodied learning experience of a drumming teacher playing hand drums, to aid higher rhythm understanding and accuracy. Essentially by providing novices the first-person perspective of a drumming teacher, while learning to play a West-African djembe drum. A stereoscopic video of a drum lesson was developed, capturing the first-person perspective of a drumming teacher. Participants learning was measured objectively by their ability to follow the drumming teacher’s rhythms comparing the rhythm feature of tempo measured in beats per minute (BPM), with the teachers. Participants subjective learning was assessed through a self-assessment questionnaire measuring aspects of Flow, User-experience, Oneness, and Presence. Two test iterations were conducted. In both there was found no significance difference in participants ability to follow the drumming teacher’s tempo for the experimental group exposed to the first-person perspective of the teacher in a VR drum lesson, than for the control group exposed to a 2D version of the stereoscopic drum lesson. There was found a significance difference in the experimental group’s presence scores in the first test iteration, and a significance difference in experimental group’s one-ness scores in the second test iteration. Participants subjective feelings indicated enjoyment and motivation to the presented learning technique in both groups.
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1 Introduction

How to teach music can be an art. As effortless it can seem for the spectator to play music while observing, learning to play music may not come across that easy, as it does for a talented few (Xiao, 2016). Learning music requires effort, time and dedication, which can prevent people from learning music and miss the benefits of the art. Musical practising has been shown to improve mathematical skills and verbal memory (Gardiner, Fox, Knowles, & Jefferey, 1996). Through a historic perspective, music has shaped our ancestors and culture. It reflects evolution by the discovery of some of the oldest human-made artefacts on archaeological sites, comprising musical instruments. This reminisce us of the important value music had, and keeps contribute to our lives (Levitin, 2008, p.2).

Studies have shown the potential of Virtual Reality (VR) as an alternative training and learning platform for acquiring new skill sets and improving existing. Amongst other seen in the field of music learning, training rhythmical skills and musical expression (Serafin et al., 2017a), along training physical movements (Bailenson, et al., 2008). The multidimensional nature of VR provides a unique possibility to take the perspective of another person than one self. This quality provides a strong tool to facilitate learning and communication between individuals, which has been examined by expert-novice mentorship simulations in the art of painting (Gerry, 2017).

One advantage of using VR for education, is the ability to present abstract topics in to tangible. For example, teaching mathematics through collaborative environments for learning geometrical concepts, against traditional pen and paper (Slater and Sanchez-Vives, 2016, p.14). Secondly, VR supports “doing”, instead of observing, as the user participates in the virtual world instead of using it, compared to other types of human-computer interfaces (Slater and Sanchez-Vives, 2016, p.3, 14).

The focus on incorporating the body in designing movement-based interfaces has been fueled by the advances in sensor technology (Isbister and Mueller, 2015, p.366). The affordance of VR technology leverages interactivity, not seen in medias such as video and text, based on the vast possibilities for behavioral tracking.
Introduction

(Bailenson et al., 2008, p.355). This essentially allows users to participate in a VR instead of using it, through embodied interactions.

This project seeks to investigate how to teach music more effectively, by incorporating VR to communicate somatic knowledge of a drumming teacher; providing a first-person perspective of the playing teacher. Essentially, to aid higher rhythm understanding and accuracy. The research question for this project is:

“To which extent can a Virtual Reality setup teach rhythms effectively on a hand drum with an expert-novice mentorship simulation, by learning through the embodiment of a drumming teacher’s first-person perspective, compared to video”
2 Background

2.1 Embodiment in Immersive Virtual Reality

VR can simulate reality by placing the user into a surrounding 3D world, by its immersive technology. From headtracking seen in head-mounted displays (HMD), sensor technologies, motion capture systems, and computer-generated images (Slater and Sanchez-Vives, 2016, p.1) (Serafin et al., 2017b, p.8). VR can be defined as: “Immersive artificial environments experienced through sensory stimuli provided by technology and in which one’s actions partially determine what happens in the environment” (Serafin et al., 2017b, p.6). An ideal immersive virtual reality (IVR) system is commonly composed by displays of visual, auditory, and haptic, along a tracking system (Slater, 2009, p.3549) (Slater and Sanchez-Vives, 2016, p.4) (Serafin et al., 2017b, p.8). Though, the real power of VR is not only to be seen by the technological potential of reproducing realities digital. But, rather that it can accomplish scenarios that goes beyond what can be done in the real world (Slater and Sanchez-Vives, 2016, p.1-2). In terms of embodiment in VR, one of the most powerful aspects is to have a body representation (Slater, 2017); or, allowing human expression just as in the real physical world (Lanier, 1989, p.8). The term embodiment refers to the sense of one’s own body (Longo et al., 2008, p.979), and is defined as:

“The property of being manifest in and as a part of the world” (Dourish, 1999, p.2).

Embodiment reflects a physical presence in the world, which can be simulated by IVR (Dourish, 1999, p.1,3). Jaron Lanier, the man who coined the term “virtual reality” (VR), expressed how the medium can situate embodied experiences in a reality just as shared as the physical world:

“It’s a very interesting kind of reality. It’s absolutely as shared as the physical world. Some people say that, well, the physical world isn’t all that real. It’s a consensus world. But the thing is, however real the physical world is -- which we never can really know -- the virtual world is exactly as real, and achieves the same status. But at the same time it also has this infinity of possibility that you don’t have in the physical world”.

(Lanier, 1989, p.8).
However, the virtual world is not real, but VR has the ability to induce realistic responses in people, in its core function of being a “reality simulator” (Slater and Sanchez-Vives, 2016, p.6). The perception of a user’s actions in Virtual Reality Environment (VRE), likewise the immersive quality of an IVR, depends on the given system’s ability to reproduce the sensorimotor contingencies (SCs) contained in our interaction within the physical world (Gillies, 2016, p.2) (Slater, 2009, p.3550). Besides sensory inputs, SCs is a fundamental construct of the perception of our world, as it covers the relationship between motor action and the resulting sensations (Gillies, 2016, p.2). For example, rotating the head in a VRE, will simultaneously update the virtual world (Gillies, 2016, p.1). The sense of embodied interaction, moreover the naturalness of the interaction, depends on the representation of the SCs. Though, it can be argued if the given movement-based interaction is not discoverable for the intended users - natural, even though a VRE is replicating the SCs with high fidelity, users’ have no support in what actions to do (Gillies, 2016, pp.2-3). Meaning, the specific behaviour or functions of what a system is meant to do, must be clear by offering learnability and memorability of the system. This way of thinking relies on the notion of embodied cognition; the concept by which we include our learned experiences in our daily approach to interacting within the world (Gillies, 2016, p.3). When designing movement-based interaction, one must consider how well a system represents the SCs, and if those representations affords discoverable actions towards what a system is supposed to do. The next section describes two studies that examines how to design movement-based interaction, that facilitates learning by exposing users to a mentor’s somatic knowledge, allowing users to embody themselves with the mentor’s movements.

2.2 Learning through an Embodied Perspective: Expert-novice Mentorship Simulations

To elucidate how this report will approach and design an embodied learning experience in VR, the studies of (Gerry, 2017) and (Xiao, 2016) has been reviewed. Both studies integrate a mentor’s first-person perspective, with the aims to facilitate learning, creativity and expression within the field of art and music, respectively.
Embodied Perspective Taking of a Painter in VR

IVR offers the unique possibility to step into the shoes of another person, and has been used to facilitate empathy, to motivate cognitive awareness of another person’s state (Gerry, 2017) (Hamilton-Giachritsis, 2018). The embodied experience of another person’s perspective is explored in study Paint with Me (Gerry, 2017), using a Mixed Reality (MR) to stimulate creativity and empathy while simultaneously painting with a painter in VR. MR is a subset of VR related technologies, which incorporates the real and the virtual worlds together. The degree of virtuality incorporated in a MR, can lie on a “virtual continuum”, ranging from completely real to completely virtual environments (Milgram and Kishino, 1994). In the study, users were taught to paint by taking the first-person perspective of a painter’s. Users wore a HMD, displaying a stereoscopic 3D video with view range of 230 degree, showing the painter’s hands painting on a canvas. Users own hands were tracked, to digital superimpose their hands, on top of the painter’s hands, while they paint on a physical canvas.

 Leap Motion integrated with the HMD Oculus DK2, was used to track the user’s hand movements, to digital superimpose their hands, on top of the painter’s hands, while they paint on a physical canvas (see figure 1, image right). The present study’s hypothesis was: “that moving together (in this case, drawing) during an embodied experience in IVET can enhance empathic accuracy and stimulate creativity” (Gerry, 2017, p.1399). The study measured the effects of visuomotor synchrony (moving together) on oneness. Oneness was measured by the Inclusion of Other in the Self Scale, originally developed by Aron et al. (1992). The scale covers measures of self-other merging and feelings of oneness, which in this case, refers...
to how close the participants felt to the painter. The effect of the painting simulation was further measured on a codec of empathic accuracy. A qualitative comparison included the participants own subjective inferences about the painter’s experience while painting. These were coded to the similarity of the painter’s own generated report of experienced thoughts and feelings during a specific sequence in the viewed stimuli (Gerry, 2017, pp.1402-1403). The results from the experience of simulation of empathic accuracy was deemed inconclusive. Though, the study findings showed that the virtual environment contributed to a relaxed environment to learn a new skill set for novices, that can be experienced complex in its form (Gerry, 2017, p.1404). However, this potentiality was not compared to a control condition, to measure the effect of the embodied first-person perspective on learning. Whilst the study by Gerry (2017) investigated how moving together, and stepping into the shoes of a painter’s, could enhance empathic accuracy and stimulate creativity. The motivation for this study is to examine the effect from wearing a music teacher’s sensory apparatus on music learning; focusing on teaching rhythmic drumming skills, to examine if you learn rhythms better if you experienced their performance from a first-person perspective of a drumming teacher. Further, the aim is to incorporate an objective measure, to quantify the novice ability to follow a drumming teacher’s instructed rhythms. To look further into embodied concepts of expert-novice mentorship simulations, the study by Xiao (2016) is examined to inspect new thinking strategies for music learning.

**Music Learning: Reflecting Music through Movement**

Learning music requires the learning of pieces, consisting of musical notes, that through practice and repetition can lead to successfully mastering of the chosen instrument. Xiao (2016) describes these mainstream views, as misguided views about what it requires to learn music, also characterized by the ideas of the ‘Pop-Ed Music Culture’ originated from Seymour Papert (1972). Xiao (2016), states that solely teaching music through the pop-ed methods (learning pieces, learn notes, repeat), before learning to be expressive, one would limit the potential of finding one’s own unique musical expression, thus becoming better to convey a musical sequence (Xiao, 2016, p.11-12). Further, learning to be expressive, must be understood through the body, which relies on the awareness of listening, imitating and experimenting with sound, beyond headless repetitions of hitting musical notes flawlessly, along technical exercises:
“Learning to “think” like a musician involves learning to play music and to play with music. Playing music is first about feeling music through the body. This involves knowing how to carry a beat, how to “sing” a phrase, and how to channel emotions through movement … Expression is about translating what impresses on us-by bringing forth in our own ways” (Xiao, 2016, p.11,19).

The core of Xiao’s learning strategy is to teach music through an embodied approach, by offering methods to think like a musician, in the head, body and heart (Xiao, 2016, p.24). This strategy is grounded in Seymour Papert’s concept of ‘body-syntonicity’. A concept which essentially learned children to think like a mathematician. Children were taught to program a Logo turtle by given it instructions to draw geometric shapes. The programming incorporated children’s own body sense and direction, thus imagining themselves moving in the place of the Logo turtle (Xiao, 2016, pp.13-14). Body-syntonicity as a concept, describes an embodied thinking strategy, connecting knowledge and one’s own body sense, paired with syntonicity - meaning “in tune” (Xiao, 2016, p.14). The musical interface MirrorFugue, incorporates interactive technologies to instruct the body, with the motivation to teach users to play and learn music more effectively, enjoyable, and with greater expressivity (Xiao, 2016, p.11, 13). In MirrorFugue, both videos of the teacher’s hands and upper body is projected on to the piano. The piano teacher’s playing hands is projected on the tangents, whilst the upper body is projected on the vertical piano surface. Users learn by imitating a piano teacher’s hands, reflected on the piano tangents (Xiao, 2016, p.50-52). Projecting the teacher’s moving tangent keys, along the teacher’s hands on the keys was found most preferable by users; opposed to no visualization of moving keys, and the teacher’s hands projected on the vertical piano surface (Xiao, 2016, p.61). The study’s results showed that the participants felt presence of the virtual pianist, along a strong credibility of the experience by perceiving the presented information (moving tangents and teacher’s hands) as an integrated experience (Xiao, 2016, p.63).

In relation to the work of Xiao (2016, p.14), this study will incorporate body-syntonicity as a strategy to music learning. The aim is to exploit the perspective afforded by a HMD, to aid bodily synchronicity with a drumming teacher. Thereby, supporting the novices to imagine themselves moving in the place of the drumming
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teacher, by gaining a direct insight to the teacher’s somatic knowledge - perceiving from the teacher’s perspective.
3 Design and Implementation

This section presents the design of a VR setup for teaching novices drums through an embodied first-person perspective of a drumming teacher. The underlying motivation is to aid higher rhythm understanding and accuracy through the participant’s embodiment of the playing teacher. The design consists of two parts. First, the development of the teaching material constituting the test stimuli of a pre-recorded drum lesson, and a discussion of the suitable hand drum for the rhythm teaching of novices. Secondly, the recording setup with a stereoscopic 3D camera is discussed, for capturing a reliable first-person perspective of the drumming teacher, to be viewed through a HMD while playing along the teacher.

3.1 Design of Test Stimuli: Teaching Material

The design of the teaching material for the drumming recording was revised and discussed in two iterations, with two professional drummers respectively. A prerequisite to the drummers’ qualifications were teaching experience, and skills on hand drums of a West-African Djembe and a bongo drum. Hand drums were chosen based on the common knowledge in the world of its perceived affordances and signifiers on how to be operated – by the hands. Secondly, allowing immediately haptic feedback, to provide a direct sense of the drum when viewing the stereoscopic footage of the hand drum through a HMD.

Before each of the two individual drumming recordings, the drummers were explained motivation for the research of the study. Additionally, the test objective of comparing two learning medias (VR and video), and their effectiveness on rhythm learning. The requirements for the teaching material included content directed to novices, who has no to little experience with drum lessons before. This is to ensure an equal level of drumming experience, and skill level between the test participants. Further, the drum recording is structured with drumming sequences that leaves enough time for the novice to play along. This is based on the objective measure, to test the effect of the two learning medias, which involves a comparison of the drumming rhythms produced by the mentor and the novice. The drummers'
knowledge was incorporated into structuring the suitable rhythms for teaching hand drums to novices.

### 3.11 Drumming Recording 1

The first drummer had over 40 years’ experience of music practicing. The teacher’s experience included teaching, performing drumming shows with a west African drumming group, along skills in other instruments. A bongo drum (size 6 and 7 inch) was used for the first recording (see figure 4.), due to affordability. An initial instruction and trial phase was dedicated to familiarization with the bongo before the rhythm training. It was incorporated in the first part of the drum lesson, allowing the participants to get familiar with the bongo. This included, how to place the bongo between the knees, the hit method, and how to produce a pulse on the bongo. The general structure of the drumming lesson was composed of 4 sequences of rhythm patterns.

Each of the rhythm patterns were structured as follows. First, the teacher demonstrates the rhythm, while counting the beats. Next, the novice is asked to play along, by a verbally instruction: “now you try”, following the count in, in four beats. To indicate when each rhythm pattern training stopped, the teacher verbally counts down on four. The first pattern, was altered for the second pattern, with a second beat, to increase the level. Pattern 3 increased the skill level further. The last pattern was chosen to challenge the novice, as the pattern started on the fourth of the fourth counts, with greater complexity than the previous patterns thought. Each rhythm pattern taught, was picked based on being simple to play, whilst being fun. Further, gradually increasing the rhythmic skill level, to challenge the novice, as a teacher would strive to.

### Recording Setup

**3D Camera: LucidCam - Stereoscopic viewing**

The recording was filmed with the stereoscopic 3D LucidCam (see figure 2), and is referred to a VR180 camera (Redohl, 2018). The LucidCam was chosen based on its delivery of depth, with two front facing fisheye lenses, resembling peripheral vision, placed with the average distance between human eyes (Redohl, 2018). The Field of View (FOV), produces a 180-degree 3D spherical visual field, comprising left, right, up, and down, for each of the two lenses. The LucidCam records in 4K.
for each of the lenses with a video capture of 30 fps, and produces 50MB per minute (Dove, 2018).

![LucidCam](image)

Fig. 2: The 3D VR LucidCam (Marketing, 2018). Two stereo fisheye lenses capture a Field of View of 180 degrees. The LucidCam offers stereoscopic recordings.

**Recording rig**

The recording rig, was comprised of a static tripod, placed behind the drummer, with an extender arm reaching over the drummer’s head. This was to ensure a reliable angle and steady capture of the first-person perspective from the drummer’s eyes. The tilt angle of the LucidCam was tested, to provide a reliable perspective, when viewing the recorded 3D footage. An angle of 62 degrees was tested through the LucidCam app for live-preview, which gave a realistic impression of capturing the drummer’s chest spanding to his drumming hands (see figure 3 for originally test of the static rig, and viewing angles, with a test person). Due to the recorded drummer’s height exceeding 181 cm, the rig was not flexible enough to allow the LucidCam to reach over the drummer’s head, with a proper capture angle. To document the design of the learning material, the Lucid camera was attached to the drummer’s head, with a head-mounted GoPro head strap (see figure 4). Such that the stereo fisheye lenses would approximately be positioned in front of the drummer’s eyes (see figure 4).
Fig. 3: Initial test of mounting the Lucid camera with a static rig for stabilisation of footage, and testing viewing angles.

Fig. 4: Shows the first drumming recording with the bongo drum. Documentation of teaching material was taking with the GoPro head strap.
Discussion of Drumming Recording 1

Verbal Instructions
It was a prerequisite to count the beats for the instruction of each rhythm pattern for the instruction phase. Though sporadically, the teacher counted on top of the drumming in the ‘play along’ sequences. This can complicate the rhythm comparison of the teacher and the novice, for the objective measure. Therefore, the next drumming recording will ensure that the ‘play along’ sequences leaves enough silence for the rhythm comparison.

Drum Hitting Canvas
The canvas of the bongo is split into two drums, making it more complex, in terms of the alignment of the virtual drum seen in the HMD, against the physical ones. The bongo drum can both be positioned with a stand, or between the knees. The last method was applied for the recording. Though, the method produced a slightly skewed angle; expressed as optimal by the teacher. However, this can complicate the ease of getting a close to perfect alignment with the physical bongo to the virtual. Due to both the novices experience of holding a bongo drum, as well as differences in body sizes and height of novices. The first drumming recording is used a background knowledge for a second iteration of designing the learning material, along revising the optimal drum - hitting canvas.

Feedback from the Drumming Teacher
The drumming teacher was asked for his feedback about the VR setup as a teaching scenario for drum and rhythm learning: “The users won’t be able to see the real physical drum and their own physical hands, which is a big part of the whole idea of getting into the feeling to see your own hands on the physical drum responding”. In terms of the look and feel of the learning experience to be designed, participants can be given feedback of their own hand movements in relation to the teachers with a digital render seen in the HMD, similar to the study of Gerry (2017). This can be solved by providing virtual affordances by superimposing participants hands digitally on top of the teacher’s. Which can serve as a strong cue on matching participants own physical hands to the teacher’s hands, and to give optimal circumstances.
for the participants to hit within the canvas of the drum skin. Essentially, the participants will not be able to see the real physical drum, thus a 3D stereoscopic recording of that in the HMD.

### 3.12 Drumming Recording 2
The second drummer was recruited based on his comprehensive experience in drum and percussion performance, as a workshop facilitator and teacher. The drumming teacher shared his knowledge about important factors for constructing quality teaching material for the novices. The approach to teaching and likewise teaching of the given teacher, has a great impact of the quality of the material presented. Essential, the teacher could be a highly talented drummer, but not a great teacher; the method of teaching is just as important. The hand drum used for the second drumming recording consisted of the West-African Djembe hand drum. The teacher expressed the qualities of this drum, for teaching novices drumming: “The djembe is an easy drum to just get started on, the djembe is accessible to start with for beginners. The bongo is slightly harder for a beginner, with the coordination - two drums together; the djembe has a whole surface”. Based on the findings in the first drumming recording, the djembe’s hitting canvas was found less complex, in terms of a more even centered surface (not split into two like the bongo) to hit, when wearing the HMD; easier target area, and less prone to hit error. Moreover, the djembe drum has been known for its low learning threshold compared to other instruments, which makes it suitable for novices to drumming (Kilteni, Bergstrom, and Slater, 2013, p.3)

### Static Recording Rig
For the second drumming recording, the static rig was improved from the first recording. The rig was altered to be positioned from the side, without the two fish-eye lenses capturing the extended rig arm, allowing more flexibility for adjusting to the drummer’s height (see figure 5).
Fig. 5: Image left displays the complete setup from the second drum recording. Image right shows the alteration of the LucidCam rig for the second drumming recording; the rig is positioned from the side in front of the drumming teacher’s view, without capturing the rig extender arm.

Teaching Material
The teaching material for the second drumming recording followed the general structure of the first drumming recording: A trial phase, and four rhythm patterns. The trial phase included how to hit the djembe. The teacher instructed how play two different djembe tones in the trial phase, to match the skill level for a novice. The base tone (centre drum skin), and the ‘tone’ (edge of drum skin). Halfway in each ‘play along’ sequence, the teacher increased the tempo, to challenge the novice (see appendix 1 for drumming recording 1 and 2 details)

3.2 Implementation
This section gives an overview of the implementation of the first-person perspective of the teacher recorded with the stereoscopic 3D LucidCam. Further, a preliminary design test of a pair digital renders of the taught novice’s hands, by the Leap Motion software. The digital hand render was explored as a tool to provide the novice a sense of aligning their hands with the teacher’s, to support the following of the teacher’s rhythms on the djembe.
3.21 LucidCam Footage: Stereoscopic viewing

The game engine Unity3D 2017 (Unity, 2018) was used as the software to implement the 3D stereoscopic viewing for the HTC Vive HMD. The 3D stereoscopic footage consists of the footage from the two fish-eye lenses from the LucidCam (see figure 6). The characteristic of fish-eye lenses appearance is their strongly curved surface (Bettonvil, 2005, p.9), which can cause distortion at the image corners (Unity Documentation, 2018).

![Fig. 6: The Raw stereoscopic footage from the two fish-eye lenses from LucidCam, showing the image distortion around the corners from the lenses curvature.](image)

The avoid distortion and to enable the stereoscopic viewing, the fish-eye footage is wrapped on to a hemisphere (see figure 7 for Unity scene setup with the hemisphere). A render texture of 4K resolution (3840 x 2178) is targeted to the hemisphere, for playing the stereoscopic video. To enable a dual channel stereoscopic viewing, each eye (left, right) has an individual render texture, parented under the hemisphere, as child objects of hemi left and hemi rgt. The right eye has an offset of 0.5 in the attached render texture to enable peripheral viewing. The positions of the hemi left and hemi rgt is match with the Camera position in the scene. The hemisphere was angled 60 degrees downwards, by a rotation value of 60, to enable a realistic first-person perspective, by tilting the view to capture the drummer’s chest to the drumming hands (see figure 8).
Fig. 7: The Unity scene setup showing the hemisphere, used for projecting the stereoscopic filmed footage of the drumming teacher.

Fig. 8: The Unity scene setup showing the hemisphere angled downwards, with a rotation by 60 degrees.

3.22 Leap Motion Hands

The digital Leap Motion hands are incorporated to support the position of novice’s own hands within the physical drumskin, and the matching of their own hands to the playing teacher’s. As noted by the first drumming teacher, the novice cannot see their own hands on the virtual drum. Additionally, seen in Gerry (2017), the Leap Motion hands was used to digital superimpose the novice hands on to the painter’s, to support the novice in following the painter’s movements. A digital render of the novice’s hands is provided by the Leap Motion hardware and software (Leap Motion, 2018) integrated in the Unity scene with Stereoscopic viewing. The
Leap Motion consist of two cameras and three infrared LEDs (Colgan, 2018). Attached to a HMD, the Leap Motion controller beams infrared light on the user’s hands, to detect hand, and finger movements, with the individual joints. The information is piped through an API to render the digital version of the novice’s hand to operate in VR (Hollender, 2017). The user’s digital hands renders are created with the capsule hands available in the Hands Module package from Leap Motion, imported to Unity. The capsule hands appear as a skeleton version of the novice’s hands (see figure 4.4).

![The Leap Motion capsule hands (Benson, 2017).](image)

### 3.3 Preliminary Design Test: Leap Motion Hands

A preliminary design test of the digital Leap Motion hands was conducted. The purpose of the test was to evaluate usability aspects of the Leap Motion Capsule hands. Further, how consistent the Leap Motion hands were experienced to the movements of the participants own physical hands, while following the drumming teacher’s hands. Next, if the appearance and tracking of the Leap Motion hands while drumming, caused the participants attention to be led to the quality of the movements of the Leap Motion hands, instead of engaging with the drumming lesson.

5 participants saw the pre-recorded video in the HTC Vive HMD of the drumming teacher from the second drumming recording. Participants’ own hands were
tracked in real-time by the Leap Motion, and rendered on top of the teacher’s hands, with the Leap Motion Capsule hands (see figure 9). Before watching and participating in the drumming recording, participants were told how to position the djembe. After, a calibration phase was dedicated for the participants to see their Leap Motion hands in the HMD, while adjusting their seating, and position of the djembe. In the viewed Unity scene of the drumming recording, the position transform coordinates of the prefabs CameraRig and LMHeadMountedRig, were adjusted accordingly to participants’ perception of their perceived height (Y), center (X, left and right), and their position along the depth axis (Z). Participants experience of the Leap Motion hands were assessed on three self-assessment questionnaire items displayed below:

1. How did you experience the digital versions of your hands?
2. How consistent were the digital hands with your own hand movements?
   Please rate your agreement to the question below on a scale from 1 (not consistent) to 7 (very consistent).
3. Do you have any other comments on your experience?

Question 1, targeted the immediate experience of the digital version of the participants hands. Question 2, asked the participants to report on how consistent the digital hands were with their own hand movements on a Likert scale from 1 (not consistent) to 7 (very consistent). Question 3, served the participants to express additionally thoughts about their user experience. After the self-assessment questionnaire, participants were verbally asked by the test-conductor if they had additional comments to their experience towards the tracking of the participants hands of the Leap Motion.

**Participant Feedback**

The reports in question 1, indicated inconsistent tracking of the participants hands with the Leap Motion, as the virtual hands would disappear, dropping in and out, and only be showed flashes of time. One participant reported: “Sometimes not align with my real hands”. Participants rating to question 2, was on average 3.5 out, with 7 as the maximum rating possibility. Only one participant reported to question 3, expressing positive feelings expressing enjoyment, and stating seeing the teacher’s hands supported the following of the tempo. On the negative part, the same participant stated that it was difficult to control the tone of the drum, as you cannot see
the real drum when hitting. However, the same participant also reported in question 1, that the tracking was not great, and the digital hands did not add much: “The tracking wasn't great, they would drop in and out. I don't think they added too much anyhow.”

In the additional feedback gained after the questionnaire, one participant stated that the hands in general spaced in and out and took the attention away from the drumming. The participant thought that drumming along the teacher would work just fine without the Leap Motion hands; experiencing the Leap Motion virtual hands annoying. Additionally, they did not add anything to the experience due to their bugs, spacing in and out. One participant spoke out loud in the beginning of the video; mentioning that the Leap Motion hands spaced out. Three other participants stated in the additional feedback that the hands would space out, but was not considered severe. However, even slight an inaccuracy of the Leap Motion hands by the disappearing and appearing, can cause the Leap Motion hands to feel unnatural and leading participants attention to the quality of their appearance. Therefore, the Leap Motion hands are discarded for the First test iteration. Eventually, the Leap Motion hands will be a confounding variable, limiting the possibility to test the effect of the first-person perspective of the drumming teacher.
4 First Test Iteration

4.1 Methods and Materials

Experimental Design

The purpose of the first test iteration is to conduct a learning experiment, comparing two different teaching scenarios of playing hand drums taught on a West-African djembe drum. The test hypothesis is that learning hands drums through an embodied first-person perspective mediated in VR, leads to better rhythmic understanding than learning through a 2D video. This renders the Alternative and Null hypothesis of the learning experiment:

**Alternative hypothesis**
Novices rhythm understanding and learning, is significantly higher when being taught drums rhythms through an embodied first-person perspective, compared to people taught through a 2D video.

**Null hypothesis**
There is no significant difference between novices’ rhythm understanding and learning, when being taught drums rhythms through an embodied first-person perspective, compared to people taught through a 2D video.

The first test iteration included a between-group design, comparing two viewing conditions of VR and video. The test stimuli for both test groups, was the same pre-recorded video of a drum lesson instructed by a drumming teacher, from the second drum recording. The test stimuli consisted of 5 phases. An initial trial phases taught the participants how to hit the djembe drum, to get comfortable with the djembe drum. Next four phases of rhythm patterns were taught. In each rhythm pattern, the teacher demonstrated the rhythm three times on the djembe drum, before the count in on four, to play along. Each ‘play along’ rhythm sequence was on average 49.5 seconds long. The total length of the test stimuli was 5 minutes and 53 seconds. The first 5 seconds of the recording was a black screen. 11 seconds was left in the end, after the teacher finished the final and fourth rhythm. In the experimental group, participants were taught to play drums by taking the first-person perspective
of the drumming teacher in VR, viewed through a HMD, projecting the stereoscopic recording of the teacher. Participants were presented with a physical djembe drum, matched to the position where it is located in the virtual world (test stimuli). In the control group, participants viewed the same test stimuli, thus non-stereoscopic, on a 2D monitor placed in front of them. The audio of the test stimuli was recorded with the built in stereo microphones in the LucidCam, recording audio in 48Hz, uncompressed 16-bit audio, from the teacher’s visual perspective. The viewed test stimuli was recorded in the same room section as the participants were seated, with the participants sitting on the same position as the teacher on a stationary chair.

**Participants and Recruitment**
35 participants were recruited on the University of New South Wales Art & Design (Sydney). Five participants data were not usable and discarded, producing a final sample of 30 (male=12, female=18). The group’s ages range from \( \leq 20 \) to 40; the majority accounted 25-34 years (50%). The majority were students (86.6%). Before conducting the test, participants were handed a consent form (see appendix 2) along a Participant information sheet and consent form (see appendix 3), for the test. Participants data were assured confidentiality, along their right to withdraw from the test at any time. Participants were recruited based on the criteria’s of being novices to drumming, not having any hearing disabilities, and fully functional limbs.

**Setup**
A djembe hand drum of height 60cm and diameter 30cm was used (see figure 5). Participants were seated on a stationary stool of fixed height 43.5cm, and a diameter of 33cm. The drumming lesson took place in a section of a closed room, partly covered by a black curtain (see figure 10 and 11) of (LxWxH) 250cmx320cmx390cm (see figure 10 and 11 for the setup of the experimental and control group). Each participant sound from the drumming, were recorded with a lavalier microphone clipped to their clothes, centre at chest. On-ear headphones was used to play the sound of the viewed test-stimuli. The HTC HMD were used to display the test stimuli for the experimental group. The control group sat in a distance 1 meter from the 2D monitor.
Procedure

Participants were randomly assigned to each of the two test groups, and all naive to the purpose of the test. Participants were asked demographic questions before the drumming lesson in each of the two test groups (experimental and control), in an online self-assessment questionnaire (see appendix 4). Both groups were asked about their experiences with music practising. The experimental group was further asked about their previous experience with VR, by a rating scale from 1 (never tried it before) to 7 (uses it daily). Participants were recorded to compare the rhythm accuracy between the drumming teacher’s recording and the participant. At the beginning of the viewed test footage, an audible synchronisation clap from the test
footage, was outputted through a pair of speakers, before switching the sound output to the worn headphones by the participant. This was done to generate the same synchronization point in the participants audio files to the teacher, for the rhythm comparison. After the pre-recorded drum lesson, participants completed post questions to their subjective learning experience, filled out in the online self-assessment questionnaire (see appendix 4).

4.2 Measures

Objective Learning: Rhythm Accuracy
The variable of rhythm accuracy was chosen to objectively quantify the novice’s ability to follow the teacher’s djembe rhythms. The rhythm comparison between the novice and teacher was assessed through the rhythm feature of tempo. Tempo is referred to the pace of a piece, usually indicated in beats per minute (BPM) (Lumen-Learning, 2015) (Medusaworks-Oy/ML, 2006). Meaning that the amount of time between successive beats - a note, is a specified fraction of a minute. (Lumen-Learning, 2015). For example, a tempo of 60 bpm is one beat per second; meaning if a drummer is hitting the drum-skin 60 times a minute, the bpm value is 60. A tempo of 120 beats per minute is double as rapid, given a greater amount of BPM, resulting in a smaller amount of time between successive beats (Lumen-Learning, 2015). Each participant produced a unique audio file, capturing their rhythmic performance during the experiment. The learning efficiency of both test groups was quantified by comparing participants individual audio files analysed in BPM, with the drumming teacher’s, described later in the results section.

Subjective Learning: Self-assessment Questionnaire
Participants answered a self-assessment questionnaire post to their participation in the pre-recorded drumming lesson. The questionnaire was designed to measure 4 aspects of the participants subjective experience of the given learning media, including: Flow, User-experience, Oneness, and Presence (see appendix 4, for the self-assessment questionnaire).
Flow: A Predictor of Learning Experience

Flow is measured using the Flow Short Scale (FSS) by Engeser and Rheinberg (2008). The concept of Flow was coined by the social psychologist Csikszentmihalyi in 1975 (Csikszentmihalyi, 1975), describing a highly functional state by which individuals both feel highly challenged and capable in an activity. Further, defined by experiences of a merging of action and awareness, sense of control, and high levels of concentration (Custodero, 1998, p.22). You enter the flow zone when a task matches the right amount of challenge, that is neither too easy leading to boredom, or to difficult leading to anxiety (Engeser and Rheinberg, 2008, p.160). It has been found that people experiencing flow tends to be more motivated to commit and continue with learning activities (Engeser and Rheinberg, 2008, p.160). Evaluating participants flow experience is used to gained subjective data on the learning experience. Additionally, to use it as a predictor of performance. The FSS consist of 10 items covering factors of involvement, concentration, and (optimal), challenge, measured on a 7-point Likert Scale from 1 (not at all) to 7 (very much).

Below are listed the 10 items from the FSS:

1. I feel just the right amount of challenge
2. My thoughts/activities run fluidly and smoothly
3. I don’t notice time passing
4. I have no difficulty concentrating
5. My mind is completely clear
6. I am totally absorbed in what I am doing
7. The right thoughts/movements occur of their own accord
8. I know what I have to do each step of the way
9. I feel that I have everything under control
10. I am completely lost in thought

User-experience

9 questions were tailored specifically for the test hypothesis, to evaluate the participants user-experience. Questions 1-5 targets the participants perceived difficulty of following the mentor’s rhythm patterns. Question 6 assessed the feeling of dizziness. Enjoyment is rated on a single item in question 8. All items are rated on a 7-point Likert Scale from 1 (strongly disagree) to 7 (strongly agree).

1. I had no trouble following the teacher’s drumming rhythms
2. It felt in control of following the drumming teacher tempo
3. I felt in control of coordinating my hands to the drumming teacher’s hands
4. I felt no anxiety through the drumming training
5. Seeing the teacher’s drumming hands supported my rhythmic understanding
6. I felt no dizziness at all after the drumming session
7. I enjoyed the drumming teaching

In the final section of the questionnaire, participants were asked if they would recommend the experience learning technique to their friends:

8. a. Experimental Group: I would recommend this VR learning technique to my friends
   b. Control Group: I would recommend this learning technique to my friends

The closing questionnaire item was asked to gain additional feedback towards the learning experience:

9. Do you have any other comments on your experience?

Oneness
The Inclusion of Other in the Self Scale is originally developed by Aron, A., Aron, E.N. and Smollan (1992). The scale was used to measure the extent to which the participants feel bodily in sync with the mentor’s location and rhythmic movements, related to the concept of body-syntonicity. Moreover, if the participants sense they are located besides the mentor or playing from the mentor’s position. The scale is a pictorial measure of closeness shown in figure 12. First picture depicts non-overlapping circles, and the seventh picture of two nearly overlapping circles. Participants were asked to select the figure of circles, which best captured the extent to which they felt close to the drumming teacher: Please select the number of the picture below which best describes your relationship with the drummer.
Fig. 12: Inclusion of the Self in the Other Scale measuring Oneness (Aron, A., Aron, E.N. and Smollan, 1992).

Presence

The measure of presence targeted presence seen through the Plausibility Illusion (Psi) and not the Place Illusion (PI). Psi relates to the scenario presented is actually happening, even though you know it is not (Slater, 2009, p.3549, 3553). PI refers to presence experienced as the ‘sense of being there’ in the environment represented by the VR system (Slater, 2009, p.3551). Further, connected to the physical properties of the given system, situating technological immersion. Presence viewed through PI is discarded, as the experiment compares two different learning medias - VR and Video. Essentially producing to different systems of physical and technological properties. Therefore, Psi is used to evaluate: “the extent to which the system can produce events that directly relate to the participant, the overall credibility of the scenario being depicted in comparison with expectations” (Slater, 2009, p.3549). Here, it is meant whether the two test scenarios can produce an automatic and instinctive response of the participant to engage in the action of drumming, in accordance to the credibility of the scenario being depicted – a drum lesson. (Slater, 2009, p.3555). 4 questions served to measure presence, accompanied by 7-point Likert Scales. Question 1 was adapted from Nichols et al. (2000). Questions 2 and 3 were adapted from the Igroup Presence Questionnaire (IPQ) (Schubert, Friedmann and Regenbrecht, 2000). Question 4 was constructed for the experiment, directly targeting Psi.

Presence (Psi) Questions:

1. The viewed drumming sequence became more real or present to me compared to the "real world"?
   1 (at no time) to 7 (almost all the time)
2. I was not aware of my real environment
   1 (strongly disagree) to 7 (strongly agree)
3. I was completely captivated by the drumming teaching
   1 (strongly disagree) to 7 (strongly agree)
4. I felt like the viewed drumming session was actually happening
   (strongly disagree) to 7 (strongly agree)

4.3 Results

Objective Learning: Rhythm Accuracy
In the experimental group, the audio recording was discarded of participants 2, 5, 8, 11, and 14. Participants noticed that the audio and video played through the Unity application was out of sync. After participant 2, all participants were asked after the questionnaire, if they perceived the audio and video out of sync. The synchronization of the audio and video played through Unity was fixed during the test, by the participants wearing the HMD at their drumming position before starting and playing of the unity application. Participants’ wav files were synchronized with the teacher’s in Audacity with the synchronization clap. The drumming lesson consisted of four rhythm patterns, both including a normal and fast tempo. Eight wav files were generated for each participant, containing the normal and fast tempo of each rhythm. It was prioritized to avoid the teacher’s voice in the generated wav files, to not cause a further difference in the teacher’s and participants’ audio recordings. Eight sequence markers of label tracks were created in Audacity related to the teacher’s starting points. The sequence markers contained both the normal and fast tempo of the rhythm ‘play along periods’. The sequence markers ensured the generation of the eight individual wav files for each participant, to match precisely the teacher’s wav files respectively. Each sequence marker in the normal tempo wav files, started on the point where the teacher started the drumming rhythm, after the count in on four. The end was marked before the teacher counted down on four. The fast tempo wav files were created after the teacher has instructed to play faster, from the point where the rhythm started, without the teacher’s voice-over. The fast pace tempo of the rhythm accelerated from the instruction of playing faster; the last part of the accelerated tempo was kept in a steady fast pace. The MIRtoolbox 1.7 for Matlab, was used to analyse participants rhythm performances (Humanistis-yhteiskuntatieteen tiedekunta, 2018). The MIRtoolbox offers
tools to extract musical features from audio files, such as rhythm with its subcomponents. The audio feature of tempo was analysed by the `mirtempo` function, applied to extract the tempo in BPM from the generated wav files. The tempo was calculated for the teacher’s and the participants eight wav files. To evaluate the participant’s accuracy of following the teacher’s tempo, the difference for each of the participants tempo results, were found from the teacher. An average was taking of the eight tempo differences from the teacher of the participant, to compute their final tempo score. The tempo score expressed on average how many BPM the participant differed from the teacher out of the eight wav files.

The final tempo scores were evaluated as ratio data. An independent t-test were performed with participant’s final tempo score in the two test groups. The reported results showed no significance difference for the experimental group exposed to the VR drum lesson (M=35.311, SE=2.956), than for the control group exposed to the 2D drum lesson (M= 30.821, SE=2.1043), t(28)= 1.236, p= 0.226, α = 0.05. Thereby accepting the null hypothesis that the participants rhythm understanding and learning in both groups produced equal means.

![Histogram and Box plot](image)

Fig. 13: Image left: Histogram displaying the participants total average of the eight tempo differences from the teacher. The tempo difference average scores are marked by red for the experimental group, and the control group score is marked by blue. Image right: Box plot, displaying the variance of the participants total average of the eight tempo differences from the teacher. The tempo difference average scores are marked by 1 for the experimental group, and the control group scores are marked by 2.

Though there was found no significant difference among the two test groups, the control group performed better with 4.49 BMP less in difference from the drumming teacher, than the experimental group. Inspecting the data further, the total
average of the fast tempo difference scores of the two test groups, produced almost equal results. The control group produced a fast tempo difference score with a mean value of 20.29 BPM. While the experimental group produced a mean value of 20.49 BPM. The total average of the normal tempo difference scores produced 41.36 BPM in the control group, and 50.13 BPM in the experimental group. Indicating the control group was 8.77 BMP closer to following the teacher’s tempo, than the experimental group, in these sequence parts. An independent t-test was also performed among the two groups total average of the normal tempo scores. The result also indicated no significance among the two groups ability to follow the teacher’s tempo in normal pace (see table 1 for descriptive statistics of the tempo evaluation).

<table>
<thead>
<tr>
<th>Descriptive statistics</th>
<th>Tempo (BPM)</th>
<th>Mean</th>
<th>Std.Dev.</th>
<th>Std.Err</th>
</tr>
</thead>
<tbody>
<tr>
<td>Experimental (BMP)</td>
<td>Total average</td>
<td>35.11</td>
<td>11.45</td>
<td>2.95</td>
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<td>Control (BMP)</td>
<td>Total average</td>
<td>30.82</td>
<td>8.15</td>
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<tr>
<td>Experimental (BMP)</td>
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<td>50.13</td>
<td>17.22</td>
<td>4.45</td>
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<tr>
<td>Control (BMP)</td>
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<td>41.36</td>
<td>13.91</td>
<td>3.595</td>
</tr>
<tr>
<td>Experimental (BMP)</td>
<td>Fast</td>
<td>20.49</td>
<td>12.08</td>
<td>3.12</td>
</tr>
<tr>
<td>Control (BMP)</td>
<td>Fast</td>
<td>20.29</td>
<td>7.82</td>
<td>2.02</td>
</tr>
</tbody>
</table>

**Subjective Learning: Self-assessment Questionnaire**

**Flow**

An independent t-test was performed with participant’s average flow score from the FSS in the two test groups. The result of the FFS flow scores was found not significantly different for the experimental group exposed to the VR drum lesson (M=5.580, SE=0.152) than for the control group exposed to the 2D drum lesson (M= 5.1067, SE=0.254), t(28)= 1.601, p= 0.121.

**User-experience**

Participants ratings in the first seven user-experience items produced a total mean value for the experimental group at 5.73, and a mean value at 5.70 for the control
group. Item 8, covering the recommendation of the presented learning experiences, produced a mean rating of 6 in the experimental group, and 5.6 in the control group.

The experimental group reports to the final question in the questionnaire: “Do you have any other comments on your experience?”, indicated feelings of absorption, immersion, enjoyment, and expressing the learning scenario as an effective and interesting way to learn drums. Contrary these reports, two participants also in the experimental group, stated that the realness and credibility of the drumming lesson, was affected by the fairly short duration of the drumming lesson:

“The longer I spent in the VR, the more real the experience felt”.

“You could really only grasp the basics because it was such a short video. But if VR is used in actual situations of teaching drumming, it would be an effective and interesting way of learning to drum- though the pace could be a little slower...”.

In the control group, two participants stated that it was hard to hear their own drumming over the teacher’s. As the participants wore headphones, it diminished their hearing of their own produced rhythms. However, the participants wore headphones to enable a rhythm comparison with the teacher wav files. Not playing the sound through a set of speakers.

The questionnaire item I would recommend this learning technique to my friends, produced a mean value of 6 in the experimental group, and 5.6 in the control group, out of 7 as the maximum score possible.

Oneness
There were found no significance difference between the experimental and control group, in the reported oneness ratings, with the exact same mean of 4.73, and median of 5 in both groups. The Oneness scores, indicated that the first-person perspective rendered in the HMD experienced by the experimental group, did not provide a stronger sense of feeling in tune and synchronizing with the teacher’s movements in this experimental setup.
Presence

An independent t-test were performed with participant’s average presence score in the two test groups. The result of the presence scores was found significantly different for the experimental group exposed to the VR drum lesson (M=5.617, SE=0.251) than for the control group exposed to the 2D drum lesson (M= 4.7333, SE=0.263), t(28)= 2.4282, p= 0.0219, α = 0.05 (see figure 14, for histogram of presence scores). The presence item that rendered the greatest rating difference among the two test groups was item 2: “I was not aware of my real environment”, 1.67 difference; with a mean score on 6 in the experimental group, and 4.33 in the control group.

![Histogram and Box plot](image)

Fig. 14: Image left: Histogram displaying the average of the four presence items for the experimental and control group. The experimental average scores are marked by red, and the control group scores are marked by blue. Image right: Box plot, displaying variance of the participants total average of the four presence items. The presence scores are marked by 1 for the experimental group, and 2 for the control group.

See appendix 5, for descriptive statistics of each measurement for the control and experimental group.

4.3 Discussion of First Test Iteration

Drum lesson: Trial phase

It was found through observation and the recorded audio files, that the participants in both test groups, did not hit the djembe that hard, and with the same method/precision as instructed by the teacher. In addition, the participants, in general did not
drummed along the teacher in the trial phase, where the drum hit method were demonstrated. Meaning, the first time the participants hit on the djembe, were in the first rhythm play along phase with the teacher. Improvements to the design of the teaching material, could be a longer trial phase, were the teacher engages the participants more directly to play along. To ensure practise in the hit method, before the rhythm sequences, which the participants are judge upon in the objective rhythm accuracy measure.

Audio Recordings

Participants’ sound was recorded by a lavalier microphone clipped to their clothes - centre on chest. Besides participants lack in practise in the trial phase, participants recording method also influenced the outcome of their produced audio data. As the lavalier microphones provides a good capture perspective for voice recording, they do not serve as the optimal recording method for capturing the sound originated from the djembe. Fundamentally, it is the sound produced that is used for the objective measure of the rhythm accuracy. For the second test iteration the recording method of the participants should be revised to capture the drumming audio more effectively.

Position of the Djembe

It was found after the first test iteration, that how the participants were instructed to hold the djembe was incorrect; holding tilting the djembe from the ground in the opposite direction from the teacher (tilting the drumskin towards oneself, instead of away). The incorrect position of the djembe could have affected the proper matching of the virtual djembe to the physical djembe sensed by the participants in the experimental condition. Which essentially could cause participants to haptic perceive a different angle than what they were visually presented in the HMD. This error is notified to be corrected for the procedure in a second test iteration.
5 Second Test Iteration

5.1 Methods and Materials

Experimental Design
The experimental design followed the same as the first test iteration. Though the test stimuli was revised with a third drumming recording, to produce a final pre-recorded drum lesson. The drumming teacher hired, was the same used for the test stimuli in the first test iteration. The structure of the test stimuli followed the same as the first test iteration, with the same four rhythms. The total length of the recorded test stimuli was 7 minutes and 9 seconds long. The test stimuli consisted of a longer trial phase with more deliberate instructions. This was to ensure that the participants got a sense of how to hit the djembe properly before the first rhythm instruction. The four rhythm patterns taught was on average 82 seconds long each.

The audio recording of the mentor in the first experiment, was recorded with the in-built stereo microphones in the LucidCam. In the first experiment, the participants could see what the teacher saw, but not hear a reliable version of what the teacher heard. This experiment revises the audio capture to be recorded from a binaural point-of-view with the Roland CS-10EM binaural microphones. The microphones are electret and omnidirectional, capturing a frequency range of 20 Hz to 20,000 Hz (Roland, 2018).

Participants and Recruitment
41 participants were recruited on the University of New South Wales, Art & Design (Sydney). Additional by advertisement posters and online recruitment through the university’s mailing list system for students and staff. It was ensured that none of the participants had participated in the first test iteration. One participant’s data were not usable and discarded, giving a final sample of 40 (male=14, female=26). The group’s ages range from <=20 to 55; the majority accounted <=20 years (35%) and 21-25 years (30%). The majority were students (80%). Participants were recruited by the same conditions as in the first test iteration, likewise treated with the same ethical rights and consent forms.
Setup and Procedure
The setup and procedure followed the general structure of the first test iteration. Thus, the audio of the participants was captured with a Zoom H4n Pro, placed in front of the drum. The changes to the procedure, included the test conductor demonstrating how to hold and position the djembe correctly, with the right angle tilting the djembe from the floor away from the participant (see appendix 6). Further, the test conductor explained in the brief about the drum lesson content, that the participant would first be instructed by the teacher in the drum lesson on how to hit the djembe. Next, following a count in on four beats, to hit along the teacher.

The evaluation of the second test iteration relies on the same measurements methods used in the first test iteration (see appendix 4, for the self-assessment questionnaire).

5.2 Results
Objective Learning: Rhythm Accuracy
Similarly the first test iteration, there was found no significant difference between the experimental group exposed to the VR drum lesson (M=24.567, SE=2.282), than for the control group exposed to the 2D drum lesson (M= 21.739, SE=1.932), t(38)= 0.946, p= 0.350.

Fig. 15: Image left: Histogram displaying the average of the four presence items for the experimental and control group. The experimental average scores are marked by red, and the control group scores are marked...
Independent t-test was also performed for the normal and fast tempo of the four rhythm sequences. Similar to the first test iteration, there was found no significance in the normal and fast tempo scores between the two test groups. (see table 2 for descriptive statistics of the tempo evaluation).

**Table 2: Summary of Tempo Evaluation - Second Test Iteration**

<table>
<thead>
<tr>
<th>Descriptive statistics</th>
<th>Tempo (BPM)</th>
<th>Mean</th>
<th>Std. Dev.</th>
<th>Std. Err</th>
</tr>
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<td>Experimental (BPM)</td>
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<td>2.216</td>
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<td>Control (BMP)</td>
<td>Fast</td>
<td>14.933</td>
<td>10.175</td>
<td>2.275</td>
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</tbody>
</table>

**Subjective Learning: Self-assessment Questionnaire**

There was found no significance in the subjective ratings of flow, user-experience, and presence, from independent t-test’s (see appendix 7 for descriptive statistics of the subjective learning). The Mann-Whitney test was used as a significance test of the oneness ratings, due to non-parametric data. The feeling of oneness with the teacher showed significance difference between the experimental group exposed to the VR drum lesson (M=5.250, SE=0.332), than for the control group exposed to the 2D drum lesson (M= 4.400, SE=0.303), t(38)= 1.558, p= 0.048, α = 0.05 (see figure 16 for visualization of Oneness scores). Though the reported p-value is 0.002 from the alpha level of 0.05, showing that the experimental group oneness ratings was barely significance.
Fig. 16: Image left: Histogram displaying the average of the single item Oneness for the experimental and control group. The experimental average scores are marked by red, and the control group scores are marked by blue. Image right: Box plot, displaying variance of the participants total average of the single item Oneness. The presence scores are marked by 1 for the experimental group, and 2 for the control group.

Participants additional comments to the experience in the last questionnaire item, indicated enjoyment in the both groups. In the experimental group, participants expressed positive feelings to VR as a learning medium:

“I have never tried anything like this before. I'm in complete awe of this experience. I really enjoyed it and would love to see VR contribute to practical learning experiences in the near future”.

“It was my first time to try VR, and I could learn drumming as enjoying it. I felt this method should be used in many areas.”

One participant also in the experimental group, noted that it was harder to know if the bass tone was hit correctly, because it was farther away; compared to producing the tone, which was easier to know where to hit, because the participant could feel the edge, being closer to the body. In the control group one participant explained how the increase in the teacher’s tempo led the participant to focus on the teacher’s hands, whilst when the participant was comfortable with the speed the 2D monitor became less important. Likewise, the first test iteration, one participant found it challenging to hear the sound from the participant own drumming, due to wearing headphones:
Second Test Iteration

“I could not hear myself properly as I was using headphones, so I could not tell clearly whether my drumming sounded good or bad or like the drumming instructor. But in terms of rhythmical training, it was very good”.

The questionnaire item I would recommend this learning technique to my friends, produced a mean value of 6.5 in the experimental group, and 6.1 in the control group. This was 0.5 higher in rating than the first test iteration for both test groups.

5.3 Discussion of Second Test Iteration

In this section the results of the second test iteration will be discussed, supported with reflections to the first test iteration results.

To evaluate participants performance objectively, participants tempo in BPM was computed from their recorded audio and compared with the teacher’s performance. As BPM evaluates the number of beats per minute, participants could eventually hit off beat, but still produce the same number of beats as the teacher. This comparison could be evaluated further, to include an onset detection quantifying the rhythm accuracy by comparing participants drum hits in the time domain with the teacher’s. This method could provide a more accurate estimate of whether participants hit on the drum skin exactly at the same time the teacher did. A recurrent critique from the first and second test iteration was, that wearing headphones diminished participants hearing of their own drumming. Headphones was chosen for the sound output, due to the rhythm comparison between the teacher and novice. This setup could affect the participants ability to follow the teacher’s rhythms, in terms of the diminished audio feedback from themselves, to be match with the teacher’s sound. As a pre-requisite to carrying out the independent t-test for significance difference between tempo scores, a variance test was computed, finding an equal amount of variance in the two test groups computed tempo scores in BPM. However, inspecting the tempo scores in BPM, comparing the poorest performing participant to the best in the experimental group, gave a difference on 35.16 BPM; in the control group the greatest difference between two participants was at 34.81 BPM. A rating system of BPM tempo score performance could be developed to categorize participants performances, in addition to the rhythm comparison.
The experimental group presence scores were found significant different in the first test iteration. Moreover, a significance difference was found in the oneness scores in the second test iteration. These results can be influenced by the perspective rendered in the HMD, rendering the same position as the drummer. Though, as the significance difference of the presence and oneness scores were not recurrent in both test iterations, it can be argued that the sample size had an effect, with 30 and 40 participants in the first and second test iteration respectively. The mean of the user-experience ratings was reported as the highest compared to ratings of flow, oneness, and presence, in both test groups and both test iterations. This can raise the question whether the given teaching material was constructed in a way that provided clear instructions, along a suitable skill level. Inspecting the flow scores further in both test iterations, the lowest scored item in the FSS was: *I am completely lost in thought*. In the first test iteration the item produced a mean value of 3.73 in the experimental group, and 3.46 in the control group. In the second test iteration the item was scored 3.9 in the experimental group, and 3.65 in the control group. It was noted during the second test iteration that three participants asked what the question meant. Participants was explained according to Harmat, et al. (2016, p.150), that the item meant: loss of self-consciousness. The comprehension of the question could have differed between the participant, possible affecting the rating, and dragging total mean values down of the FFS.
6 Conclusion

This thesis investigated if learning hands drums through an embodied first-person perspective mediated in VR, leads to better rhythmic understanding than learning through a 2D video. The results of the rhythm comparison in the two test iterations, found no significance difference between the experimental and control group learning of rhythms, evaluated in the ability to follow the teacher’s tempo in BPM. Though, the majority of the participants described their experience as enjoyable in both test iterations. Additionally, indicating motivation towards the given learning technique in both test groups. Which can situate the question whether the given musical instrument and task was a motivation, along the given teaching material. The two test conditions were designed to detect the effect of a first-person perspective of a drumming teacher, on a novice’s rhythm accuracy and learning. Thus, the two conditions differed in visual display, the control group had the ability to watch their own hands playing on the physical djembe. This could produce an advantage in terms of acquiring a better sense of the edge when the hitting drum skin. Though, the restraints in this scenario, was the shifting of attention between the participants hands and the playing teacher viewed on the 2D monitor in front of them. The Leap motion hands was discarded after the preliminary design test. This was based on the inconsistent tracking of the participants hands, causing attention to be directed to the quality of the leap motion hands. As the viewed drum lesson was a pre-recorded video, the possibility of corrections to participants rhythm performance real-time from a teacher was not available. Participants were not given any feedback upon how well they performed the rhythm in the first and second test iteration - from an objective source. To optimize the participants learning, future studies could explore real-time feedback of participants rhythm performances.
Acknowledgment

7 Acknowledgment

I would like to thank my connected supervisors Stefania Serafin, Tomasz Bednarz and Volker Kuchelmeister for their guidance during the project. Further, I would like to thank the EPICentre for facilitating the project development and the connected facilities. Two professional drummers were used to design the learning material for the project, who I would like to thank for their knowledge and time: Blair Greenberg and Saul Smith.
8 References


References


Slater, M., 2009. Place illusion and plausibility can lead to realistic behaviour in immersive virtual environments. Philosophical Transactions of the Royal Society B: Biological Sciences, 364(1535), pp. 3549-3557.


Appendix 1 – Drumming Recording details

Drumming Recording 1
Drummer found through drumbeats.com.au. 40 years practicing, teaching, drumming shows with a west African drumming group, skills in instruments Djembe, bongo, and guitar. The drummer was 181 cm tall.

Drumming Recording 2
Drummer was found through Souldrummer.com.au. Examples of the drummer’s experience, included drum circle facilitator and performer, practice in teaching on workshops. The drummer was hired based on his skills on the djembe. The drummer was 175 cm

Drum lesson: Practice structure

0. Introduction on how drumming/hitting on the djembe (1.5 minute)

1. Instruction of rhythm #1 (1.5 minutes)
   The first rhythm you are going to learn is ..
   It is build up by
   Guide the student verbally to play along, countdown
   Now you play along with me, 1 2 3 4

2. Instruction of rhythm #2 (1.5 minutes)
   The second rhythm …
   It is build up by
   Guide the student verbally to play along, countdown
   Now you play along with me, 1 2 3 4

3. Instruction of rhythm #3 (1.5 minutes)
   The third rhythm ...
   It is build up by
Guide the student verbally to play along, countdown
Now you play along with me, 1 2 3 4

4. Instruction of **rhythm #4** (1.5 minutes)
The fourth rhythm ...
   It is build up by
   Guide the student verbally to play along, countdown
   Now you play along with me, 1 2 3 4

**End:** Closure of the drumming sequence (15 seconds)
Appendix 2 – Consent Form

Study Abroad Research Practicum at EPICentre, UNSW ART & Design Conducted by Mie Moth-Poulsen

Consent form for participation in a pre-recorded Drumming lesson

Please read the following information carefully.

I Mie Moth-Poulsen is conducting today’s research, used as a part of writing my Danish master thesis [postgraduate final semester]. I am a Study Abroad Research Practicum Student at the EPICentre located at University of New South Wales, ART & DESIGN. The topic is concerned with the design of a pre-recorded drumming lesson to teach novices to play drums.

As a participant, I will ask you to participate in a pre-recorded drumming lesson. You will be instructed in how to play a set of drumming rhythms by a drumming teacher. Next, asked to play along the teacher. The observations and information I will collect today will help me to build improvements into the design and will be used as part of my research project. If you have any questions, I encourage you to ask them.

As your participation is entirely voluntary, you may choose to withdraw from the session at any time.

If you have any further queries you can contact me: Mie Moth-Poulsen on phone number: +61 449 892 707, or email: mmp123@gmail.com.

Your privacy, observers & recording of data

Please be assured that the information and opinions you provide today will be used only for research purposes.

I will record information about the drumming lesson including video, audio, and questionnaire. This will help me to see how to make improvements to the design and provide data for the research. For any and all uses of this recorded data, I undertake to guarantee your anonymity. Your name will appear only on this form, which will be filed separately, and is kept only to verify your consent to participation in this session. The form will be destroyed after the completion of the related exams to the project.

The data recorded may be used for:

• Analysis, to review interactions after the session
• Documenting the findings of the session
• Presentation video for my exam, uploaded to youtube, including video recording of you playing the drums. You can say no to this in the provided questionnaire, and no video footage of you will be included in the presentation video.
• Providing feedback to the project about the design and how well it succeed.
• Teaching or training purposes by the researcher, but only for demonstrating the process of a typical research session (e.g. how to run this type of session).
• Notes and questionnaires may be reviewed by project connected supervisors. If you sign this sheet, you give your permission to have notes recorded and for the notes to be passed on to project supervisors.

The notes will not be transferred to anyone else unless your consent has been obtained.

Please continue over…
Appendix

Non-disclosure

By participating in this session, you may be privy to information that the project regards as confidential, and must accept that the participant is the sole and exclusive owner of this confidential information.

It is required that you have no hearing disabilities and have full functioning limbs of hands and arms.

You must not at any time after the session disclose to any other person or use, adopt, be a party to, aid or abet any disclosure, use, adoption or employment of this confidential information either directly or indirectly for any purpose.

If you have read the above information carefully and understand and accept its contents, please complete and sign the following statement:

1. ________________________________
   (Participant’s Name – please print)

I have read the above passage carefully and understand its contents. I voluntarily agree to participate in the drumming lesson evaluation conducted by Mie Moth-Poulsen.

______________________________  ________________________________
(Participant’s Signature)         (Date)

______________________________  ________________________________
(Researcher’s Signature)         (Date)
Appendix

Appendix 3- Participant information sheet and consent form

EPIContra (Expanded Perception and Interaction Centre), UNSW Art & Design

ONLINE PARTICIPANT INFORMATION STATEMENT
Participation in a pre-recorded drumming lesson
Mie Math-Poulsen, Tomasz Bednarz, Volker Kuchelmeister

1. What is the research study about?
   You are invited to take part in this research study. The research study aims to evaluate learning material concerning drumming teaching to novices using a West-African djembe. The research is a part of a postgraduate research project, and is executed at the UNSW Art & Design, EPIContra. You have been invited because you expressed your interest in this experiment, and responded to our advertisement.

2. Who is conducting this research?
The study is being carried out by the following researchers: Mie Math-Poulsen, Tomasz Bednarz, Volker Kuchelmeister.
Research Funders: This research is being funded by Expanded Perception and Interaction Centre, UNSW Art & Design

3. Inclusion/Exclusion Criteria
   Before you decide to participate in this research study, we need to ensure that it is ok for you to take part in it. The research study is looking to recruit people who meet the following criteria:
   • You are a novice to drumming
   • You not have any hearing disabilities
   • You have fully functional limbs

4. Do I have to take part in this research study?
   Participation in any research study is voluntary. If you do not want to take part, you do not have to.
   If you decide you want to take part in the research study, you will be asked to:
   • Read the information carefully (please ask questions if necessary).
   • Complete the online questionnaire.

5. What does participation in this research require, and are there any risks involved?
   If you decide to take part in the research study, we will ask you to complete an online questionnaire. The questionnaire will ask you questions about your user-experience of the pre-recorded drumming lesson. It should take approximately 10 minutes to complete.
   We don’t expect this questionnaire to cause any harm or discomfort, however if you experience feelings of distress as a result of participation in this study you can let the research team know and they will provide you with assistance.

6. What are the possible benefits to participation?
   We hope to use information we get from this research study to benefit others who is investigating music learning within media.

7. What will happen to information about me?
   Submission of the online questionnaire is an indication of your consent. By clicking the ‘I agree to participate’ button you are providing your permission for the research team to collect and use information about you for the research study. Your data will be kept for a period of 7 years after the project’s completion. We will store information about you in a digital format at EPIContra backup share drive and hard drive. Your information will only be used for research purpose only and used in fully anonymous way. We are not planning to use any personal information, and research outcomes will be combination of all results collected from the participant.
8. How and when will I find out what the results of the research study are?
   The research team intend to publish and report the results of the research study in a variety of ways. All information published will be done in a way that will not identify you. You can receive a copy of the results. You will be asked to provide your contact details if you want to receive those results. We will only use these details to send you the results of the research.

9. What if I want to withdraw from the research study?
   If you do consent to participate, you may withdraw at any time. You can do this by closing the questionnaire. If you withdraw from the research we will destroy any information that has already been collected.

10. What should I do if I have further questions about my involvement in the research study?
    The person you may need to contact will depend on the nature of your query. If you require further information regarding this study or if you have any problems which may be related to your involvement in the study, you can contact the following member(s) of the research team:

Research Team Contact

<table>
<thead>
<tr>
<th>Name</th>
<th>Position</th>
<th>Telephone</th>
<th>Email</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tomasz Bednarcz</td>
<td>Director of Visualisation, A/Professor</td>
<td>0459555376</td>
<td><a href="mailto:t.bednarcz@unsw.edu.au">t.bednarcz@unsw.edu.au</a></td>
</tr>
<tr>
<td>Mie Moth-Poulten</td>
<td>Practicum Student at EPICentra, Postgraduate Student</td>
<td>0449989707</td>
<td><a href="mailto:mmp123@gmail.com">mmp123@gmail.com</a></td>
</tr>
<tr>
<td>Volker Kuchelmester</td>
<td>Senior Lecturer</td>
<td>0417333778</td>
<td><a href="mailto:v.kuchel@unsw.edu.au">v.kuchel@unsw.edu.au</a></td>
</tr>
</tbody>
</table>

If at any stage during the study you become distressed or require additional support from someone not involved in the research please call:

Contact for feelings of distress

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<tr>
<th>Name</th>
<th>Position</th>
<th>Telephone</th>
<th>Email</th>
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</thead>
<tbody>
<tr>
<td>Mie Moth-Poulten</td>
<td>Practicum Student at EPICentra, Postgraduate Student</td>
<td>0449989707</td>
<td><a href="mailto:mmp123@gmail.com">mmp123@gmail.com</a></td>
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</tbody>
</table>

What if I have a complaint or any concerns about the research study?
If you have a complaint regarding any aspect of the study or the way it is being conducted, please contact the UNSW Human Ethics Coordinator:
## Appendix

**EPICentre (Expanded Perception and Interaction Centre), UNSW Art & Design**

### ONLINE PARTICIPANT INFORMATION STATEMENT

Participation in a pre-recorded drumming session

Mie Moth-Poulsen, Tomsaz Bednarz, Volker Ruchtelmeister

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<th>Complaints Contact</th>
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<tbody>
<tr>
<td>Position</td>
<td>Human Research Ethics Coordinator</td>
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<tr>
<td>Telephone</td>
<td>+ 61 2 9385 0222</td>
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<tr>
<td>Email</td>
<td><a href="mailto:humanresearch@unsw.edu.au">humanresearch@unsw.edu.au</a></td>
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HC Number: HC180245

Version dated: 27 March 2018

Online Participant Group:

Page 59 of 70
Consent Form – Participant providing own consent

Declaration by the participant

☐ I understand I am being asked to provide consent to participate in this research study;
☐ I have read the Participant Information Sheet or it has been provided to me in a language that I understand;
☐ I provide my consent for the information collected about me to be used for the purpose of this research study only;
☐ I understand that if necessary I can ask questions and the research team will respond to my questions.
☐ I freely agree to participate in this research study as described and understand that I am free to withdraw at any time during the study and withdrawal will not affect my relationship with any of the named organisations and/or research team members;
☐ I would like to receive a copy of the study results via email or post, I have provided my details below and ask that they be used for this purpose only;

Name: ____________________________
Address: __________________________
Email Address: _____________________

☐ I understand that I can get access to this consent form by contacting research team

I agree, start questionnaire
Appendix 4 – Subjective Learning Self-assessment Questionnaire

Note that the questionnaire showed below was used also for the second test iteration. Further, the questionnaire displayed below was used for the experimental group; the only difference from the questionnaire used for the control group was the items:

- How much experience do you have with Virtual Reality equipment? (Experimental Group)
- I would recommend this VR learning technique to my friends (Experimental Group)
  - Asked in Control Group:
    ▪ I would recommend this learning technique to my friends

The first introduction text (questionnaire brief), the control group was briefed as follows:

Thank you for participating in this test. The questions and answers are processed anonymously and will only be used for scientific purposes for my semester project. First of all you will be asked demographic questions. Next, you will be explained about the drumming session. Afterwards, you will be given questions about your experience.
Drumming Questionnaire

Thank you for participating in this test. The questions and answers are processed anonymously and will only be used for scientific purposes for my semester project. First of all you will be asked demographic questions.

Next, you will be equipped with the Virtual Reality headset, and be explained about the drumming session. Afterwards, you will be given questions about your experience.

*Required

Please fill out the questions below

1. Participant number (Filled by conductor) *

2. Test number (Filled by conductor) *

   Tick all that apply:
   
   ☐ A
   ☐ B

3. By checking this checkbox, you give the permission to film during the test procedure. This footage will be used for a project related presentation video. When checking the box, please also write your full name in the "other" box. If you do not check this box, no footage of you will be used. *

   Tick all that apply:
   
   ☐ I agree to this
   ☐ Other:

4. Age *

   Mark only one oval:
   
   ☐ <=20
   ☐ 21-25
   ☐ 26-30
   ☐ 31-35
   ☐ 36-40
   ☐ 41-45
   ☐ 46-50
   ☐ 51-55
   ☐ 56-60
   ☐ 60+
Appendix

5. Sex *
   Mark only one oval.
   ○ Female
   ○ Male
   ○ Other:

6. Occupation *

7. How much experience do you have with Virtual Reality equipment? *
   Mark only one oval.
   
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8. Do you have practise in a music instrument. Please describe your experience (which instrument, when and for how long). *

   
   
   
   
   

Interlude
Getting to this page means that you can start the drumming session. Contact the test conductor.

Drumming experience
During your drumming experience, please rate your agreement to the questions below, on a scale from 1 (not at all) to 7 (very much).

9. I felt just the right amount of challenge *
   Mark only one oval.
   
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10. My thoughts/activities run fluidly and smoothly *
    Mark only one oval.
    
    | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
    |---|---|---|---|---|---|---|
    | Not at all | | | | | | Very much |
11. I don’t notice time passing *
   Mark only one oval.

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12. I have no difficulty concentrating *
   Mark only one oval.

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13. My mind is completely clear *
   Mark only one oval.

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14. I am totally absorbed in what I am doing *
   Mark only one oval.

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15. The right thoughts/movements occur of their own accord *
   Mark only one oval.

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16. I know what I have to do each step of the way *
   Mark only one oval.

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17. I feel that I have everything under control *
   Mark only one oval.

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<tr>
<td>Not at all</td>
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<td>Very much</td>
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</tbody>
</table>
### Appendix

18. I am completely lost in thought *

Mark only one oval.

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</table>

Not at all    Strongly agree

### Drumming experience

During your drumming experience, please rate your agreement to the questions below, on a scale from 1 (strongly disagree) to 7 (strongly agree).

19. I had no trouble following the teacher's drumming rhythms *

Mark only one oval.

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</table>

Strongly disagree    Strongly agree

20. I felt in control of following the drumming teacher's tempo *

Mark only one oval.

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<td>7</td>
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</tbody>
</table>

Strongly disagree    Strongly agree

21. I felt in control of coordinating my hands to the drumming teacher's hands *

Mark only one oval.

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</table>

Strongly disagree    Strongly agree

22. I felt no anxiety through the drumming training *

Mark only one oval.

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<td>7</td>
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</tbody>
</table>

Strongly disagree    Strongly agree

23. Seeing the teacher's drumming hands supported my rhythmic understanding *

Mark only one oval.

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<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
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</tbody>
</table>

Strongly disagree    Strongly agree

24. I felt no dizziness at all after the drumming session? *

Mark only one oval.

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<tbody>
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<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
</tr>
</tbody>
</table>

Strongly disagree    Strongly agree
25. I enjoyed the drumming teaching? *
Mark only one oval.

26. Please select the number of the picture below which best describes your relationship with the drummer *
Mark only one oval.

Drumming experience

Please rate your agreement to the question below on a scale from 1 (at no time) to 7 (almost all the time).

27. The viewed drumming sequence became more real or present to me compared to the "real world"? *
Mark only one oval.

Please rate your agreement to the questions below on a scale from 1 (strongly disagree) to 7 (strongly agree).

28. I was not aware of my real environment *
Mark only one oval.
29. I was completely captivated by the drumming teaching *
   Mark only one oval.

   1  2  3  4  5  6  7

   | Strongly disagree | | | | | | | Strongly agree |

30. I felt like the viewed drumming session was actually happening *
   Mark only one oval.

   1  2  3  4  5  6  7

   | Strongly disagree | | | | | | | Strongly agree |

31. I would recommend this VR learning technique to my friends *
   Mark only one oval.

   1  2  3  4  5  6  7

   | Strongly disagree | | | | | | | Strongly agree |

32. Do you have any other comments on your experience?

   ____________________________
   ____________________________
   ____________________________
   ____________________________
   ____________________________
   ____________________________
Appendix 5 – First Test Iteration Descriptive statistics of the Subjective Self-assessment Questionnaire for each measurement for the control (con) and experimental (exp) group

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Mean</th>
<th>Std.Dev.</th>
<th>Std.Err</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flow Exp.</td>
<td>5.580</td>
<td>0.588</td>
<td>0.152</td>
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<tr>
<td>Flow Con.</td>
<td>5.1064</td>
<td>0.982</td>
<td>0.254</td>
</tr>
<tr>
<td>User-experience Exp.</td>
<td>5.733</td>
<td>0.833</td>
<td>0.215</td>
</tr>
<tr>
<td>User-experience Con.</td>
<td>5.704</td>
<td>0.827</td>
<td>0.213</td>
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<tr>
<td>Oneness Exp.</td>
<td>4.733</td>
<td>1.792</td>
<td>0.463</td>
</tr>
<tr>
<td>Oneness Con.</td>
<td>4.733</td>
<td>1.624</td>
<td>0.419</td>
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<tr>
<td>Presence Exp.</td>
<td>5.617</td>
<td>0.972</td>
<td>0.251</td>
</tr>
<tr>
<td>Presence Con.</td>
<td>4.733</td>
<td>1.019</td>
<td>0.263</td>
</tr>
</tbody>
</table>
Appendix 6 – Correct Position of the Djembe

Appendix 7 – Second Test Iteration Descriptive statistics of Subjective Self-assessment Questionnaire for each measurement for the control (con) and experimental (exp) group

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Mean</th>
<th>Std.Dev.</th>
<th>Std_Err</th>
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<tbody>
<tr>
<td>Flow Exp.</td>
<td>5.333</td>
<td>1.159</td>
<td>0.259</td>
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<tr>
<td>Flow Con.</td>
<td>5.105</td>
<td>0.881</td>
<td>0.197</td>
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<tr>
<td>User-experience Exp.</td>
<td>5.714</td>
<td>1.061</td>
<td>0.237</td>
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<td>User-experience Con.</td>
<td>5.728</td>
<td>0.828</td>
<td>0.185</td>
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<tr>
<td>Oneness Exp.</td>
<td>5.250</td>
<td>1.564</td>
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<tr>
<td>Oneness Con.</td>
<td>4.400</td>
<td>1.353</td>
<td>0.303</td>
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<tr>
<td>Presence Exp.</td>
<td>5.575</td>
<td>1.162</td>
<td>0.259</td>
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</tr>
<tr>
<td>Presence Con.</td>
<td>4.975</td>
<td>1.186</td>
<td>0.265</td>
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