Exploring the Experience of Becoming and Unbecoming a Cyborg Using Performing Arts Techniques

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Abstract

The project proposes using performing arts techniques to aid people in becoming and unbecoming a cyborg. Cyborgs are human-machine hybrids with organic and mechatronic body parts which can be implanted or worn. The transition into and out of experiencing additional body parts is not fully understood. This project draws from techniques used by actors for their performances to facilitate the experience of becoming and unbecoming a cyborg. A study where actors entered a cyborg state, performed as a cyborg, and then exited from that cyborg state was conducted. The observations suggest that these techniques can be useful in technology augmented experiences. Furthermore, to translate the lessons learned from the actor study to a cyborg user context, a design session was formulated and conducted and the data was analyzed. The results of this design session informed the specification of a prospective prototype that supports the performing arts techniques. Finally, a discussion of the project limitations as well as future work is presented.

Key words: cyborgs; user experience; becoming; unbecoming.

1 Introduction

Humans transition in and out of states throughout their daily lives. These transitions and experiences dictate the way in which they integrate with and detach from non-human objects. For example, a person integrates with their vehicle when they transition into a "driver" state by entering and immersing themselves in the vehicles environment by acts such as wearing a seat belt, and adjusting the seat and mirrors. The same person also transitions out of that state by leaving the car, thus detaching from their driver selves. Generally, these integrations with objects are made seamless by learned routines over a period of time and a deep understanding of the transition actions. But with the advent of new technology augmented experiences such as wearables, the experiences of seamless integration and detachment are yet to be perfected. [10].

These experiences can be challenging because not only does the person have to adapt to certain physiological transformations (e.g., wearing additional limbs in the case of cyborgs), they also need to transform cognitively and overcome fear, build trust, and feel in control so as to effectively perform with their machine counterpart. Consider a factory worker who is asked to wear robotic arms, i.e. become a cyborg, to help them complete their tasks with less effort. This factory worker will need to become and unbecome a cyborg repeatedly and stay as a cyborg for long periods. How can this factory worker become and unbecome a cyborg in a healthy and maintainable way? Humans engage in actions and routines to help with changing states and completing tasks, but how does one support such exercises when technology is involved? This overarching question is the focus of this work, and this project delves into this question by exploring how people may become and unbecome cyborgs by wearing additional limbs. The project draws from performance art methodologies to better understand how to facilitate people to enter and exit technology augmented experiences.

Actors constantly shift between states. Whether from one character to another, or from pre to post performance, actors are experts at shifting between psychological states [2, 16, 1, 11, 7]. Their work is measured by their effectiveness in their integrated state, and by their ability to move in and out of states quickly and efficiently over time. The requirements of their work have resulted in the development of a methodical process, warm-up and cool-down, for shifting states and returning to neutral. These methods include various exercises that support deliberate shifting of psychological or emotional states. Motivated by the established strengths of these techniques, this work examines how professional performers use traditional warm-up and cool-down techniques to help them in becoming and unbecoming their cyborg selves. Furthermore, as the goal of this work is to improve the becoming and unbecoming experience for all, not just actors, this work aims to build upon the study with the actors by translating the lessons learned to a non-actor context.

For this project, the Rethink Robotics robot, Baxter, was used to simulate a piece of wearable technology. Padding and a system of comfortable straps were added

Figure 1: In this image, A2 is strapped into the Baxter robot

to the robot, allowing the user to "wear" Baxters two arms (Figure 1). The researchers of this project collaboratively worked with the professional actors to craft the warm-up and cool-down protocols, and the actors also prepared and performed a monologue as a cyborg. The effect of these protocols on the actors integration and acceptance of having become a cyborg were observed. Overall, it was observed that performance methods used for becoming and unbecoming a cyborg are effective, and with further refinements can be used as a means to support efficient transitions. Thus, with these lessons in mind, the next phase of the project is to translate the warm-up and cool-down techniques used by the actors in the collaborative study for use by cyborg users outside of the acting context. To facilitate the exploration of how the performance techniques can be used for a cyborg context outside of monologue performance, a design session was conducted in order to determine the task that the user will attempt to accomplish while in the cyborg state. This task, derived from the design session, was used to create a new prototype specification. This prospective prototype supports the cyborg task to be completed, but also the mechanisms that support better transitions, including the performing arts techniques as well as additional lessons learned throughout the project that also influence the facilitation of transitions into and out of the cyborg state.

1.1 Project Goals

By first exploring an actors process for becoming and unbecoming a character, the aim is to:

1. Understand the becoming and unbecoming cyborg experience based on professional actors performances with the Baxter robot.

2.Translate the performing arts techniques to a cyborg context for use in a cyborg application outside of performance

3. Integrate the performance techniques into a new prototype specification that supports a cyborg application to aid a user in becoming and unbecoming a cyborg entity.

This report provides details on each phase of the project, as well as the data analysis portions of those phases. A prototype design process commences upon the completion of the design study, the details of which are also provided.

2 Related Work

Cyborgs, have been discussed and prototyped in HCI [15, 4, 14]. For example, projects such as the MetaArms prototype [15] and those by Panetti et al. [14] and Tran et al. [18, 17] examine the use of wearable arms. These arms are worn like a backpack and give the user additional limbs allowing the human to extend the range of available skills and manipulation possibilities. These projects discuss potential uses cases for cyborgs such as lifting load, communication, and navigation.

Researchers have also examined the potential ethical conundrums that could result from engaging in cyborg interactions on building sites [19]. In the article the author discusses how while the cyborg augmentation may help users overcome physical tiredness and it may also prompt workers to work for longer periods causing them more mental fatigue. Our work is inspired by these projects. We add to this growing body of literature by stepping back and exploring the experience of becoming and unbecoming a cyborg. While past research has proposed prototypes to aid people to become cyborgs by wearing additional limbs, how people transition into and out of that experience is not fully understood. We think it is important to consider and design for this experience not just to make the use cases more meaningful, but also to explore the ethical questions.

Our work is motivated by a similar exploration that was conducted by Knibbe et al. [10] who studied the experience of people exiting VR. Their work delves into what they call the moment of exit, and reveals five components related to the exit of VR: space, control, sociality, time and sensory adaptation. Upon the exit of the VR state, users described how they exit, whether it be physically first and mentally second or vice versa. In our work, we explore how people experience both entering and exiting physical technology augmented experiences

The design session for this project makes use of the work done by Bullock et. al [5]. They propose a classification of human-hand manipulation tasks. These hand-centric tasks are classified based on the contact, motion and prehension involved within the task. Example tasks within this taxonomy include hand resting, which is a no motion, no contact task, and holding an object with an open palm, which is a contact, non-prehensile and no motion task. Bullock et. als proposed task classification breaks down hand-based manipulation tasks into atomic gestures. Gestures such as these cannot be meaningfully broken down or classified any further. As such, Bullock et. al speculate that this taxonomy, and the tasks within it, can be used to build more complex tasks and actions. An example of this is picking up a pen and writing with it; this action, or rather, series of tasks, can be broken down using the following taxonomical gestures: 1. Lifting the pen from the table 2. Rotating the pen into a writing position and 3. Writing with the pen. This taxonomy provides the structure in which the design session was conducted, which will be elaborated on in this report.

3 Observational Study With Actors

Artistic Research has well-established research methodology that blends practical technique with various forms of data gathering and analysis. Given the nature of this project, the focus is on Performance Based Research and Practice as Research models [9, 13] in conjunction with participatory design methods [3, 12] used in HCI to capture, analyze and disseminate results.

The methodology for this observational study consisted of collaboratively working with two professional actors over a two-week period. In these two weeks, the researchers conducted seven sessions consisting of five phases: introduction, rehearsal and design, integration, performance and debrief. For this study, performers with strong intellect and a desire to work with technology were sought out. These performers are also very familiar with the performing techniques traditionally used for becoming and unbecoming a character.

In this study, the actors prepared to become cyborgs using the warm up protocol, performed a monologue as a cyborg with two additional arms, and transitioned out of the cyborg state using the cool down protocol. The methods used for the warm-up and cool-down protocols (explained in the next section) were selected based on their ubiquity in the world of performing arts. The "To Be or Not To Be" monologue was chosen for this study. The selection of this monologue was done in consultation with the actors and research team. The reasons for its selection were popularity and content. As one of the best-known speeches in English, it was deemed to be suitable for research designed for a global audience. Furthermore, the message of the speech, which is about choosing whether or not to accept a new way of being, is thematically relevant to the choices one makes when they find themselves working in an environment that calls for a change of state.

For this study, qualitative data was sought to better understand the evolution of the actors' transition into and out of the cyborg state. Actors have extensive training in state-change, and in the articulation of the process of becoming and unbecoming. In order to develop their craft their process entails the development of a rich vocabulary of experiential observation that promised a specialized form of reporting that is not seen with non-actor participants, thus making them a rich source of qualitative data. This data was collected in the form of written journals, which the actors carried with them through every session, from video recordings of the study sessions and interviews, as well as constant observation from the researchers throughout the sessions.

3.1 Warm-Up and Cool-Down Protocol

The actors used a three-step protocol, for both the warm-up and cool-down based on common performance practice. These exercises are conducted before attaching to and after detaching from the robot. Furthermore, the actors performed a warm-up exercise immediately upon attaching to their wearable (described below). These techniques support the actor in the transition processes by targeting physical, mental and emotional transformations. The exercises are:

1. Instrument: actors place feet in parallel, align their posture and close their eyes. This exercise allows the actors to conduct a "mind and body scan" to "tune up". Focused breathing is a key part of this routine. This exercise targets both the mental and physical aspects of transformation.

2. State: the actors use a "sense-memory exercise" to bring their psychological state to neutral. The actors close their eyes and use visualization techniques, which bring emotional and mental states to neutral. This exercise is used to restore the actor to a neutral state after state changes. By focusing on a singular image, the actors can regain their composure and calm regardless of their previous state.

3. Roll downs: Here, the actor slowly reaches for their toes, and go back up to a natural position. The actors integrate core muscles, the spine and the breath to create an integrated body-state. This releases tension and warms up the breath and body.

4. Cyborg Warm-Up: Upon attaching to their wearable, the actors execute a series of gestures in tandem with their wearable. This gives the actor the chance to "synchronize" with their wearable's movements. This exercise emerged as a result of a demo routine of the gestures that the researchers created. This demo, and the gestures, are described below.

Figure 2: In this image, A1 is standing on Baxter's base to experiment with different attachment positions

3.2 Introduction and Familiarization

The goal of this phase was to introduce the research topic to the actors, and to familiarize them with cyborg interaction. This phase was conducted in one session lasting four hours.

To solidify the actors' understanding of the targeted cyborg concepts, images and videos were shown of cyborgs with wearable technologies in popular media. The actors were also exposed to hypothetical "end-goal" cyborg interactions such as a factory worker who needs to wear a set of arms and become a cyborg. This was followed by an explanation of the research goal and the breakdown of what tasks need to be accomplished, namely 1. define a warm-up and cool-down protocol based on traditional performance art techniques (described in previous section), 2. design and implement a gesture language to be used during the performance 3. practice the performance of the monologue before the final performance in which the warm-up and cool-down protocol will be executed before and after the performance piece.

The actors were then introduced to the Baxter robot, who served as the wearable in this study. After going through the safety instructions, a short demo highlighting Baxter's movement was shown. The actors were then given time to familiarize themselves with Baxter's capabilities and limitations. This provided the actors with the context in which their monologue will be performed, and the limitations in which Baxter can move during the performance.

We observed that in this phase, the actors were already experimenting with different ways to enter the cyborg state based on the physical integration with their wearable. Different positions and straps were used before the actors found their ideal position to wear their cyborg arms.

The actors then began experimenting with the range of motion of the Baxter robot's arms. While doing this, the actors were discovering the gestures and positions their wearable arms could be placed in during their performance, as well as gaining insight into their cyborg selves' capabilities.

The actors began writing in their journals during the first session, and continued to do so in every phase of the study. The actors were asked to document their thought process during the phases. Throughout this session, the actors highlighted their initial thoughts on their cyborg selves and what they think of Baxter's capabilities.

3.3 Rehearsal and Design

The purpose of this phase was to allow the actors to rehearse the performance piece, warm-up and cool-down techniques, and, in collaboration with the researchers, to design gestures for the wearable arms. Furthermore, the researchers developed a demo routine to test the gesture combinations on the wearable. This phase took place over three, three-hour sessions. These sessions were conducted on multiple days so that the researchers had time to design and implement the gestures. In the first session this phase actors began by analyzing and practicing the Hamlet monologue without any props. This was necessary to allow the actors to understand the performance piece before attempting to perform it as cyborg entities.

Also in the first session, the actors and researchers discussed which warm-up and cool-down techniques will be used in the protocol. The protocol was designed to be two minutes in length, and the actors practiced the protocol to familiarize themselves with this length.

In the second session of this phase, the actors and researchers collaborated to create three unique gestures to be executed by the additional wearable arms. This was done to give the actors a "gesture language" to follow when performing. These gestures are referred to as gesture A, B and C. The researchers then implemented these gestures and create a system to control the transition between using keyboard presses. This was followed by the implementation of a demo routine in which the wearable

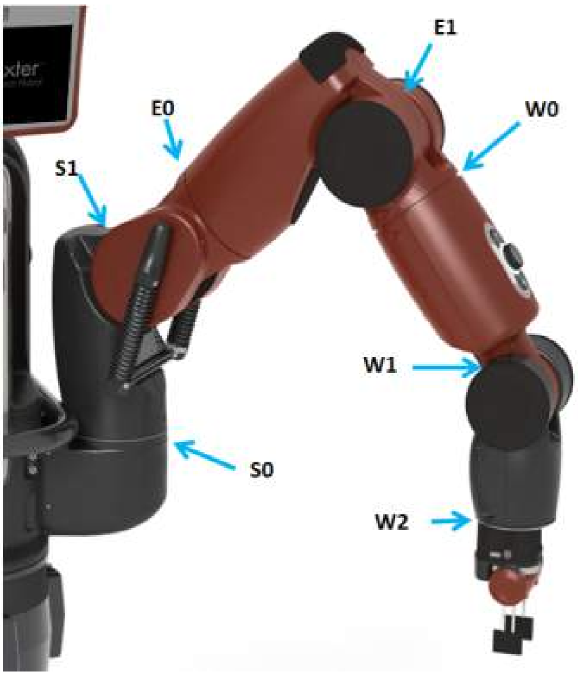

Figure 3: Diagram of Baxter's seven degrees of freedom and joint namess

executes combinations of the three gestures. This demo was presented to the actors in the integration phase.

In the third session of this phase, the actors first spent time rehearsing the gestures without their wearable arms. This process included human-human interaction between the actors, where each actor spent time as the other actor's cyborg arms. This provided the actors a basis on which they can form contextual understanding of how the gestures can fit into the monologue, as well as determine gesture comfort, before the gestures were fully implemented. This process also helped illicit further data for use in the implementation of the gestures, as using another human's arms aided in the visualization of where the actors wanted the arms to be for each gesture.

3.4 The Baxter Prototype

The Rethink Robotics robot, Baxter, was used as the wearable prototype in the observational study. Baxter's two arms possess seven degrees of freedom, each with their own angle range (Figure 3) . The robot also has various sensors such as cameras, infrared range sensors, accelerometer and cuff buttons. Baxter is equipped with a robot operating system (ROS) and an application programming interface (API) to interact with and program Baxter's behavior. The ROS API is written in both C++ and Python, and Python was chosen for this prototype due to it's familiarity to the researchers.

While experimenting with Baxter's capabilities, it was discovered that the ROS API has limitations in terms of moving the joints to specific locations based planned trajectories. An additional API called MoveIt was introduced into the prototype due to it's motion planning framework. This motion planning framework can move all the joints on each of Baxter's arms to a planned destination using Python dictionaries.

Once a gesture language was agreed upon, the researchers began implementing each gesture using the MoveIt API. To ease the process, a joint recorder program was implemented to return the exact angle and location of each joint in the arm. With this joint recorder in place, Baxter can be put in stand-by mode and the arms can be moved manually to a desired location. This manual movement allowed the researchers to iteratively find the best position for each joint for the gesture in question. Moreover, the researchers tested the comfort level of each implemented gesture by stepping into Baxter with the gesture engaged. Because of the manual movement of the arms, a mirror joint program was implemented to ensure the arms were symmetrical to each other. Once the arms were in an appropriate state for each gesture, the joint recorder program was executed and its output passed into the motion planning framework.

With the gesture positions and planned movements in place, the input mechanism for changing gestures was implemented. The ROS and MoveIT API support keyboard input due to Python's built-in input-output mechanisms. Each gesture was mapped to a key and executed when the key was pressed. Due to Baxter's speed and processing limitations, the input needed to be throttled by not allowing another input to be accepted for 0.5 seconds.

The implemented prototype was improved during the integration phase based on the actor's feedback. Multiple transition speeds were introduced for each gesture transition and some minor modifications to the position of the arms when executing the gestures.

3.5 Integration

In this phase, the actors explored integrating with their additional arms and performing using the pre-determined gestures. This phase included filming of the actors in the cyborg state, which was used to illicit feedback on how the gestures are functioning. Actors provided feedback on the gestures including: The cyborg arms' exact position for each gesture and the speed of transition between each gesture. The implementation was then iterated on based on the feedback. This phase took place over two four-hour sessions.

With the gestures now fully implemented, the actors spent time experimenting with how each gesture feels. Following this, the actors created a "gesture score" that

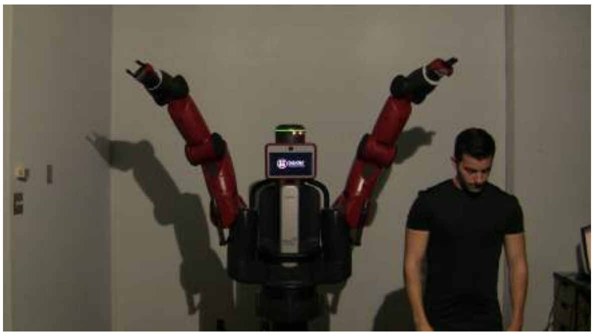

Figure 4: In this image, A1 is performing the instrument exercise before entering the cyborg state

Figure 5: In this image, A2 is performing gesture A in the cyborg warm-up

Figure 6: In this image, A2 is performing gesture B in the cyborg warm-up

structures the gesture transitions in the manner that the actor feels will support their performance. In this gesture score, the actors specified the exact location in the monologue script where they want that gesture to begin executing. Each actor created their gesture score based on what emotion they wanted their cyborg self to elicit in that particular moment. For example, one actor wanted the starting position of the cyborg arms to be in gesture B, and have them transition to gesture A when the second line of the monologue is read.

This phase concluded with a "dress rehearsal". Traditionally, a dress rehearsal for a performance is used to smooth out any wrinkles, and to test out the technology before the real show. Similarly, the dress rehearsal at the end of this phase helped the actors and researchers finalize the warm-up and cool-down protocol, debug the gestural implementation as well as finalize physical integration ideas such as the strapping techniques.

3.6 Performance

The goal of the performance phase was to record the final performance of the actors. This included executing the warm-up protocol, performing the monologue and executing the cool-down protocol. First, the initial warm-up protocol was conducted before entering the cyborg state (Figure 8). Then, upon strapping into Baxter, the cyborg warm-up was executed (Figures 5, 6, 7). The monologue performance was then completed, followed by unstrapping and executing the cool-down protocol.

The performance process was repeated six times for each actor. In each iteration, the actors explored a new approach to conveying a different mood than the one before. For example, one actor explored their cyborg selves being angry at a former partner in one iteration, and then explored a more somber mood in the next.

Between each performance, the actors wrote in their journals about their experience of entering and exiting the cyborg state. Researchers also recorded data based on observation of the performances.

3.7 Debrief

In conclusion, we conducted a semi-structured interview session with the actors. The questions were grouped into categories that were aimed at the various stages of the becoming and unbecoming process. First, the actors were asked a set of questions concerning the experience of entering the cyborg state. These questions focused on physical as well as mental integration, and how the warm-up protocol improved the experience of entering the cyborg state. The next set of questions concerned the cool-down protocol and its effect on the unbecoming experience. .

4 Observational Study Results and Discussion

To further understand what is needed to continue this project, the qualitative data collected during the actor study was revisited. This was done to better understand the strengths and weaknesses of the initial warm-up and cool-down framework created by the researchers and the actors

4.1 The Experience of Entering

The way in which the actors were physically strapped into Baxter played a role in their integration process: *"I felt I really needed the straps. The fact that I can give my*

Figure 7: In this image, A2 is performing gesture C in the cyborg warm-up

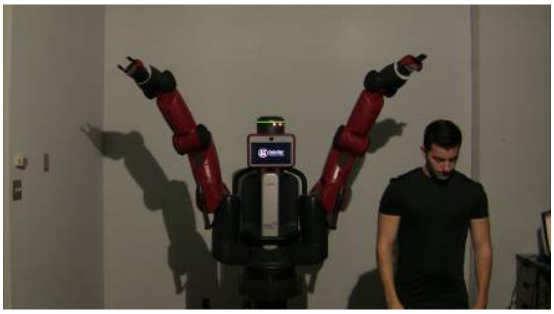

Figure 8: In this image, A1 is performing the instrument exercise before entering the cyborg state

body weight to Baxter and relax and feel (the robot) totally helped my immersion"[A1]. Furthermore, A2 stated that getting comfortable with the straps felt like the *"first step towards becoming a cyborg"*. The actors feelings toward their physical attachment to Baxter highlights that the way we physically wear the technology plays a role in the integration process.

We also learned that the simple exercises included in the protocols were also helpful for the actors to feel integrated with the cyborg arms. For example, A2 described how the instrument exercise helped: *"finding my center helped me because when standing on his base, it forced me to move forward..."*. Similarly, the state exercises were also found to be useful: *"(having) to go back to a centered, neutral spot is a jump off point, it really helped because (the cyborg state) is a different state, it is a different me"* [A2]. Lastly, the roll-down was also helpful: *"being able to breathe deeply helped me feel more relaxed. It helped me to be in such a state to connect to Baxter."*[A2]

From this study, we learned that practicing with the wearable arms in the cyborg warm-up was found to be extremely useful by the actors. Recalling the human-human session in the design and rehearsal phase, A1 noted that compared to a human, *"Baxter was on a five second delay... (practising) made me familiar with how Baxter moves the way he does and how long he takes to move the way he does."*

4.2 Experience of Exiting

Both actors discussed what they felt immediately after detaching from their wearable, before performing the cool-down, and expressed a feeling of vulnerability: *"I felt vulnerable after detaching. (Baxter) is literally protecting your back. You step out of it, you lose this big comfort right behind you, so subconsciously you feel more vulnerable. Cool-down offers safety and addresses the vulnerability."* [A1].

A1 further expressed that *"once youre in sync with Baxter, you come out with a gigantic exhale. Having the physical reset of the centering (the instrument exercise) and roll-downs, and then the (state) exercise, I felt that it was a very gentle transition into the real world"*. In both the becoming and unbecoming process, A2 noted the importance of the state exercises and getting to the neutral state, which highlights its importance in helping with the mental and emotional transition between states.

Both actors expressed physical strain from their performances, particularly on their lower legs. A2 expressed that this is a result of *"constantly pushing back with my legs and leaning forward."* While this is a specific physical ramification of working with Baxter, it implies that the cool-down should be tailored to the wearables physical integration to reduce the physical strain, thus improving the unbecoming process. The cyborg warm-up was extremely popular among the actors, to the point where they expressed a desire for a corresponding cyborg cool-down: *"A cyborg cool-down would really help. When I finish my monologue, I picture the transition would be less harsh if I get to shut-down with Baxter. If you could follow Baxter in this scenario, where youre not detaching from this still active machine, if you can shut down with it, if you share that moment, its almost like sharing exhalation with Baxter."* [A1].

4.3 Lessons Learned

Both actors expressed the importance of a proper physical integration with Baxter through the straps. This knowledge will help with the formulation of the prototype to be used for non-actors, as a new strapping mechanism will need to be designed. Furthermore, the physical integration can be improved by adding a proper base instead of forcing the user to stand on Baxters legs. Standing on Baxters base resulted in physical strain on the lower legs for the actors. Combined with a better strapping mechanism, a base for the user to stand on will increase comfort while integrated with Baxter.

The physical strain can also be addressed by a more involved roll-down process. The roll-down exercise targets the physical strain and releases tension within the body. Introducing a longer and more thorough roll-down process in the non-actor study, along with better strapping and an independent base to stand on, will target the physical issues encountered by the actors in their study.

The actors expressed enthusiasm towards the cyborg warm-up routine. This routine allows the actor to mimic Baxters movements, which helped them synchronize with Baxter. This cyborg warm-up will be considered for the non-actor study and prototype. However, the cyborg warm-up used by the actors was specifically tailored to the wearable prototype created for their study. The movements of Baxter in the cyborg warm-up follow the gestures created by the researchers for the actors to use during their performance. In other words, the cyborg warm-up was tailored to the task that the actors were executing, which was performing a monologue. Hence, given that the aim is to translate these techniques for non-actors, a new cyborg warm-up that is tailored to the new prototypes capabilities must be considered. Furthermore, a new cyborg warm-up will need to support the task that the non-user will execute in the cyborg state, which will be derived from the results of the design session.

5 The Design Session

When working with the actors, the task to be executed within the cyborg state was well defined. They are professional performers, so the task that they executed, performing a monologue, was one that they were extremely familiar with and was a natural choice for the cyborg task. However, the next step is to translate the warm-up and cool-down techniques for a possible cyborg application outside of performance. Moreover, since the future of the project requires the performance techniques to be properly tested by different users, the task they are executing as cyborgs, and by extension the wearable itself, will need to support actions and gestures that are not performance based, as was the case with the actors.

In order to validate these techniques, a new task for the user to execute as a cyborg will need to be defined. The challenge is to determine what exactly this task will be. There are many different possible tasks to choose from, and given the novelty of a wearable experience, it is likely that there are tasks and actions that have yet to be created.

In order to aid in the task design process, a design session, or series of sessions, was proposed. In a design session, designers gather to brainstorm ideas and critique them, thus providing a platform for ideation and creativity. These gatherings are open ended and relatively informal, and they provide the researchers an opportunity to explore a series of ideas from different sources. For this project, seeking the input from experienced designers serves as the first step towards designing and implementing a task and prototype for use in a non-performance based context, which will be used to evaluate the warm-up and cool-down techniques.

Hence, this session involves designing possible cyborg applications with fellow designers. The purpose of this session is to help facilitate the designing and creation of the prototype, and to determine what task the cyborg user will accomplish during the user study. In the observational study, the task that the actors were to perform was well defined. In order to examine a non-actor cyborg users immersion and detachment, we need to determine what the user will actually do.

The challenge the researchers faced was creating the design session such that it constrained the ideas within the problem domain yet spurred the designers creativity without inhibiting them with limitations. Providing constraints was paramount to the success of the session. The designs need to be limited such that the prototype implementation of the task can be completed within an appropriate time frame. Moreover, if no structure is provided, it is likely that the designers will be lost and unable to generate a large number of ideas.

With these constraints in mind, the researchers sought a structured methodology for exploring various tasks. This structure came in the form of a taxonomy proposed by Bullock et. al at Yale University. This taxonomy provides a detailed classification of hand manipulation tasks. In this taxonomy, the hand manipulation tasks are classified by the following factors: contact, motion, prehensility, and hand placement. It provides a classification mechanism for simple tasks involving the hand. Different gestures are classified using the factors, resulting in a tree with eleven nodes. For example, resting position is classified as a no contact, no motion task, while open handed hold tasks such as holding a plank of wood or a tray of food are classified under contact, non-prehensile and no motion.

Despite the focus on hand-based gestures, this taxonomy provided the structure the researchers sought for the design session. By nature, this taxonomy classifies extremely simple tasks such as writing and gripping an object. This simplicity is in line with the limitations resulting from Baxter and the time frame. Moreover, inspecting this taxonomy introduced a question that, eventually, became the key question in the design session; what would simple tasks look like if you had four arms? What would resting your hand look like if you wore two additional arms? What would the arms do? This question provided the structure necessary for executing the design

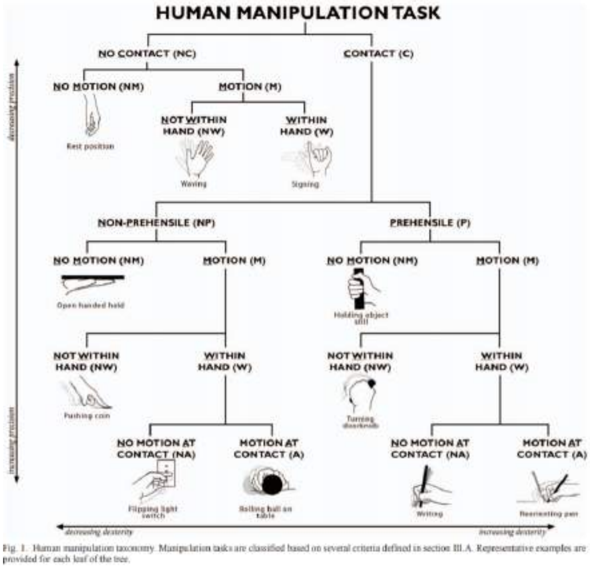

Figure 9: The taxonomy proposed by Bullock et. al

session and also maintains the creativity of brainstorming various cyborg applications. No longer are the designers tasked with inventing entirely novel cyborg applications with no basis in reality. Moreover, Bullock et. al propose that this taxonomical breakdown of tasks can be used to build more complex tasks and experiences. Hence, theoretically speaking, exploring how these simple tasks change in the cyborg context can create building blocks from which more complex cyborg actions can be derived.

The participants targeted for this session are members of the Interactions Lab as well as students who have taken CPSC 581 (Human-Computer Interaction II). This is due to their familiarity and experience with human-computer interaction concepts; participants with these qualifications possess a strong foundational knowledge of design principles and prototyping techniques. When formulating this session, it was agreed that this session should be open ended and relatively relaxed. Food and drink were to be provided to the participating designers, as the goal was to cultivate an environment that fosters creativity, constructive criticism and exploration of ideas.

In terms of the actual ideation process, various methodologies were considered. Among these methodologies was the IDEO method called Customer Journey Mapping. In Customer Journey Mapping, the goal of the designer is to empathize with the end user by imagining the experience, i.e. their journey when using the product, from start to finish. By evaluating the experience from the beginning until the end, the goal is to gain new insights into the proposed design and create more opportunities for design improvement. This design methodology was heavily considered, however, upon introducing the taxonomy of hand manipulation tasks, this design technique was determined to be not ideal. The nature of the taxonomy is that it classifies extremely simple tasks. Due to their simplicity, these tasks are not ideal for deep experiential analysis. Instead, another advantage of their simplicity is that a large number of designs can be generated in a short amount of time. Thus, a low-fidelity sketch prototyping approach was chosen for the ideation process. This is a variation on the popular 10 plus 10 prototyping method [6], in which a designer sketches ten unique designs for a problem before refining their ideas. Here, the designers will use paper and pencil to propose new ideas and explore their existing ones. It is an excellent way to generate ideas and suits the nature of the taxonomical tasks extremely well. Furthermore, a human-human prototyping method was introduced in order to allow the researchers, and other designers, to visualize the design (Figure 12). An important part of this process is the critiquing of ideas, and a human-human display of the design, where one designer acts as the cyborg arms and the other is the cyborg user, is easier to showcase to the other designers than a sketch on paper.

5.1 Design Session Procedure

The design session itself was broken down into three phases; framing, taxonomy breakdown and prototyping. Overall, the session was created to not only design an array of prototypes in a short amount of time, but to also allow the designers to collaborate in the brainstorming process and to critique other designs. Five designers were present, and were provided with sketching materials. Food and drink were provided at the session, and the session itself was three hours long. The designers that were sought were ones that were extremely familiar with each other in order to facilitate human-human prototyping without discomfort.

The goal of the framing phase was to establish the context of the project and why the designers were needed. This phase took less than ten minutes to complete in order to give the designers as much time as possible to brainstorm. A small number of slides were shown to the designers. The projects definition of cyborgs was introduced, as well as various depictions of wearable arms in popular media, which was done to start the imaginative process for the designers without yet considering the limitations. The broad objective of the designers was established; to brainstorm and design tasks that a cyborg can accomplish. Note that this is the high level purpose of the study, the structure and limitations have not yet been introduced so as to allow the designers to start thinking without any limitations placed on them. It is also worth noting that the minute details of the project, such as the study with the actors, were not discussed as it is superfluous to the designers. The designers were given the exact information needed in order to start prototyping, hence going through the details of the observational study is not necessary.

To conclude the framing phase, the constraints of the design session began being introduced. The Baxter robot was shown very briefly so as to give the designers a notion of the limitations of the project. Note that the designers were first introduced to cyborg implementations in popular media before being introduced to the constraints of working with Baxter. This decision was made with the goal in mind of invoking the creativity of the designers first before introducing limitations. This same technique was used in the actor study in the first co-design phase.

The taxonomy breakdown phase was next. Here, the goal was to establish the remainder of the constraints in which the designers will work by introducing the taxonomy and the main design session question. Similar to the framing phase, this phase took less than ten minutes to complete, meaning that only the necessary information about the taxonomy was given to the designers. To start this phase, a more specific goal was introduced, building on the initial overall goal that was introduced in the first phase; the designers were asked to brainstorm a simple, everyday task that a cyborg can accomplish. Following this, the taxonomy was introduced in order to establish what a simple task means within the context of the session. A breakdown of the taxonomy was shown using slides, with each branch of the taxonomy being briefly explained. The example tasks provided by Bullock et. al in the taxonomy diagram, shown as leaves in the taxonomy tree were highlighted. The main design question was then posed to the participants; how does a user accomplish these simple tasks as a cyborg? Finally, to conclude this phase, a task context was established. The taxonomy tasks themselves could mean different things depending on the environment. For instance, the way one writes at home is different from writing in the workplace, on the bus or in class. Hence, a specific context was chosen for the designers, the home, so as to introduce a scenario in which the task can be accomplished. This context was chosen because of the ubiquitous definition of home to the designers. The home context is more consistent across various home instances compared to a workplace context, which could vary from designer to designer.

Thus, the full constraints of the session were revealed to the designers; the objective is to brainstorm and design simple cyborg tasks within the home context using the hand manipulation taxonomy. With this information, the final phase of the session, the prototyping phase, fully

Figure 10: In this image, the five designers are sketching one of the tasks

commenced. The prototyping phase is structured as follows; The five designers were split into one group of two and one group of three. A task from the taxonomy is selected, such as the no motion/no contact hand resting task. The designers are given ten minutes to sketch various ideas on paper of how the selected task will look like in the cyborg context, following the 10 plus 10 method. After ten minutes, the groups are to present their ideas using human-human prototyping to demonstrate the design. Both sets of designers then discuss the proposed task designs, briefly exploring possible ramifications of the design and how it can be improved. Another task type is then selected from the taxonomy, and the process is repeated again.

Out of the eleven tasks in the taxonomy, the designers prototyped for eight of them during the session before running out of time. However, due to the open nature of the session, more complex ideas were generated, and upon further analysis, these complex ideas were shown to be classifiable under other taxonomical nodes. Thus, with these complex ideas, the entire taxonomy was covered by the designers in this session.

For each taxonomical task, each group generated their sketches in a ten minute period. The designers displayed their exceptional creativity in their work despite the constraints placed upon them. Even for relatively trivial task types such as a no contact/motion task type, e.g. waving, the groups brainstormed various ways and scenarios in which wearable arms can function when waving. For example, one group proposed using the wearable arms to wave if the user is too tired and is lying on the couch, while the other group proposed using the wearable arms to wave while the user holds out a real hand to shake another persons hand, which could streamline the self-

Figure 11: A designer group brainstorming for one of the tasks

Figure 12: In this image, two designers are demonstrating their design for signing four letter words using wearable arms

introduction and greeting scenario.

More speculative and complex ideas were proposed for the signing taxonomical node, in which one uses their hand to gesture or communicate. In their sketches, the designers proposed use cases in which the wearable arms can non-verbally communicate and provide social or emotional cues. One interesting design that emerged from exploring a signing gesture was using the robot arms as a sign language interpreter for users with hearing disabilities. In this scenario, the cyborg user will communicate verbally, and the cyborg arms will translate the words into sign language for a deaf user to interpret. This proposed design highlights that even through non-verbal communication, most of the designs displayed some form of utility rather than purely emotional reflection, which is unlike the actors, who used their wearable to execute gestural communication based solely on emotional reinforcement.

6 Design Session Results Analysis

Before progressing to the prototype design and specification, the results of the design session were analyzed to derive the design, but also to derive lessons and conclusions based on the data collected. The data generated by the design session included the paper sketches, video recordings, interview-style questions and observational data.

Multiple data analysis techniques were employed in the design session analysis. First, the design session was qualitatively analyzed based on the videos collected, interview questions answered and overall observations of the designers during the session. From this qualitative data, the exact thoughts of the designers are captured with their answers and comments throughout the session. The answers the designers gave to the questions served as the foundation for the set of conclusions. The observational study also made use of qualitative data analysis to derive conclusions. However, unlike the observational study, the design session produced data that can be analyzed in other ways that can further support the observations in the qualitative data.

A technique referred to as image boarding was utilized with the collected sketches. As defined by Hannington et. al in the book "Universal Methods of Design" [8], image boards are a collage of pictures used to communicate a description of design aesthetics and design intent . This technique was applicable to the project because the main output of the session was the paper sketches, which are visual mediums that are akin to pictures and can form collages. For this project, the sketches were used to create various collages from which patterns and conclusions can be determined. The image board technique provides a visual mechanism for emerging patterns within the sketches to be easily recognized and validated.

The last form of analysis conducted was a quantitative analysis based on the sketches and the patterns found within each sketch. Counting, comparing quantities and graphing were employed to quantitatively analyze the data. Furthermore, quantitative analysis is made easier through the image board technique because the patterns found in the image boards and collages can easily be counted.

Another form of data analysis, referred to as artefact analysis, was considered. Artefact analysis is a technique borrowed from architecture design, and in this technique, the data produced, the artefacts, are analyzed in the form of a fifty-question survey. The goal of this technique is to gain new information about the artefacts by answering simple questions about its qualities, such as how it was constructed, how it would react if put under different forms of stress, and the necessity of the features. These questions are standardized and were provided by the artefact analysis tool-kit. This technique was attractive to the researchers due to the questionnaire style of analysis. However, when this technique was applied on the paper sketches, the results did not reveal any concrete information about the data. This is due to multiple reasons. First, as this is a technique that is popular in another discipline, many of the questions are either inapplicable or they do not reveal any relevant information. Questions such as how the artefact would react if wet and if placed in an oven will often not yield favorable results in technological contexts. Second, the researchers found it challenging to clearly define what the artefact was when the data was in the form of a sketch. Is the artefact the paper sketches as a collective or individual sketches? Should the artefact defined as sketch's intended meaning (i.e. a hypothetical wearable prototype) or as the actual drawing itself? As a result of this challenge, it was difficult to yield any useful information that did not pertain to the actual paper. Thus, this form of analysis was discarded for this project. However, there is a speculative future in which this technique can be applied to a real implemented prototype, as it is a physical object and not a drawing on paper.

6.1 Qualitative Analysis

Throughout the design session, the researchers present made note of their observations of the designers. Video recordings were also revisted to capture any observations that might have been missed. Furthermore, The last ten minutes of the design session were dedicated towards a debrief to summarize the session. Observations about the patterns the designers noticed were also discussed.

When asked about what they found the wearable most helpful for, multiple designers noted that their designs focused heavily on reducing the physical strain on the user. In other words, designs where the wearable arms somehow reduce the physical effort required by a user to accomplish a task were quite common. Using the wearable arms to lift a couch while vacuuming, or for pushing a heavy door are examples of reducing physical strain by using the robot arms. Furthermore, the designers observed that many of their proposed designs also heavily focused on multi-tasking scenarios that increase the user's efficiency such as having the wearable hold trays of food while the user shakes the guests' hands. These two commonalities in the designs are in stark contrast to what was observed with the actors' desired feature list for their wearable prototype. Unlike the actors, who focused more on expressing emotion through their arms, it is clear that the tasks brainstormed by the designers were focused

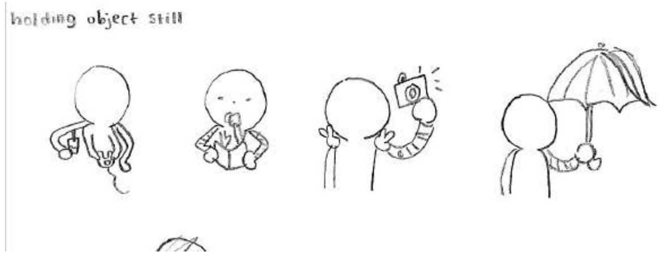

Figure 13: A series of sketches by one of the designers for multi-tasking

on utility and not non-verbal communication through the arms.

Moreover, for some rounds of the prototyping phase, both groups struggled to brainstorm more ideas after seven to eight minutes. This is an expected result due to the selection of a simple task taxonomy, as the tasks are so simple that there is a limit to the number of unique ideas that can be generated. This further justifies the selection of the paper prototyping as opposed to Customer Journey Maps; the taxonomical tasks are, predominantly, simple and shallow.

When asked about what they found was most difficult in their sketching process, one designer stated that the taxonomy was at times hard to follow, which was a statement agreed upon by the other four designers. It was also observed that the designer groups asked more and more questions as they delved deeper into the taxonomy. This is most likely a result of confusion resulting from trying to define the classifications of Bullock et. als proposed model. As the taxonomy deepens, the task classification becomes more complex. For example, the writing task is classified as a No Motion at Contact/Within Hand/Motion/ Prehensile/Contact. During the prototyping round for this task, the groups both questioned the definition of within hand and prehensility. The lack of familiarity with the taxonomical vocabulary and classification terms could have played a part in the difficulties the designers experienced as the design session went on.

Furthermore, an interesting roadblock that the designers commented on was that of feasibility. Most of the designers expressed that they felt that they were thinking too deeply into the technical requirements necessary to actually make a design a reality. While this could have been a result from introducing Baxter as the wearable, the concerns that the designers shared can be applied to other wearable prototypes. Every single designer had a computer science background and had a deep understanding of what technology is available today. This understanding of existing hardware and technology could explain the extreme focus on utility and multi-tasking rather than

Figure 14: Another set of sketches of multi-tasking tasks, including using the wearable to help with holding a nail and hot coffee

having the arms interpreting social cues and reacting to them, as is popularly depicted in media. The technology required in order to allow the wearable to display some form of autonomy or advanced behavior does not yet exist.

Finally, when asked about any further drawbacks in their designs, the designers described that in some cases, the user does not want robotic arms to help in executing their current task. One of the designers asked if one even needs cyborg arms for doing something as simple as waving, which is usually a one-handed task. This question also introduces the concept that sometimes, having more arms is more of a hindrance than an advantage. Thus, as these wearables become more ubiquitous, in future designs it is important to design the wearable to support a method to reduce the hindrance when the arms are not required. The designers displayed this consideration for reducing hindrance in the hand resting task; all of the designs proposed for this task were entirely focused on how to reduce the annoyance that emerges from the wearable arms presence when trying to rest ones hands.

6.2 Image Boards and Quantitative Analysis

The image board technique was used to visualize the observations found in the qualitative analysis, as well as for recognizing new patterns and observations within the data. To create the image board, copies of the sketches produced were cut and displayed in different collages. Due to this techniques use of physical cut outs of the sketches, it further enabled the quantitative analysis to be done in conjunction with the creation of the image boards. Thus, the image boards were used to visualize and derive observations, while the quantitative analysis was conducted by counting the sketches in each collage to re-enforce the observations made.

In total, group 1, the group with two designers, sketched fourty-one designs, while group 2, the group with three designers, sketched thirty-eight. Hence, in total, seventy-nine sketches were generated during the design session. Interestingly, there were seventy-three unique sketches drawn, meaning that only six sketches displayed an exact overlap between the two groups. When considering that the taxonomy classifies extremely simple tasks, it is peculiar to see such a small overlap. However, this small overlap can be justified by multiple factors. First, the different backgrounds of the designers could have played a role in the generation of entirely unique ideas by both groups. Second, the open nature of the design session likely played a large role in the small overlap because the designers were never warned to strictly stick with the taxonomy. While the taxonomy provided structure, it is clear that the designers did not hesitate to create more complex designs that overlapped with other taxonomical nodes, such as the sign language interpreter previously mentioned.

In the short interview phase at the end of the session, designers described their confusion due to the taxonomy as a roadblock that was difficult to overcome. Given this statement, it can be assumed that there would be a correlation between the number of ideas generated and depth within the taxonomy. However, when the sketches were categorized on the image board based on the taxonomy category the sketch was based on, it is evident that there is no clear down-trend in the sketch generation as the session went on (Figure 16). The quantitative results show that the hold object still node produced the most sketches with seventeen, yet this is a node that is in the middle level of the taxonomy. Moreover, when the quantities of each cateogry are graphed, there is no clear correlation either (Figure 15). The task with the least number of ideas generated was the writing/re-orienting taxonomical node, with ten ideas produced. While this is a task that is deep into the taxonomy, the number of ideas generated could be justified by the designers' inability to think of a great number of tasks where a writing gesture is involved, with most of the ideas being focused on writing in a diary or painting a picture.

Based on the qualitative results, the designers concluded that their designs were focused on two areas: reducing physical strain and multi-tasking. Image boards were created to examine these statements, and it is evident that these two areas contain the greatest number of common sketches within them. Of the seventy-nine sketches, twenty-eight displayed cyborg applications that explicitly reduce physical strain (Figure 17), while sixty-two displayed some form of multi-tasking (note that a sketch can possess both traits of reducing physical strain and multi-tasking) (Figure 18). Another observation that was found when image boarding the multi-tasking

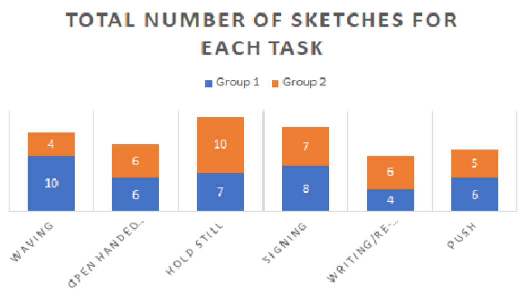

Figure 15: This graph shows the number of sketches generated per taxonomical node. The bars are sorted based on their depth in the taxonomy, with waving being the shallowest

Figure 16: This image board shows the grouping of sketches based on taxonomy classification

Figure 17: This image board shows the sketches depicting reduction of physical strain

sketches is that the act of multi-tasking can be classified in two ways; either the wearable arms and the user are executing DIFFERENT tasks (Figure 19), or they are executing the same task (Figure 20). Both of these classifications increase the user's efficiency, but there are some cases where the user and the wearable are conducting the exact same gesture and task to potentially double the output of a task within the same amount of time. Thus, when classified as such, forty-seven sketches exhibited the execution of two different tasks simultaneously, while fifteen displayed the execution of the same task with both sets of limbs.

In terms of drawbacks to equipping a wearable, the designers did note that there are cases where attempting to incorporate the wearable arms in a task served as more of a hindrance than an advantage.With this in mind, it is important to consider designs where the wearable arms are in a position such that the user can perform a task un-abated. Surprisingly, when image boarding this observation, only five sketches explicitly features the wearable in a position that doesn't restrict the user, such as having them tucked in when waving or have them placed on the hips when shaking someone's hand. This could be a short-coming to the design session's explanation, as it could have been made more clear to the designers that they are free to consider cyborg applications where the arms are in a rest mode. However, upon further analysis of the sketches, it was observed that a further twenty-eight sketches exhibited a rest mode for at least one of the robot arms. This means that in situations where only one robot arm is being used, the designers implied in their sketches that the other arm was in a rest mode, or in most cases, down by the user's sides. This further supports the conclusion that prospective cyborg prototypes will need to accommodate situations where at least one of the wearable arms will need to be in a rest mode of some sort, especially as more time consuming cyborg experiences become more prevalent. Further patterns were recognized when making use of the image board technique, although they are not as predominant as the patterns described above. One image board was created to explore if there are any sketches that focused on relieving mental or cognitive strain, as opposed to physical. Allowing the robot arms to write out mathematical formulas for you while writing a test or having the wearable use sign-language when a user is speaking to a deaf individual are examples of reducing the cognitive load of a task. Five of the sketches displayed this property.

Another interesting observation that emerged from the image board technique was that there are some sketches that showcased how the arms can re-enforce emotional or contextual cues. In other words, the wearable is not performing an explicit task, but is rather emphasizing the task the user is accomplishing. Examples of this include a design where the wearable can point to a board or a screen while the user is speaking to a crowd, or angrily gesturing at someone while driving. This particular pat-

Figure 18: This image board shows the sketches that depicted multi-tasking capabilities

Figure 19: This image board shows the sketches depicting two-task multi-tasking

tern was explored because of the experience with the observational study with the actors, and due to the designers' statements about their emphasis on utility. Twelve sketches showcased this pattern.

Lastly, an image board was formulated to explore sketches where the wearable attempts to compensate for human error. When it comes to using a hammer and nail, or even helping the user knit, there are some tasks that can be hindered by human error. Ten sketches showcased attempts to involve the wearable in tasks that are prone to human error.

The patterns of reducing mental or cognitive strain, reenforcing contextual or emotional cues and reducing human error contained less than fifteen sketches each. This could be justified by the designers' thoughts on the technical limitations of existing wearables. Because of their consideration of technological limitations, it is more difficult to design such speculative applications. For example, with the designs that reduce human error, a wearable needs to be implicitly controlled by the user's mistakes, and due to tasks that require fine detail work, a dexterous

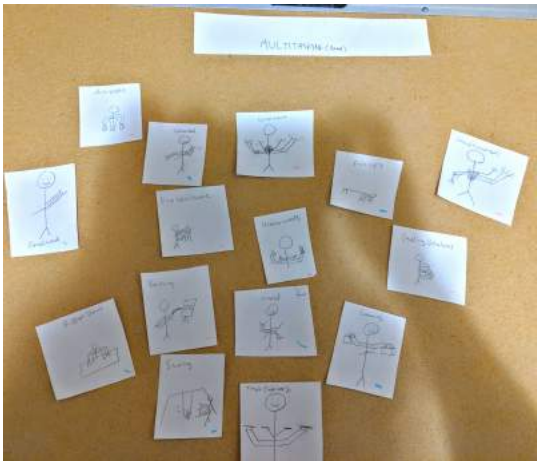

Figure 20: This image board shows the sketches depicting same-task multi-tasking

set of limbs is needed as well. Despite this justification, these patterns still provide an interesting provocation of the possible future of cyborg application design, technology permitting.

6.3 Lessons Learned

Based on the three forms of analysis outlined above, three main conclusions can be made about the cyborg applications designed in the session:

1.) The wearable arms are helpful when they support multi-tasking, be it the multi-tasking of the same task or two different ones.

2.) The wearable arms are helpful when they alleviate physical strain.

3.) Designing mechanisms to support a "rest mode" for the arms is necessary, as there are cases where integrating two more limbs into a task can reduce productivity rather than increase it. This is especially important as longer-time cyborg experiences become available.

7 Final Prototype Design

With the results of the design session analyzed, the final step of the project is to design a prototype that supports the performing arts techniques for transitioning, but also a cyborg application, which is derived from the design session. Once this prospective prototype is implemented, the performance techniques will need to be properly tested to determine their efficacy outside of performance. Because of this, the prototype must support the completion of a task (i.e. a wearable with a specific purpose) in order to test the performing arts' techniques' effects on immersion and integration

7.1 Deriving a Cyborg Application From The Design Session

There are seventy-six unique sketches produced in the design session, and one of these designs must be chosen for the prototype. The results of the design session indicate that the cyborg applications generated in the session are most commonly used for multi-tasking and/or reducing physical strain. Hence, selecting a design from these subsets is a logical choice for the prototype design, especially when considering the future prevalence of such cyborg applications.

It is worth noting that designs can fall under both reducing physical strain and multi-tasking. Design such as this can be doubly beneficial and important to explore due to the potential utility they provide. Hence, a design was chosen from the set of sketches that showcase the reduction of physical strain as well as multi-tasking capabilities. One particular sketch that fits this description makes use of the wearable arms to hold heavy textbooks so that the user can open a door with their free hands. This task was chosen for the prototype design and specification because of its utility, but also due to its simplicity. The simplicity comes in the form of implementational simplicity, but also for the potential user who will be executing the task. A cyborg application that supports this task is easily describable to a prospective user, meaning the testing of the system (the task execution and the warm-up and cool-down techniques) will be streamlined as a result. Therefore, the prospective prototype being designed in this final phase of the project will support the execution of the following task: The wearable will perform an open-handed hold gesture from the taxonomical breakdown, and will support heavy books so that the user can use their arms to turn a doorknob.

7.2 Prototype Specifications

The prototype being specified will not only need to support the warm-up and cool-down protocols from the observational study and the heavy textbook task from the design session, but must also integrate the design lessons learned throughout the phases of the project. The experiences in both the observational study and the design sessions provide a series of lessons learned to improve the overall experience for the user. With these lessons in mind, as well as the performance techniques and the supported task, the prototype specification is as follows:

Physical Integration:

1.) The prototype must support a comfortable and efficient strapping mechanism. Use of thick straps with padding is necessary, but the straps must also be easily detachable by the user themselves. This specification is a direct result of the observational study, where the actors stated in the debrief phase that the strapping mechanism was uncomfortable and resulted in an increase in strain on the legs. Furthermore, the strapping mechanism required two other people to strap and unstrap the actor from Baxter, which needs to be refined to promote a more self-contained and seamless experience. Figure 21 is a prototype sketch depicting this specification.

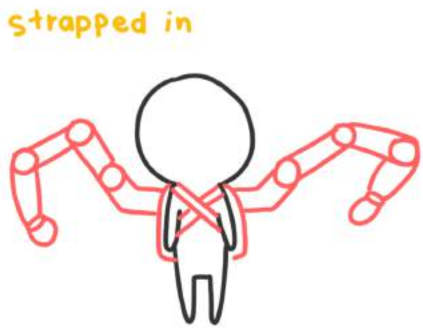

Figure 21: This image shows the straps that should be used by the prototype

Figure 22: Prototype design showing specification 3, the warm-up initiation on startup

2.) The prototype must support the spine of the user and avoid a rigid contact point between the wearable and the user. This means making use of padding along the back of the user, rather than having the rigid machinery make direct contact with the user's back. The actors indicated that Baxter's rigidity required some adjustment upon strapping, and also contributed to strain on the back.

Transitions:

3.) The prototype must support a mechanism to in-

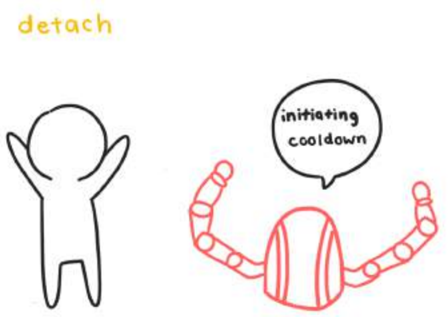

Figure 23: Prototype design showing specification 4, the cool-down initiation on detachment

Figure 24: Prototype design showing specification 5, execution of the open handed hold task

duce the warm-up protocol in the user upon start-up. This means that when the wearable is turned on, it will remind the user that the warm-up needs to be executed, and will walk the user through the warm-up through voice or possible a graphical user interface. Figure 22 showcases the protoype sketch for this specification.

4.) The prototype must support a mechanism to induce the cool-down protocol once the user unstraps from the wearable. This means when the user unstraps, the prototype will initiate the cool-down protocol, and will turn off upon the completion of the cool-down. Figure 23 is an example sketch of a prototype supporting this specification

Task Execution:

5.) The prototype must support the task derived from the design study, which is an open handed hold of heavy textbooks. Supporting this task means implementing an explicit control mechanism for the user to initiate the execution of the task. A possible explicit control mechanism is voice control; when the user speaks the command, the prototype will enter an open handed hold position for the user to place the textbooks on. Furthermore, the open handed hold needs to be designed such that it leaves an opening for the user to freely use their arms, meaning the wearable will need to spread widely to allow that free movement. Figure 24 is a sketch showing a design supporting this specification.

6.) The prototype must support a "stand-by" mode. This mode will tuck the arms by the sides of the user so that it reduces the overall hindrance on the user. This implies that the wearable can be worn in situations outside of the task execution, and the user will still be able to perform other tasks. Similar to the execution of the main task, this stand-by mode will need an explicit control mechanism to be implemented, such as a voice command.

Other:

7.) The prototype must support an emergency exit or power off mode that is easily accessible by the user at all times. This is due to the potential risks of having the prototype malfunction while the user is equipped with it. The Baxter prototype for the actors implemented an emergency stop button that forces the robot to shut off, and this stop button was always placed in proximity of the cyborg actor in case of an emergency. This specification must be supported so as to ensure the user has a safe experience. The above specifications, if followed in the implementation, will incorporate the performing arts techniques with a cyborg task, as well as necessary features needed to successfully function as a cyborg. A series of sketches was produced showing a possible prototype that adheres to this specification. The sketches show the behavior before attaching to the wearable, the task execution while equipping the wearable, and the behavior after detaching from the wearable.

8 Limitations

One of the biggest limitations of this project is the small selection of data from the various phases. Only one observational study was conducted, and only two actors participated. Furthermore, the actors were only available for a limited amount of time, which not only reduces the amount of time for refinement, but also the amount of qualitative data collected. More lessons could have been learned in order to refine the warm-up and cool-down protocols even further were it not for the time restriction. In the future, another study, or series of studies, should be conducted with actors to refine the techniques further, but also to properly determine which aspects of the warm-up and cool-down were most effective for the experience.

Moreover, only one design session was conducted with only five designers. These designers were only available for two hours, and this time restriction affected the sketches produced as well as the qualitative data collected in the form of interviews. While the amount of sketches produced was substantial, there is very little support for the conclusions being made due to the single data set being used. More design sessions are needed to generate a large enough data set to truly support the conclusions made.

The taxonomy also introduces limitations. While the shallow nature of the taxonomy provides a rigid structure for designers to follow, this can result in shallow cyborg experiences as well. Furthermore, the taxonomy is focused exclusively on hand-based tasks, which limits the cyborg applications prototypes to tasks involving the hand. A different taxonomy should be considered for future design sessions. An alternate solution would be to consider a different type of structure outside of a task classification taxonomy for future sessions.

The Baxter robot used in this project is also extremely limited. The robot is not a real wearable, and is entirely stationary. Baxter is also extremely large and cannot feasibly be worn for large periods of time. From an implementation perspective, the provided APIs are outdated and do not provide sufficient documentation, which will prove to be a challenge should a more complex prototype be implemented using Baxter. The robot's large size and its age, combined with the processing limitations mean that it is extremely slow when it comes to any task, and is also susceptible to malfunctions. A different wearable prototype must be considered for future explorations of this project's topic.

9 Future Work

The immediate future of this project will revolve around the proposed prototype's implementation. This implementation will adhere to the specifications provided. While the Baxter robot is readily available for use at all times, considering other robots for a prototype implementation will alleviate many of the technical limitations imposed on this project. Once the prototype is fully implemented, the performing arts techniques used in this project can be tested properly in a cyborg application context. A series of pilot studies will be conducted to test the efficacy of these performance techniques and to measure their effects on immersion and task execution.

The intermediate future of this project can potentially be focused on alleviating the limitations with regards to the data produced. This means conducting more observational studies and design sessions to support the conclusions made in the phases of this project. Moreover, different types of performers outside of dramatic performers should be considered, as the techniques used in this project are universally used in the world of performance. Similarly, designers with different backgrounds should be considered for future design sessions so as to generate more varied data.

The goal of this project was to improve the experience of becoming and unbecoming a cyborg. Along the way to exploring this goal, a large amount of prospective cyborg applications were proposed. Many of these proposed designs are extremely novel, and should be discussed and analyzed further so as to explore their potential in the future of cyborg experiences. By exploring the novel ideas produced in the design session, a possible implementation of such cyborg applications could potentially be explored in the future. Also, during the formulation of the prototype specifications, the research team considered a feature in which the prototype can "learn" new gestures and tasks from the user. A cyborg prototype such as this can potentially support a multitude of different tasks in different scenarios, and thus it is worth exploring and, technology permitting, be implemented.

10 Conclusion

This report presents the phases and results of the project in which determining more effective cyborg transitions are explored. An observational study, structured in the form of co-design sessions in collaboration with professional actors, was conducted. The qualitative results from this study are outlined. The results reveal that the actors found that these protocols helped the experience of entering and exiting cyborg states. The next step of the project, translating the techniques to a cyborg application context, commenced through a design session that was formulated and then executed with five designers. The analysis of the results from the design study indicate that additional wearable arms are most useful for reducing physical strain or for multi-tasking purposes. From the series of sketches produced in the design session, a subset was chosen for designing a prospective cyborg prototype. This prototype, along with the techniques formulated and used in the observational study will form the basis of a system that supports effective transitions into and out of the cyborg state. By using this system, the user will be able to accomplish the task the prototype is designed for, but will be aided by integrated performance techniques to help facilitate transitions, thus increasing productivity and immersion as a cyborg being.

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