DHQ: Digital Humanities Quarterly
2021
Volume 15 Number 1

Another Type of Human Narrative: Visualizing Movement Histories Through Motion Capture Data and Virtual Reality

Eugenia S. Kim <eugeniakim_at_hkapa_dot_edu>, The Hong Kong Academy for Performing Arts

Abstract

In this article I propose that motion capture (mocap) and virtual reality (VR) technology can be used to record and visualize movement histories as a supplement to oral histories or for when a memory is based in a embodied experience. One specific example would be the presentation of illness narratives. To illustrate this situation, I examine the concept of illness narratives, particularly those created by dance artists, and use my movement history, *Lithium Hindsight 360*, as a case study. This analysis comes from the perspective of a hybrid movement artist, VR creator, archivist and digital humanist, with first-hand experience of the challenges encountered when creating a movement history. The challenges are presented within the context of mocap recording, data curation, digital preservation and sustainability issues. I end this article by providing some basic practical strategies and recommendations for researchers who are new to documenting movement histories.

Introduction

Human narratives are one of the most compelling and versatile information sources. One specific category, oral histories, "play a unique role in to documenting cultural heritage and in preserving memories of historical and everyday events" [Tebeau 2013]. These verbal narratives have traditionally been recorded in audio, video and as written transcriptions. Based on the importance of how an oral history is performed [Abrams 2010] and of how much information physical gestures and facial expressions can convey [Ritchie 2003], a question arises about whether the media formats listed above sufficiently capture all the nuances of non-verbal information. By extension, there is also a question of whether all memories can be verbalized and if other means of expression are better suited for communicating the content of those memories. 1

The issue of performance and non-verbal information within an oral history poses a complex translation problem. Video recordings or "videohistory" helps capture physical movement and nuances that audio recordings and transcripts cannot [Williams 2011]. Furthermore, certain kinds of cultural experiences cannot be fully described using only words. A concrete example of this are descriptions of symbolic poses and gestures used for complicated rituals. Similarly, physical interactions between individuals and their reactions to situations also lose their nuance when described verbally or through controlled cinematography. From an ethical standpoint, voice and photographic images can be potentially compromising even if censored or modified. This may be important if a memory includes some form of physical trauma, distress or injury. Based on the notion that an oral history is the verbal recounting of an experience, then it could be posited that a movement history is a kinesthetic rendering of lived human experiences where identifying voice and visuals could be obscured if needed. 2

With these factors in mind, I propose that the concept of a "movement history" be considered for memories that are based in physical embodied experiences which can be difficult to describe with only words or depict using photographs and video. This definition reflects Albert Lichtblau's statement that "physically active remembering also influences the narration, especially when psychology and mentality can be brought into contact with the past [Lichtblau 2011]. Additionally, I recommend that movement histories be captured and presented in a way which enables a viewer to see 3

all angles and details of the movement rather than be restricted to a single angle or framing. It is currently easiest to achieve this effect by combining mocap and VR technology with the understanding that other technologies may be used in the future.

I begin my exploration of this concept by reviewing how the evolution of oral history practices can lead to the creation of movement histories. For this article, I will focus on illness narratives expressed through somatic movement practices with my own movement history, *Lithium Hindsight 360* as a case study. Following that I offer some practical insights from my own experience as a motion capture (mocap) and virtual reality (VR) researcher to offer practical tips and relatively affordable technology solutions. One key issue will be the dissemination and accessibility of the mocap data as there is still a usability barrier in the form of technological devices. Additional resources tailored to content creators helping to maintain the movement dataset and accompanying visualization interfaces are also suggested. 4

Background

The roots of this article started in my previous research on digital dance preservation. As a choreographer and digital archivist, I was intent on finding a practical way to preserve human movement as accurately as possible. At first I believed very strongly in all the existing preservation practices, whether it was collecting good metadata, using high quality video for documentation or ensuring that a repository followed the Open Archival Information System [OAIS] model. These practices worked well in the archives and libraries where I worked, but were not so feasible as an independent artist working alone. From an archivist's perspective it meant processing haphazardly maintained content. From a choreographer's perspective, it was frustrating to be unable to see and analyze all the nuances of how a dance work was performed. 5

In 2013, I started to become more invested in the Boston dance community and its history since the 1950s. In an effort to fill gaps in the existing documentation, I was inspired by The Dance Oral History Project created by the New York Public Library [New York Public Library 2020]. 6

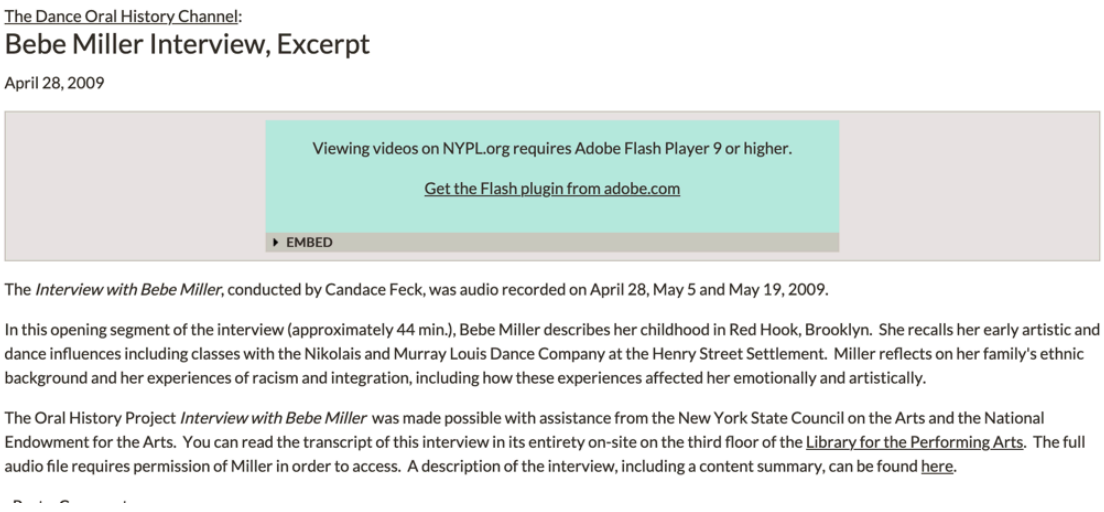

Figure 1. "Bebe Miller Interview, Excerpt." Source credit: New York Public Library. https://www.nypl.org/audiovideo/bebe-miller-interview-excerpt.

By luck, dance scholar Jeffrey Friedman happened to be teaching an oral history workshop in Boston around this time. Hearing him talk about dance-specific examples was very useful as I prepared to conduct my own interviews. Very quickly, however, I encountered the same problem that had plagued me for documenting dance: how does one verbally describe movements that defy words? 7

This problem eventually formed the basis for my practice-based research on creating movement-based pathographies. My original motivation for using mocap and VR was to give patients and viewers alike a sense of privacy. After constructing my initial prototype, however, I realized another benefit. By using mocap data to create an animation 8

viewable in VR, viewers could have complete freedom to examine the movement from any angle or distance. In some ways this meant a more unbiased form of moving image documentation in that the framing of the content had not been decided for the viewer.

I also began to notice some similarities between illness narratives and pathographies with oral history which I address later in this article. The most obvious commonality is the autobiographical narrative based on an individual's memory. This common trait thus made me start to wonder about the possibility of movement-based equivalent to oral history – that is, a movement history. 9

Oral History into Movement History: Mutable Memories

Oral history was originally considered the domain of historians and has since been adopted by a variety of disciplines such as ethnology, anthropology and sociology as well as used for social work and community-led projects [Abrams 2010]. For example, a local historical society may conduct oral histories to help a community learn about its past [Baum 1978]. Guidelines and instruction courses for how to conduct an oral history are available but there is technically no single correct way to engage in oral history [Ritchie 2003]. In terms of specific activities, Lynn Abrams describes oral history as consisting of three main components: 1) an interview process and product of interview, 2) research methodology and result of research process and 3) an act of recording and final record [Abrams 2010]. 10

At the core of any oral history is a human memory. These memories usually reflect recollection of and/or commentary on significant events, although they may also be centered on daily life or more private events. The fact that these memories are not always precise [Matusiak et al. 2017] can be seen as problematic or beneficial in that it can affect the accuracy and presentation of content. To avoid frustration, interviewers are encouraged to think of oral history as a shared responsibility with those whom they are interviewing [Ritchie 2003]. To that end, the extent to which an oral historian must gain the trust of their subjects is no small matter. When this trust is well-placed, a potential platform for communicating information through narratives is created. This platform can be useful for bringing awareness to marginalized communities and hidden histories [Abrams 2010]. 11

Although visual content may help supplement verbal descriptions, the perspectives are often limited or curated by the documenter. Sometimes a lack of aural clarity or a need to adhere to "filmic language" can also interfere with accurately capturing all the information provided [Williams 2011]. Given the rapid developments in 21st century audio/video technology, it is increasingly easier to supplement oral histories with additional information or options for interaction. An example of this would be the University of Southern California Shoah Foundation's Dimensions in Testimony exhibition which combines holographic projections, voice recognition and natural-language processing [USC 2020]. This immersive way of viewing and interacting with a subject speaking their oral history could generate a deeper understanding as it would allow users to change distance, angle and relationship to the subject. At the same time, the use of multimedia technology must make logical sense given the costs, logistics and ethics involved [Hughes 2015]. 12

To address the issues of providing an enhanced viewing experience without being extravagant in one's technology choices, it may be useful to look to the field of dance for performance strategies that can help add nuance. The connection between dance and oral histories is that dances are a part of oral tradition that can be intangible and ephemeral in such a way that challenges the act of documentation itself [Whatley 2017a]. Furthermore, "Dance also challenges other experts to think about devising imaginative methods or scoring, notating, annotating, and archiving a processual, somatic, and multisensory practice" [Whatley 2017a]. Since a movement history is still based on a personal memory, it would be logical to look at how somatic dance forms that embrace the unique attributes of an individual body for strategies on how to recall, express and perform embodied experiences in a physical manner. 13

Somatic movement practices often require practitioners to explore the idiosyncrasies of their bodies and their relationship to other bodies in a way that generates a sort of autobiography. These movement practices can also be used to literally illustrate life events which leads to a form of double-layered autobiography. Improvisational methods may incorporate internal and/or external questioning which then becomes reminiscent of an oral history interview. The range of somatic movement practices range from the Asian disciplines of yoga and tai chi to more recent systems such as Feldenkrais and Body Mind Centering. Within that spectrum lie somatic dance forms that have become increasingly 14

used for artistic expression: Authentic Movement, Contact Improvisation and Skinner Releasing Technique amongst others. Steve Paxton, founder of Contact Improvisation, was known for his Small Dance ritual which guides the individual to examine their own body. This self-examination was later part of Paxton's documentation about his process which essentially served a sort of autobiography of his body [Corin 2017].

Similarly, Bill T. Jones, who also used Contact Improvisation, created several solos based on both his own life events and his body's mechanics. Jones helped pioneer the combining of somatic movement practices with motion capture technology. The particular nature of Jones' works yielded what could be considered a type of movement history. An early example would be the 1999 Bill T. Jones collaboration with the Open Ended Group, *Ghostcatching*. Originally intended to challenge the boundaries of the human body [Open Ended Group 2019], *Ghostcatching* was not intentionally autobiographical but in the end took on autobiographical elements specific to Jones [Open Ended Group 2019].

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Figure 2. "After Ghostcatching HD excerpts." Source credit: The OpenEndedGroup.

Similarly, the motion capture samples performed by Steve Paxton as part of his research on contact improvisation that started in 1986 and were released on DVD-ROM in 2008 were not necessarily autobiographical [Corin 2017].

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Figure 3. "STEVE PAXTON : MATERIAL FOR THE SPINE - DVDrom TRAILER." Source credit: Contredanse.

More recently, somatic movement experts such as Ruth Gibson are more consciously adapting their technique to the limitations of mocap systems [Whatley 2012] and taking a phenomenological approach to mocap recording for VR environments [Kozel et al. 2018].

Figure 4. "MAN A VR." Source credit: Ruth Gibson and Bruno Martelli.

An Overview of Motion Capture, VR and Somatic Movement Practices

The integration of new technologies into oral history practice is not unusual. Digital technology in particular can be integrated across all aspects of the process, whether it is in recording, archiving or disseminating content [Boyd 2011]. It is therefore reasonable to assume that oral history can evolve to the next level of incorporating virtuality. This is already present in projects such as the previously mentioned Dimensions in Testimony exhibition. Virtuality can be used for various purposes whether it is to increase access, create a sense of immersion, generate a sense of embodiment or any other number of reasons. For movement histories, the goal is to allow viewers to examine physical memories without being invasive to the source. To that end, mocap and VR can help create a safer way to view and interact with such content. 18

Mocap data is extremely versatile in that it can be used for everything from scientific motion analysis to mainstream entertainment. Conceptually mocap has its roots in Eadweard Muybridge's animation experiments and Max Fleischer's rotoscope device [Boucher 2011]. Technologically, the systems used at the time of writing descend from motion tracking systems developed in the 1970s and 1980s. One such example are the point light displays developed by Gunnar Johansson [Jensenius 2013]. Since then a variety of systems have been released such as sensor-based systems that rely on accelerometers and camera-based optical systems using infrared markers. The latter type of system allows for reliable tracking and orientation of joints [Jensenius 2013] and accurate capture that enables a variety of data interpretation and facings [McCormick et al. 2020]. 19

The visualization of this mocap data can also help with human movement analysis [Whatley 2017a]. Although mocap data can be visualized in both 2D and 3D spaces, the latter option allows viewers full rein over perspective within a 6DOF (degrees of freedom) interactive context. The term "6DOF" refers to the three directions in which the head can move (3DOF) combined with the three directions in which the body can move through space [Cisneros et al. 2019b] An added benefit of VR is that it is fully immersive and therefore visual distractions can be eliminated. Untethered headsets such as the *Oculus Quest* provide additional freedom in movement. This adds to a sense of immersion which can be a useful element for supporting a narrative. Previous concerns about motion sickness and ergonomic issues [Cobb 1999] are being addressed through improved headset design, increased graphics computing power and a generally better understanding of VR design principles. Researchers such as Michael Madary and Thomas K. Metzinger have released recommendations for more ethical design [Madary and Metzinger 2016] and constant updates in software platforms and standards also contribute to an improved experience. Another benefit of using an immersive environment is the ability with which it is possible to blend both visual and aural media with sound playing as vital a role to immersion as visuals. This balance between types of media may help address Mark Tebeau's concerns about overemphasizing visual representations of oral histories and the need for novel ways of data visualization [Tebeau 2013]. 20

Illness Narratives in Oral History and Somatic Movement Practices

The concept of phenomenology or "the experience of" is very relevant to memories. A specific type of memory rooted in phenomenology is the illness narrative. The purpose of an illness narrative is to share a patient's perspective on experiencing symptoms, treatment, stigma and other aspects of an illness [Frank 1995]. This perspective may agree or contrast with a medical professional's. Like oral histories, illness narratives can focus on specific incidents, lifelong stories or become part of a collection of multiple narratives. More importantly, certain types of patients such as the chronically ill can be categorized as part of a marginalized and/or silenced group who are able to regain their voice through sharing their stories [Hawkins 1999]. Abrams states that "Oral history was intended to give a voice to the voiceless, a narrative to the story-less and power to the marginalized" [Abrams 2010]. From this perspective, the collective experiences of patients can potentially reflect hidden truths about society. 21

Within the history of medicine, the use of oral history has evolved significantly over time. Oral histories were initially conducted for male figures of influence in medicine before taking on a social history role in the 1970s and a supporting evidence role in the 1990s [Winslow and Smith 2011]. It was the course of this evolution that the question of how to provide a patient's history as opposed to that of a doctor's came into existence. Scholars such as Arthur W. Frank and Arthur Kleinman would start to collect and analyze the narratives of patients while G.Thomas Couser would start to bring the term "pathography" forward into the 20th century. 22

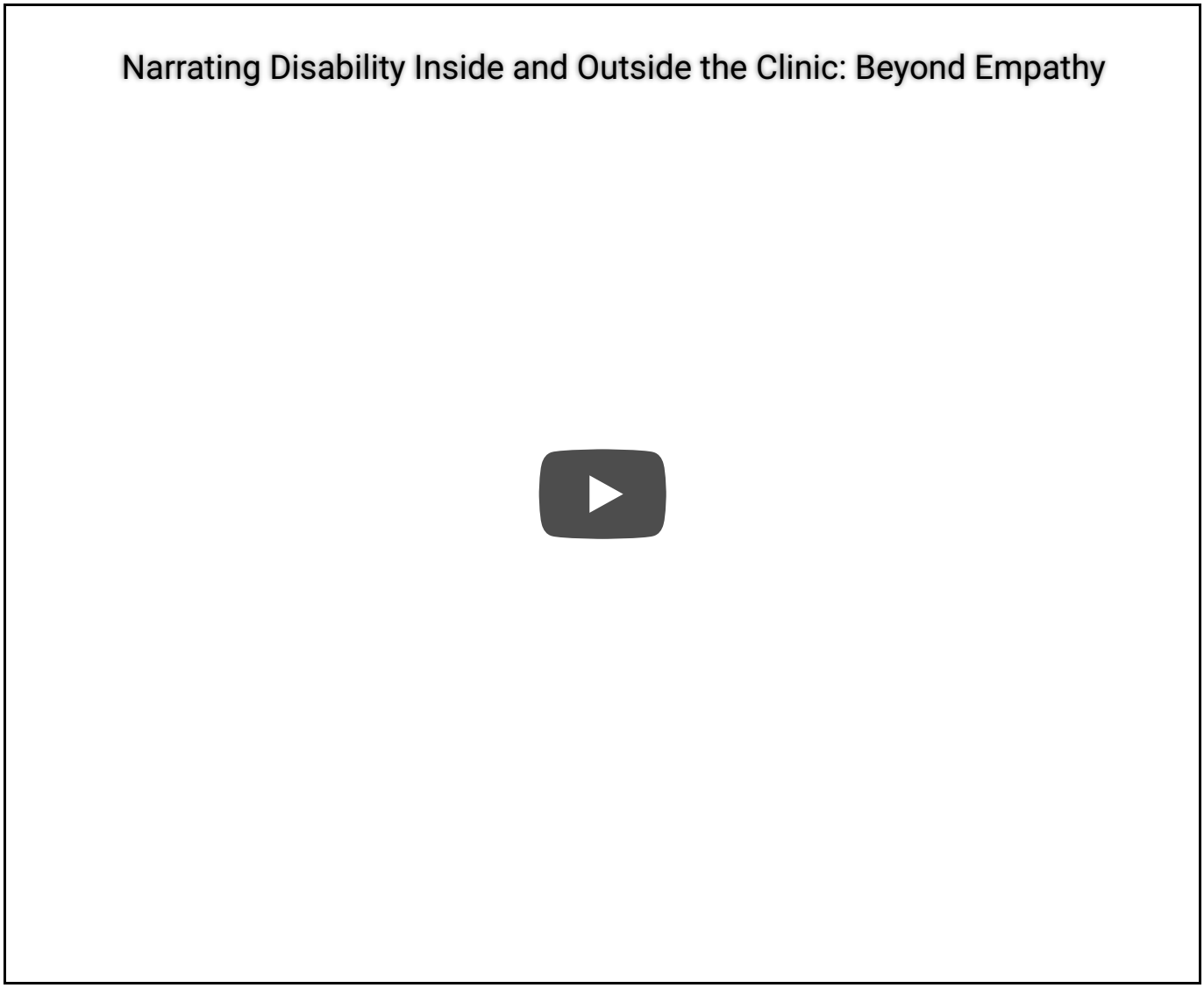

Figure 5. "Narrating Disability Inside and Outside the Clinic: Beyond Empathy." Source credit: Centre for Culture and Disability Studies.

Some debate would be spurred by Anne Hawkins' very specific definition of pathography in that it is limited to a written account of physical illness [Hawkins 1999]. Her approach would later be challenged by performing arts scholars such as Alex Mermikides and Gianna Bouchard who identified theatrical performance as a type of "embodied pathography" [Mermikides and Bouchard 2016].

Figure 13. "pain[byte] VR on Vimeo." Source credit: Genevieve Smith-Nunes.

Lithium Hindsight 360 Video Capture July 2019

from **Eugenia Kim**

Figure 14. "Lithium Hindsight 360 Video Capture July 2019." Source credit: Eugenia S. Kim.

In order to generate the movement histories presented in *Lithium Hindsight 360*, I combined several somatic movement practices to translate the experience, structure the movement and perform the memory. I chose this approach because I noticed that universally relatable physical gestures and movements being expressed by mental health patients while sharing their experiences in a group setting. Examples might include hand tremors, moving slowly due to exhaustion or agitated rapid gesticulation with the arms. For translating and structuring memories into movement, I adapted the Life Art Process to help me identify key positions and gestures with specific experiences. To do this, I first compiled a list of commonly known adolescent bipolar disorder symptoms, read the individual testimonials in medical reports and then tried to translate what I had read. Based on that experience, I decided that it was more appropriate to use my own bodily experience as a patient with bipolar disorder. This decision lead to the creation of two different scenes, "Symptoms" and "Maintenance". 31

In "Symptoms", individual symptoms are depicted by a group of mannequins that resemble each other. They are anchored by a mannequin attempting to ask for help but unable to articulate its needs. Presenting the physical movements without an explanation of the symptom can make a viewer pause and rethink their previous understanding of what a mental health condition looks or feels like. For "Maintenance" viewers are taken through a standard day of waking up, taking medicine, anxiety over interacting with others, exhaustion from feigning good health and then the return to bed. This scene has a more traditional dance sequence as I used to dance to relieve anxiety and stress. The majority of the movement is more pedestrian to the point of almost looking like pantomime. Since the predominant 32

physical feeling was the sensation of constantly falling apart, the avatar is also constantly shifting and appearing to disintegrate before stabilizing again.

To perform and generate all of the movement, I used various forms of improvisation methods including Contact Improvisation and Authentic Movement to sequence the positions and gestures into a narrative. At this level, I was not thinking about using specific vocabulary from a technique. Instead I was adapting concepts such as initiating movement from an internal point or using a video camera as my "witness" rather than a person. Taking this approach helped me avoid "performing" or overdramatizing my movements. Finally, my own movement style or "voice" is influenced by martial arts forms such as tai chi. This results in movement that is alternatively fluid and percussive. 33

Initially I had thought it would be better to translate the experiences of other patients with bipolar disorder as presented in medical reports similar to what Jones had done with his choreography. When I realized that this type of heterophenomenology exacerbates issues raised by Susan Kozel about agency and representation that could lead to silencing [Kozel 2007], I made the decision to use my own movement history of being a patient. If this type of heterophenomenology is done in conjunction with patients then it may be ethically possible and accurate for a third party to portray the experiences of another even without a close personal relationship. 34

Practical Strategies and Considerations

Two of the first assumptions that might come to mind when beginning a mocap and VR project is that it is very expensive or technically difficult to generate. In the earlier days of mocap and VR this would have been accurate given the experimental nature and limited access to technologies. As of 2020, there is a constantly growing range of consumer-level hardware and software tools that are still capable of producing high quality results. The simplification of user interfaces and procedures enables creators and researchers to think more holistically about their approach rather than having to become expert programmers and technicians. In this section I offer tips generated from discussions with some of the experts referenced in this article as well as my own personal experiences with multiple hardware systems and recording scenarios. For further details on tasks such as selecting a mocap system, data clean-up, preservation and getting started with a project, please see the Appendix. 35

In terms of performance, the most important factor is to remember that there is a difference between documenting, performing and performing for documentation purposes. Subjects may need to exaggerate their movements slightly to avoid occlusion issues. This too depends on the type of system and the level of subtlety being captured. For example, a motion sensor like the Kinect can capture full-body, facial and finger data with a single device. 36

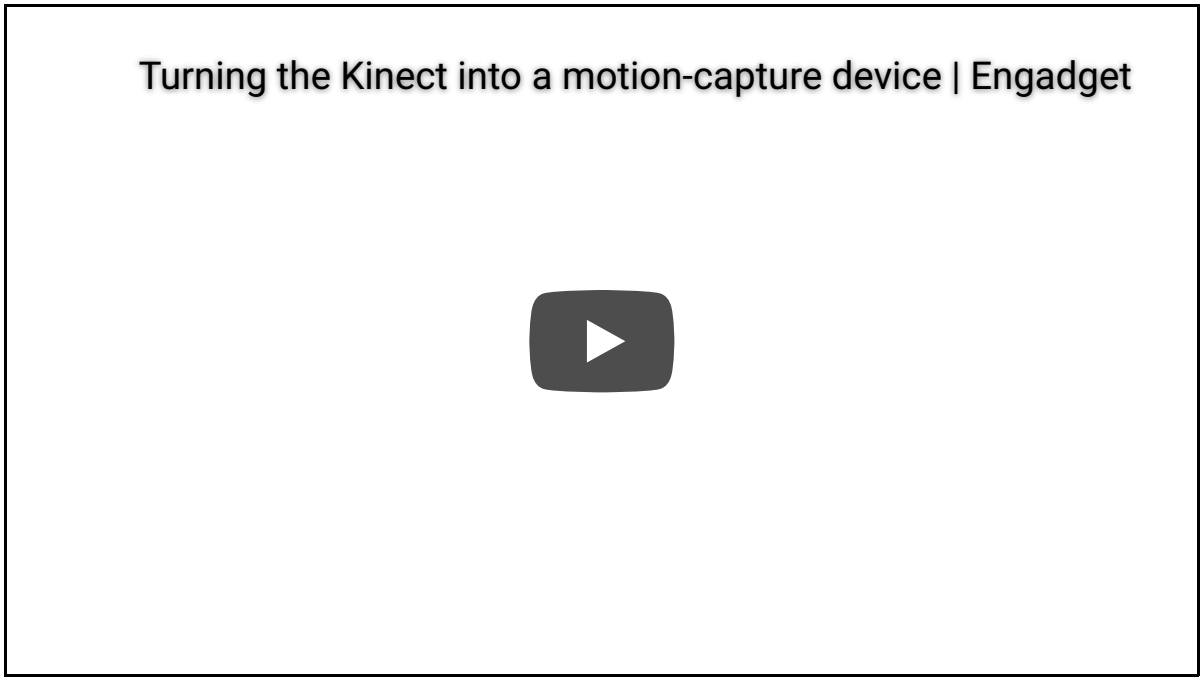

Figure 17. "WhoLoDancE: an overview." Source credit: WhoLoDancE.

From a VR perspective, one must decide whether to use an existing game engine such as Unity or engineer a bespoke solution. Further objects such as 3D models, texture maps, supplementary audio and video may also need to be taken into consideration. Fundamentally, the digital curation of movement histories comprised of mocap data and VR projects is the same as for any other set of digital objects in that standardized file formats (i.e. fbx, bvh) used across multiple industries are typically used for the source objects. If anything, the most challenges lie in the lack of a standard file format for gaming engines such as Unity and Unreal. Constant changes in both hardware and software also make it difficult to pinpoint a single ideal long-term (>25 years) file format for any of the objects contained within a VR project. 42

Given the rapid evolution of mocap and related technologies, the practical solution would be to focus on maintaining and migrating mocap data with the expectation that the visualization of that data will change over time. This is not to belittle the work that goes into creating VR environments. Instead, by focusing on movement as the primary source of information, the content can be made more accessible since it could be visualized in multiple ways. In an ideal setting, digital preservation practices such as using repositories built on the OAIS (Open Archival Information System) reference model and metadata standards would be expected. Implementing such practices, however, also comes with a significant cost [Matusiak et al. 2017]. To help relieve the burden on data stewards, it may be useful for movement history creators to reference the strategies of existing artists' toolkits [Skinner 2015] and habits of new media artists [Post 2017]. Furthermore, the previously theoretical concept of networked digital archives [MacDevitt 2012] has already materialized in the form of widespread cloud computing services. The need for large and flexible storage space is better served by these services than traditional servers. 43

Conclusion and Future Evolutions

In the past, the recording of mocap and its subsequent visualization was technically complicated and costly. The process of mocap is still not as simple as making an audio recording, but evolutions in digital technology certainly make it easier. Similar things could be said about VR as new tutorials, hardware sets and software solutions continue to be released. For the immediate future, the most frequent use of movement histories might be as a complementary pairing with oral histories. Examples include a voiceover accompanying an illness narrative using mocap or a written account of a traumatic event accompanied by movement illustrating key moments. A future concern for this type of visualization is that of enabling accessibility for the visually impaired [Hughes 2015]. In the future, haptics might be able to help resolve vision impairment or reliance on text by conveying a different type of a sensory information. The initial work conducted at Deakin Motion Lab and the Institute for Intelligent Systems Research and Innovation (IISRI) that integrates social haptics with dance to create an embodied experience through kinesthesia [McCormick et al. 2020] may well lead to being able to completely experiencing the physical memory of another individual. 44

On a more personal level, I had two major revelations while constructing my own movement history. The first discovery was that the reactions to my LH360 experience often reflected more about a viewer's previous perceptions about mental health and the communities they came from than any truth or understanding about the experience being shown to them. In other words, it was possible to induce reflexivity and intersubjectivity through presenting abstracted movement in an immersive environment. Patients would express relief and motivation that someone else was sharing an experience similar to theirs. Non-patients would question their previous perceptions of mental health patients. As I had never encountered this kind of reaction when similar movement was presented as a live performance, I was extremely surprised by this result. Presenting the VR experience and the publications about it have also brought me into contact with a wide range of artists and researchers working on similar projects. 45

These kinds of connections and discoveries are why I became an interdisciplinary practice-based researcher in the arts rather than an artist, archivist or other type of humanities researcher. Traditionally, artistic practice is supposed to speak for itself through the artistic work itself and academic research should be presentable through textual publications. Yet there are still forms of human-generated content that are too multi-faceted to be presented using only one kind of media or without contextual information. The *LH360* development process relied on methodologies such as autoethnography, 46

reflective practice and user experience design as well as an understanding of various artistic technique. Furthermore, I received comments that viewing the VR experience enhanced an understanding of its associated publications and vice versa. Based on my experience with creating *LH360*, I believe that forms of artistic expression can be utilized for purposes other than creating pure works of art or entertainment. The concept of an artistic practice-based researcher has been acknowledged in academic circles since the 1980s [Candy 2006] [Nelson 2013] which means that there are pioneers to look up to, a current peer community, and most likely an increase in this type of researcher. Regardless of whether one comes from an academic, artistic or hybrid approach, increasing developments in visual, aural, and haptic technologies should make it more feasible to reproduce non-verbal content that addresses all the senses. Over time, these innovations may lead to more multi-dimensional presentations of individual memories, historical events and entire cultures.

Appendix: Choosing Hardware and Software Options

The first thing that researchers should consider is their choice of mocap system. Ideally the system should be chosen based on the type of movement recorded, frequently used body part(s), portability and need for anonymity. It may be tempting to choose a system for its cost, convenience or availability but this can later create problems. A comparison of several systems is provided below to illustrate how the attributes of a system could be problematic or simply not useful for a researcher. The information is a combination of general knowledge and my personal experience using the listed system. It is by no means an extensive listing of all systems currently available on the market. For a more detailed look into mocap systems, I recommend reading the white paper released by Epic Games in May 2020.

System	Type/Description	Unique Attributes	Benefits	Limitations
Microsoft Kinect	Depth camera/Motion sensor device	Originally a gaming device	Excellent for point cloud effects. Very cheap to buy and easy to setup.	May need multiple devices. Combining multiple data sources may require a custom software solution.
HTC Vive Tracker	Inertial/Repurposed trackers	Repurposes part of the HTC Vive virtual reality headset package	Very portable set-up. Can be used with third party software.	The weight of the sensors affected ease of movement
Notch Pioneer	Inertial/Motion sensors strapped to body	Individual sensors are attached to adjustable straps	Easy to put on and customize location of sensors. Reasonably priced and expandable.	Need smartphone or tablet for recording
Perception Neuron	Inertial/Wearable sensors in a suit	Sensors are attached to a "suit" of straps.	Fairly easy to put on and lightweight. Includes a comprehensive software platform.	May require frequent calibration. Weight of the battery pack can affect movement. Requires wireless router setup.
Rokoko Smartsuit	Inertial/Wearable sensors in a suit	Can be used almost anywhere.	Suit is comfortable and well-constructed. Price is about the same as a high-end laptop. Can be combined with face and hand mocap devices.	Separate suits need to be purchased for each person/size. Same battery pack and wireless router issue as Neuron. Cannot accurately measure changes in levels.
Optitrack Prime	Optical/Passive markers (reflective)	Comes in multiple configuration options.	Very good software and easy calibration. Can do almost any kind of motion with ease. Easy to use data clean-up tool.	The most expensive option. Requires a lot of resources (i.e. computing, electricity, space). Good technician with knowledge of marker setups, calibration, etc. is essential.

Table 1.

Another aspect to consider about choosing a hardware system is the software platform that accompanies it as well as the external software platforms that the hardware can interface with. Software can affect how cleanly motion is captured, provide easier ways to clean up and manipulate the data, or even enable faster sharing. In some situations, the hardware may not be the most robust, but the software makes the rest of the process easier. Most systems will come with their own proprietary software or require use of a licensed program. Ultimately the final decision should take into consideration whether one is recording full body large movements or smaller subtle movements, whether identity is an issue, if factual accuracy is required or if emotional expressiveness is the main priority. 48

Just like with any other data set, mocap data clean-up is extremely time consuming. The clean-up process usually consists of manipulating coordinates using either a linear graph editor or actual points in 3D space. While there are tools to help automate the process it is useful for researchers to review the raw capture and the cleaned-up version to ensure that vital details are not accidentally erased. By contrast, mapping the data to a 3D model to generate an animation can be relatively quick so long as the skeleton has been properly mapped. 49

Based on existing practices from commercial industry as balanced by financial limitations, I would recommend the following hardware, software, digital object and project planning starting points for researchers engaging in mocap and VR for the first time. Factors include cost of renting or purchasing a mocap system, personnel time and compensation 50

and whether the project is being worked on a full or part-time basis.

Ideal Expensive Setup	Moderate Investment Setup	Basic Setup
• Marker-based/optical system with knowledgeable technician (Optitrack is good) • Programmer with knowledge of Unity or other visualization software • 3D modeler for custom figure and environment • At least 2 sessions at 2 hours each for a short recording • 3 months of dedicated time for visualization	• Portable sensor suit system • Unity or software template • A way to customize a stock 3D figure and environment • At least 2 hours for the recording session • 3 months of partial time for visualization	• Notch, Vive or Kinect type system • WebVR template using frameworks such as A-frame • Stock 3D figure for free and mapped photos • Keep interview very short and shoot as best as possible • No deadline for completion of visualization

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