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Virtual Wearables

Envisioning Future Scenarios for Wearables in Extended Reality Environments

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Abstract: Extended reality systems are among the most prominent environments of today's entertainment. They are wearable systems and there are many other supportive wearables that are designed to go together with XR devices such as haptic gloves or full–body suits. However, applications are usually limited to tactile feedback and the collection of the body data and other strong parts of wearables are neglected. These strong parts, according to previous studies, are the performative, social and interactive features of wearables. In this chapter, we will introduce those in detail and envision future uses for XR wearables drawing on this knowledge.

Keywords: Extended Reality; Virtual Reality; Augmented Reality; Games Research; Wearables.

Extended reality (XR) (virtual reality, augmented reality or mixed reality) is one of the most trending concepts in entertainment today. As a basic explanation, the aim of XR is to provide more immersive media experiences by putting the user into the virtual world of the related media. From social media environments to creative production tools, XR applications are quite varied, and compared with desktop applications, they provide unique experiences because the user is in the centre of a different reality. In 2018, the virtual reality hardware market has been around 4 billion US dollars (KZero, 2016; SuperData Research Holdings, 2018) and this number is expected to increase to 9.7 billion US dollars by 2021 (SuperData Research Holdings, 2018) if the high–adoption scenario is realised. Indus-

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try leaders, such as Facebook and Google, are investing in XR systems to realise this scenario by making XR more affordable, lightweight, usable and integrated into daily life and entertainment.

However, most of the current widespread extended reality glasses only stimulate the visual perceptions of users, which creates the need for companion devices such as 360° treadmills for incorporating other senses into the XR experience. This is where wearables come in because they can facilitate different kinds of senses and introduce various interaction styles to a XR environments.

An example of such concept is the recently released movie Ready Player One (Spielberg, 2018), which envisions a future where the utilisation of virtual reality is a common daily activity and where the virtual reality equipment is complete only with the support of whole–body wearable kits. Although this is a fictional scenario, research on XR wearables corroborates with this vision because there are many studies relying on wearables for introducing senses that cannot be provided by XR glasses. There are examples of wearables providing haptic feedback and gestural controls that are already on sale (Labs®, 2018) or in the commercialisation phase (Corp, 2018; Inc, 2018). However, wearables promise much more than just haptic feedback or gestural controls, and are postulated to make XR experiences more immersive by (1) being a tool for reflecting augmented body expressions, (2) transforming the body in versatile ways to enhance the embodiment feeling and (3) introducing new ways of interacting with the virtual layer through tangible and embedded modalities (Tanenbaum & Tanenbaum, 2015) by augmenting the physical properties of wearables in the virtual environment and expanding their capabilities of representing information.

Considering these, research on wearables for XR still does not answer the following questions: What for wearables can be used in XR, except for providing haptic feedback and gestural control? What is missing in terms of design philosophy in the XR field when it comes to interfaces that can be attached to our body? What areas are still underexplored and how do these areas can help us to reach an ideal state where we have a seamless interaction between the physicality of real life and the digital layers of virtual reality? In this paper, I will present a critical reflection on the current state of wearables for XR to answer these questions and point out a future that might allow us to create new bodily experiences in the virtual world through wearables.

Current State

Most of the work done on *XR* consider *wearables* to be mediator devices for *getting body data* and giving *bodily feedback*. Therefore, except for several specific cases, wearables have been used for providing tactile and kinaesthetic feedback to users and transferring biodata such as motion or EMG into a VR environment to better manipulate the content within. For instance, when it comes to output devices, Wolverine (Choi & Follmer, 2016) is a knuckle–type example of a wearable that is worn on the fingers; it provides tactility with force feedback. A similar study made virtual objects "feelable" to hands by incorporating a glove with haptic actuators (Israr *et al.*, 2015). Haptic Serpent (Al–Sada *et al.*, 2018) and the Force Jacket (Delazio, Nakagaki, Hudson, Lehman & Sample, 2018) are other projects that provide tactile feedback but with a focus on the full upper body. In addition, there are also released and future commercial products. such as HaptX (Inc, 2018), VMG (Labs®, 2018) gloves and Plexus (Corp, 2018) for adorning the virtual environment with physical feedback. In terms of input, WatchVR (Hirzle, Rixen, Gugenheimer & Rukzio, 2018) is a recent example that investigates smart watches as a control device for VR systems. In this project, the authors compared the different modalities of smart watches, such as gestural and touch interaction, by testing them in different positions, such as worn or handheld. Another example is Flex (Eckhardt, Sullivan & Pietroszek, 2017), a low–cost wearable device that can recognise hand gestures from EMG data for integrating body into XR. As shown by these examples, w*earables have been a part of many XR projects; however, they mostly focus on haptic feedback and gestural interaction, leaving space for the* exploration of other modalities, such as tangible or embedded.

Other than the above examples that focus on body input and output, several projects have explored novel interaction modalities that wearables could introduce into VR environments. FaceTouch (Gugenheimer, Dobbelstein, Winkler, Haas & Rukzio, 2016) — one of these examples — modifies head–mounted displays (HMDs), an essential part of XR systems; this project exploits the wide back surface of the virtual reality display as a touch area that can be used for inputs in nomadic XR systems. Similarly, FaceDisplay (Gugenheimer, Stemasov, Sareen & Rukzio, 2018) adorns the back and sides of VR glasses with displays to allow co–located social interactions between users who do and do not wear HMDs. CHILDHOOD

(Nishida, Takatori, Sato & Suzuki, 2015) aims to allow its users to experience the environment from a child's point of view by incorporating a waist–worn camera, a hand exoskeleton for simulating a child's touch and grasp and a non–functional hood to increase the transformativity (transforming into a child). *As seen here, there are several projects that modify VR glasses, using unconventional modalities and focusing on wearables' contribution to topics such as transformativity. However, these projects only address* specific use cases and do not produce generalisable design knowledge by adopting user–oriented design research.

Potential of wearables were investigated in a deeper level in non–XR entertainment projects. Hotaru (Abe & Isbister, 2016) and Magia Transformo (Jing, Nygaard & Tanenbaum, 2017) are two game projects using wearables because of wearables' affordances towards enhancing social interaction facilitation and performativity; these projects use wearables as an integral part of the gameplay and look into their design–related qualities, such as their visualities, interface properties and affordances. In addition to embodied modalities, wearables have also been envisioned as being able to adopt tangible and embedded interface modalities that are attached to body (Tanenbaum & Tanenbaum, 2015). Parallel with this theory, my previous project — WEARPG (O.T. Buruk & Özcan, 2018) — is an augmented role–playing game system that examines customisability, tangibility and character identification with wearables. These playful wearable projects show that wearables can increase the connectedness to imaginary worlds and thereby the immersion experience, which is critical for XR experience. The projects have focused on uncovering the design features of wearables, which were rarely considered by most XR wearable studies. *However, these projects have not focused on XR and have not put forth how* the physical properties of wearables can be augmented in virtual environments and how this would affect the user experience.

We have given many examples of different types of wearables that were developed for XR environments. These examples were heavily oriented towards increasing the tangible feeling of the virtual world and collecting the body data for using it as part of the interactivity. There were also few examples that exploit the features that wearables, by design, afford such as transformativity or social facilitation. Still, these examples are quite limited, and the field lacks the comprehensive design knowledge about how the devices that can be worn or attached to the body can con-

tribute to an improved and more immersive user experience in virtual environments. In this direction, this chapter presents my critical reflections on the unexplored paths by informing field for the possible research branches that can be opened for the integration of wearables in extended reality environments.

Critical Reflections

At first sight, it might be hard to imagine what wearables can bring more than the things we counted above. Of course, I do not imply that use cases such as advanced haptic feedback or the appropriation of biometric information are meaningless or improper. Just the opposite, these are perfectly suitable and very fitting to the nature of the wearables. However, the field focus on too much on elaborating these topics and missing other affordances of wearables that can enhance the XR experience dramatically. Here I present my critical reflections on the current practices and shed light on what is to come.

Virtually Augmented Body Expressions

One of the most neglected properties of wearables are the mutual properties that they share with our clothes. For the most of our time in a day, it is hard to imagine our existence without our clothes. For the particular place and the time of the day, we also imagine ourselves in different type of clothes. They are so integrated into our life, they are even considered as the "second skin" (Berzowska, 2005; Wilson, 2004: 376; Yao *et al.*, 2016). In this fashion, they are a considerable part of our self–expression. This is why we change our look according to the occasion, place, time and the social environment. The look of our clothes, and thereby our body, also is affected by the physical properties of the environment. We try to choose what to wear according to the weather conditions, temperature, light conditions or the body substances that will be produced according to the activity. Therefore, our clothes are the representation of how we choose to express ourselves and how we perceive the mechanic needs of the environment. They are continuously in interaction with our environment and with the desire of self–expression we possess. Then, how does turning our clothes into elec-

tronics that can have more advanced interaction with the environment and also with ourselves contribute to these traits of clothes?

There are several interesting interventions to understand how wearables can actually enhance our body expressions. For example, Monarch is a project developed by Social Body Lab of OCAD University (Hartman, McConnell, Kourtoukov, Predko & Colpitts–Campbell, 2015) and it is a shoulder pad that can be swollen by the user with pneumatic pumps. The project mainly aims that giving users a chance to exaggerate their body expressions. It can be for intimidating others while in conversation or simply an expression of excitement. There are other similar projects such as Spider Dress that were designed to keep other people away by protecting the body–bubble of the wearer or more playful dresses such as Intimacy 2.0 (Roosegaarde, 2013) whose transparency changes according to the excitement level of the wearer (yes, it gets more transparent as the wearer gets more excited). In one of our previous design workshops, there were also ideas of using micro–robots that walks on the body to express disturbance and intimidation to people who get too close to our body (Genç, Buruk, Yılmaz, Can & Özcan, 2018). All these projects are great examples showing how wearable technologies can be an extension of the body and enhance the self–expression in ways that were not tried before.

Along these lines, wearables promise even more when it comes to body expressions in the virtual environment. With the involvement of extended reality, we can push the boundaries of what is physically possible when it comes to augmenting our bodily expressions. However, currently research done on this area does not inform us about how physicality and the experience of wearing and using these devices can translate into virtual expressions and eventually how these expressions can become an integral part of our virtual selves and affect our real selves. I think we have the opportunity to treat wearables as tools that will uncover an undiscovered social identity that exists simultaneously in both real and the virtual world. How can the physicality of wearables affect the augmented body expressions that will be created through XR technologies? How can wearables be a bridge between our virtual identity and real identity through augmented bodily expressions? I believe these questions are of interest not only to the wearables community but to other communities who research on topics such as virtual embodiment, fashion and smart textiles.

Kinaesthetic Transformation of the Body

What we wear also affect how we move (Keali'inohomoku, 1973). I may give many examples from our daily life about how a piece of clothing would affect our body movements, but I prefer to go with an example from Nigeria drawing upon the brass njaga anklets which were worn by the Nigerian Women between 1930 and 1940. According to Tremain (2011 as cited in Adams, 2007), the weight of the anklets changed the way wearer moves creating a distinct body posture that can even be imitated without the anklets worn to carry the feeling of wealth they provide. Although this example implies a longer term and a permanent change on how we move our bodies, immediate and short–term examples are also existent. For example, wearing a skirt may motivate a dancer to move their body in accordance with how their skirt sway and even they can explicitly manipulate the movement of the skirt which can be then thought as an extension of the body. Similarly, wearing a uniform might prime the wearer to get in a posture that is associated with that uniform (a police uniform might put the wearer into a stronger and more intimidating stance). Although more of a mental transformation, a previous study called Enclothed Cognition (Adam & Galinsky, 2012) put forth that what we wear actually also change how we think. In this experiment, participants who wore a lab–coat described as a doctor's coat had an increased sustained attention compared to the participants who were told that it was a painter's coat. Therefore, wearables can be a remarkable asset for transforming our bodies into distinct embodiments.

Previously Dag Svanæs tried to understand how extending our body affects our bodily experiences and the movement of our body by designing and implementing mechanical wearables in the shape of a tail and elephant ears (Svanæs & Solheim, 2016). This project actually is an interesting attempt because it tries to rise a phenomenological questioning of our body, by drawing upon the phenomenology of Merleau–Ponty's lived body (Merleau–Ponty, 2013), by defamiliarizing the body itself (Svanæs, 2019) (or with the authors' own words, by making it strange!). A similar study was also conducted by Karpashevich *et al.* (2018) where they made observations on the movements of a dancer who wears an interactive costume. In their study, they addressed how this costume restricted the movement of the dancer and altered the proprioception of them with

an unconventional mass distribution. They also observed how the lights scattered around by the garment affected the interaction of the wearer with the environment. These projects show that how wearables (when we can get rid of the limited image of them being wrist watches or bracelets) can have a bigger impact on how we perceive our own body and how we move it.

One of the very intriguing features of extended reality environments is that they can provide remarkably unique sensation about our own body. One of the examples I can remember immediately is a very simple implementation which allows couples to explore each other's body as if their own through a camera which is attached to virtual reality headsets (Woollaston, 2014). Another compelling example is an application which aims at making people experience near–death experiences by showing them as if they leave their own body and ascend towards the sky (Barberia, Oliva, Bourdin & Slater, 2018; Slater, 2018) These examples are just a few and quite simple implementations showing that the extended reality environments can animate truly transformational experiences. Our virtual body can turn into many different shapes and forms. Considering the power of wearables that can transform us both cognitively and kinaesthetically, I believe that wearables can be great tools for providing the full transition into another object by morphing the physical shape of our body dynamically. I think we need to start asking questions such as "how can we design interactive costumes that would alter the perception of our virtual bodies?" or "how can wearables help to transform our bodies into different beings that we can embody in the virtual environment?" These questions will help us to envision wearables that are beyond bio signals collectors or haptic feedback providers and will also reveal new dimensions of virtual embodiment.

Complex Interaction through Virtual Layers

Embodied interaction methods have been the dominant way of interacting with wearables. Every time I organize brainstorming sessions on wearables with different participants, many ideas revolve around gestural controls, touch–screens or heartbeat sensors. It is true that these interaction methods are now well established in the field of wearables, however wearables can promise many other different interaction modalities that

the field misses to focus on in the current state. They can turn the body of the users into a surface for switches, buttons or tangible parts such as studs, cranks in a way that can encapsulate various embedded and tangible interaction modalities.

Previously Tanenbaum & Tanenbaum put forth speculative ideas on how bodies can be turned into a surface for switches and buttons (Tanenbaum & Tanenbaum, 2015). Taking a similar idea further, one of my previous projects incorporated tangible parts (elemental stones) that interact with an interactive gauntlet (of course, elemental gauntlet) in a game called WEARPG (Buruk, 2018; Buruk & Özcan, 2018). Again, in the design framework that I and my colleagues Katherine Isbister and Tess Tanenbaum developed (Buruk, Isbister & Tanenbaum, 2019), interactive features and the information structures of wearables have been described through four dimensions that will shift the interaction of the user towards the periphery or the artefact itself. These dimensions create a design space whose boundaries are defined by spectrums between tangible–digital, embodied–embedded, private–public and connected–standalone. I believe that focusing on less explored interaction modalities are key to divulge fulfilling bodily experiences that both extends what we feel about our body and how we interact with it.

When it comes to XR environments, I think that distinct interaction modalities of wearables will gain more importance in the near future. Just recently, Facebook announced that the Oculus Quest devices will be able to do real time hand tracking that will drop the need for the tangible handheld controllers. Even more, these controllers will become redundant because they will prevent us to use our hands freely. Therefore, as I also indicated in the beginning of this chapter, extended reality systems will be complete only with wearable companions. I think that we need to start exploring the different interaction modalities these wearables will possess in extended reality environments and the virtual layers of wearables that will augment, shape and alter the interaction affordances around these devices and around our body. Few curiosity points of mine when it comes to interaction modalities with wearables in extended reality environments are hidden in the following questions: "How should we configure tangible form and parts of wearables in a way that will promise versatile experiences in interacting with the virtual layers of our body?" or "How does the augmented virtual layers of wearables can dynamically

alter the affordances of the physical artefact and reconstruct our somaesthetic experiences in real time?" Research topics can also extend towards exploring the augmented representations of the interaction happening in the real–world but experienced in the virtual world through virtual layers. I believe that the steps towards understanding the distinct interaction modalities that can be provided by wearables will also be critical for unveiling the augmented bodily experiences.

Concluding Thoughts

In this chapter, I tried to reflect the current state of wearables for extended reality environments and presented my critical reflections for revealing the unexplored paths that can be point of interest for the field in the near future. Currently, developments in this area are heavily oriented around providing tactile feedback and collecting body data such as hearth beat or movement. Although these modalities are perfectly fine and suitable to wearables' nature of being attached to and worn on the body, I think that the same characteristics are source of other great advancements if we can shift our focus more towards the formal qualities of wearables.

The three topics that I think are underexplored currently are the utilisation of wearables as augmented expression tools in extended reality environments, the contraptions that can transform our body physically for embodying things in the virtual world and consideration of the untouched interaction modalities with tangibles, switches and buttons to explore the affordances that will be formed when the virtual layer affects those. These directions have the potential to open new paths and research branches for the extended reality wearables and also will uncover many questions about the representation of our body in the virtual world and its virtual layers.

Investments on extended reality headsets and the ecosystem are raising and these technologies move towards being a part of our daily lives. They will change how we interact with the environment in our daily lives and will also bring novel social interaction paradigms. These implementations are likely to create a solid virtual identity (we already have virtual identities but this time we will adopt it embodiedly) in which wearables will be needed to provide a complete experience of embody-

ing this new identity. I think that focusing on these missing parts will help towards better identification, enhanced interaction and improved extended reality experiences.

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