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The article addresses the challenge arising from the ever-increasing use of capacitive touchscreens, because they rely on the electrical properties of the human skin, which changes over time, often becoming less conductive with age. The research considered the potentially increasing problem this would represent, with a layered model of skin interactions, as a frame from which to conceptualise different classes of approaches and better understand the design requirements. Conscious of the need to retain a sense of touch, rather than a stylus with a conductive tip or gloves with conductive finger tips, we then propose suitable thimbles for touchscreens. A touchscreen thimble to be worn on the body that would maintain a sense of touch was conceptualised, to be a ‘pros-palliare’ rather than a prosthesis. Developing a proof of concept prototype consisting of a rigid base combined with a conductive fabric for the finger tip, to address the limitations we observed with existing approaches. Conclusions consider the wider potential of our idea in designing a preferable future for touchscreen use. Including, the potential for multiple touchscreen thimbles to support multi-touch gestures, and as a theoretical enhancement for the able-bodied to create super-human cyborgs as they interface to networked devices.

Included is a figure showing a visual summary of the then state-of-the-art referenced, and a second figure showing the subsequent second generation prototype developed.

Additional outcomes included inspiring future work into the aesthetics of prosthetics, which began to be realised in our research paper - Towards The Aesthetics of Prosthetics: Co-Design For Expressing Personal Identity (Making Futures Conference, 2017). I was also asked to advise differently-abled users of touchscreen devices at Headway East London (charity supporting people affected by brain injury), which included addressing the challenge of excessive conductivity from limited coordination.

Figure 1. Existing Alternatives: Jot Mini stylus with conductive flat circular tip - top left (a); iGloves glove with conductive fingertips - top right (b); Tech Tips finger extensions - bottom left (c); and artificial nails like Nano Nails - bottom right (d).

Figure 3. Second Iteration: Image (a)bove showing the computer-aided design (CAD) of the second iteration of our *touchscreen thimble*, consisting of inner and outer cylinders that hold the conductive fabric in between. Photo (b)elow showing the a Stereolithography (SLA) resin 3D-printed version of the CAD, in use on a capacitive touch smartphone.

Touchscreen Thimbles: Enabling Intuitive Interaction

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***Abstract*—We are interested in the challenge that the ever-increasing use of capacitive touchscreens represent. This is because they rely on the electrical properties of the human skin, which changes over time, often becoming less conductive with age. So, we consider the potentially increasing problem this would represent, with a layered model of skin interactions, as a frame from which to conceptualise different classes of approaches and better understand the design requirements. Conscious of the need to retain a sense of touch, rather than a stylus with a conductive tip or gloves with conductive finger tips, we then propose suitable thimbles for touchscreens. We conceptualised a *touchscreen thimble* to be worn on the body that would maintain a sense of touch. So it would be a pros-palliare, rather than a prosthesis. Developing a *proof of concept* prototype consisting of a rigid base combined with a conductive fabric for the finger tip, to address the limitations we observed with existing approaches. We conclude by considering the wider potential of our idea in designing a preferable future for touchscreen use. Including, the potential for multiple *touchscreen thimbles* to be worn simultaneously to support multi-touch gestures, and for them to be worn as an enhancement for able-bodied users.**

Keywords–Electrodermal; Conductivity; Skin; Age.

I. INTRODUCTION

The ever-growing availability of capacitive touchscreen displays is largely attributed to the intuitive interaction they afford [1][2]. They rely on the electrical properties of the human body to detect when and where on a display the user touches [3]. So, they can be controlled with light touches of fingers [4], which is contributing to their dominance for device interaction [5]. The touchscreen enables the user to interact directly with what is displayed, rather than via a mouse, touchpad, or other intermediate device [3].

In Digital Cultures, the practices and socio-cultural meanings of emerging digital technologies, the popularity of smartphones and tablets is driving the acceptance of capacitive touchscreens for many types of information appliances [6]. This is because the usability of capacitive touchscreens is considered preferable to other forms of device interaction [7]. Often where computer keyboards and mice do not allow a suitably intuitive, rapid, or accurate interaction [3]. So, there is a growing trend towards capacitive touchscreens for user interfaces, shown by their increasing integration into the design of different products. So much so, that they are starting to become unavoidable given their ever-increasing availability in devices [5]. However, for those with limited *electrodermal conductivity* of the skin, they can be difficult to use [8]. This can be acute as *electrodermal conductivity* of the skin is known to decrease with age [9].

In Section II we will introduce the Seven Skins conceptual framework to consider a preferable solution to skin with limited electrodermal conductivity. In Section III we define, explore and prototype our *touchscreen thimbles*. In Section IV we conclude by consider the benefits and limitations of our approach, as well as potential future work.

II. SEVEN SKINS

In considering a preferable solution to skin with limited *electrodermal conductivity*, we explore assistive sensor devices (ASDs) with reference to Professor Irene McAra-McWilliam's 'Seven Skins' concept.

1) Worn separate device:
   -fitness tracker, phone or watch as sensor
2) Sensors integrated in clothes or wearable layers:
   -smart textiles
3) Passive and attached to the body:
   -biostamp temporary sensor tattoo
4) Interactive sensors on the body:
   -myoelectric prosthetic hand
5) Interactive sensors integrated with the body:
   -targeted muscle reinnervation prosthetic
6) Passive and embedded in the body:
   -sensor pill monitoring vital body signs
7) Active and embedded in the body:
   -pace-maker

The first, outermost, layer considers ASDs worn on the body. These can generally be grouped into devices that have come to include sensors, such as smart phones and watches; and those with sensors dedicated to monitoring physiology, such as *fitness trackers*. The next, the second, layer considers ASDs integrated into clothes or wearable layers, such as smart sports shirts [10]. The third, emerging, layer considers ASDs fixed on the body, such as the recent temporary bio-stamp sensor tattoo [11]. We consider these to be passive because they only monitor and are not interactive.

The middle, fourth, layer considers ASDs on the body, such as myoelectric sensors for gesture control of a prosthetic hand. While the sensors of the prosthetic hand can be considered to be within the second layer, they are part of a system which is perceived to have a deeper attachment to the body at the fourth layer. This is because the prosthetic hand is perceived to be an extension of the body [12].

The fifth layer considers Interactive ASDs integrated with the body, such as those that enable targeted muscle reinnervation for real-time control of multifunction artificial arms [13]. The next, sixth, layer considers passive ASDs that are embedded in the body, such as tiny pill monitors that can measure vital signs from deep inside the body [14]. The innermost, seventh, layer considers ASDs embedded in the body, such as pace-makers.

III. TOUCHSCREEN THIMBLES

Considering a potential ASD for limited *electrodermal conductivity* of the skin, it would preferably be at the first layer in the seven layer *skins* explored in the previous section. So, a worn device that would compensate for limited *electrodermal conductivity*. Furthermore, it would preferably maintain a sense of touch to ensure intuitiveness.

A stylus with a conductive tip would work, such as the Jot Mini or Apple Pen. However, it would be far less intuitive, because it would lack a sense of touch. Gloves with conductive finger tips would also work, such as the iGlove or Totes SmartTouch. However, they would not be well suited for indoor use. Other approaches provide finger nail like extensions, intended to help provide accurate interaction for individuals with larger fingers, such as the Tech Tips. However, such approaches also lack a sense of touch.

We conceptualised a *touchscreen thimble* to be worn on the body that would maintain a sense of touch, while being suitable for indoor as well as outdoor use. So it would be a pros-palliare, instead of a prosthesis, as it is an *addition* that *covers* rather than *replaces*. We explored our concept as shown in the sketch of Figure 1(a), being in the first layer of the *seven skins*. A thimble consisting of two essential parts, a rigid cylindrical base, and a thin conductive fabric for the finger tip. With the conductive fabric ensuring an intuitive sense of touch would be maintained, while compensating for insufficient electrothermal conductivity by being highly conductive. We then explored suitable materials, developing a number of prototypes, as shown in Figure 1(b). Including a *proof of concept*, which consists of a rigid base made from antler, combined with a grey conductive fabric for the finger tip. While any rigid material (e.g. ABS plastic) would have been suitable for our *proof of concept*, antler was chosen because of experiences of exploring its aesthetic qualities in addition to being suitably rigid.

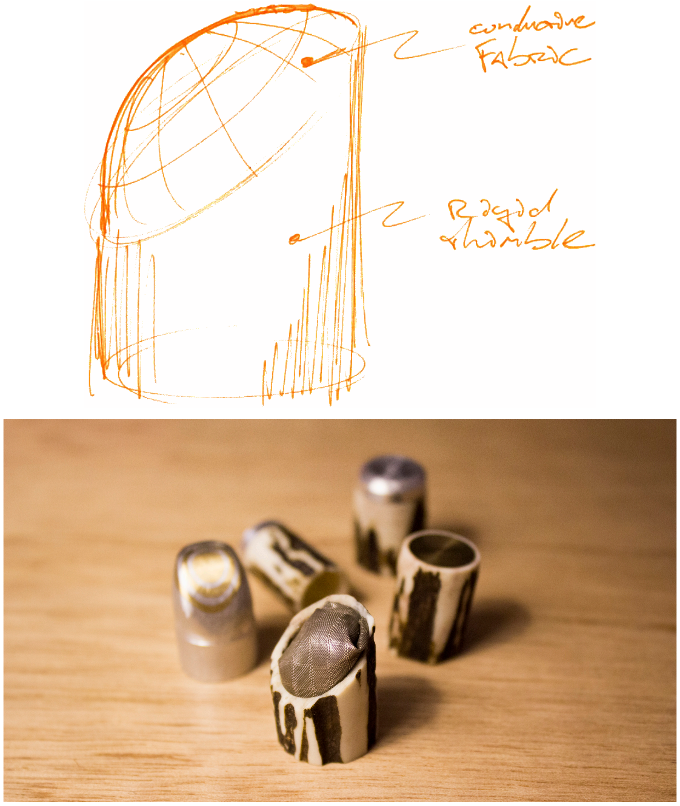

Figure 1. Sketch (a)bove showing the design of the thimble consisting of two essential parts, a rigid cylindrical base, and a thin conductive fabric for the finger tip. Photo (b)elow showing a number of thimbles resulting from exploring suitable materials, with the front thimble showing a rigid base made from antler combined with a grey conductive fabric tip.

IV. CONCLUSION

For those with skin that has limited *electrodermal conductivity* [8][9], the ever-increasing availability [5] of capacitive touchscreen displays could become challenging. However, our *touchscreen thimbles* would ensure that the intuitive usability of capacitive touchscreen displays would be maintained for them. Also, multiple *touchscreen thimbles* could be worn to support multi-touch gestures. Future development should test a prototype with potential users, especially non-technical users, to provide experimental evidence of the effectiveness of our proposed solution. Specifically, experimental confirmation of the increase of efficiency in interaction compared to bare fingers, and the increase of intuitiveness compared to alternative solutions (e.g. conductive stylus). Given that the use of *touchscreen thimbles* could indicate that users have problems in using touchscreens, some users may be self-conscious about their use. So, consideration should be given to the aesthetic, as well as functional, design. For example, considering the potential for personalised *touchscreen thimbles*, not just for accurate sizing, but also for custom styling. An *innovation through tradition* design approach, which enables connecting new technology with familiar traditions (e.g. textiles) could be helpful in determining desirable aesthetics for the adoption of *touchscreen thimbles*.

Where capacitive touchscreens are used for control in critical situations, *touchscreen thimbles* could be worn as an enhancement for able-bodied users, ensuring intended interactions when under duress. Similar to how the able-bodied can benefit from directional hearing aids, because they improve the signal-to-noise-ratio of speech occurring in noisy backgrounds, irrespective of hearing disability.

The seven layer *skins* of ASDs provided a framework from which to conceptualise different classes of approaches in the development of our *touchscreen thimbles*. So, future work should consider further development of the framework, as well as its applicability to *spaces* of a similar nature in designing preferable futures. While the *touchscreen thimble* prototype worked anecdotally as a *proof of concept*, future work would be required to confirm their effectiveness more broadly. Furthermore, future work regarding the conceptualisation of *touchscreen thimbles* should consider that while they would be worn on the body as ASDs, they interface beyond the body to a networked device. So, potentially interfacing to a meta-level beyond the touchscreen through the Internet.

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