magnetometer in my home for an additional security mechanism". Another discovered "*when I'm typing on my MacBook and someone is over my shoulder I can just move my finger [with the magnet] to the left of the tab key and it will shut off the screen, because that's where the sensor is for the lid close*". One participant used his magnet as an alternative digital interface, by wearing a device over the insertion location that converted "*any type of sensory input into something that a magnet can understand*". One such application was a distance sensor that enabled him to "*close [my] eyes and walk around a room, using only the magnet to guide*". This use is similar to Fingerflux's haptic sensing [50] however here the magnets are not worn, but inserted.

Magnets not near nerve endings do not pick up electromagnetic fields, as reported by the participants with magnets in their tragi (the tragus is the cartilage at the opening of the ear): "*there's not enough nerve endings in the tragus so I really can't feel any of the electromagnetic fields*". What the tragi magnets were used for is sound detection. One participant pioneered this phenomenon and created a device that "*produces vibrations to the magnets which creates sound*" to effectively make invisible headphones that "*sounds like it's coming from inside your head rather than through your ears*". He further explained: "*if I were to pick up the coil and put my magnetic finger in [someone's] ear they can hear it as well*" which was confirmed by another participant: "*he played Straight Out of Compton for me and I was like holy shit that's awesome, Eazy-E is in my head*". This participant has since inserted a tragus magnet and has heard tones through it.

Use of Microchips

Of the 12 participants with microchips, all male, nine had NFC and seven RFID chips. These chips are activated when within range of a corresponding transponder and communicate over radio waves. The read range of chips inserted into individuals is only a few centimeters. The uses for these chips included access and authentication, storing and sharing information and temperature readings. As one participant stated: "*they can be programmed to do whatever you want, they're not limited. I can change the behavior*". Only NFC chips can be used to unlock phones, as there are currently no RFID-compatible phones. Many modern Android phones are NFC-capable, while Apple devices have not opened this function for use other than Apple Pay.

Access and Authentication

Six participants used their chips for access to homes, offices, cars and motorcycles, similar to Warwick's Cyborg 1.0 experiment [48]. Five participants used them for logical access to phones, apps, websites and computers. One participant used his microchip for as much access as possible: "*whenever I go through a door or something like that it's an access token challenge. The traditional token is a key, you know that old piece of metal just seems a little archaic to me. So I use it mostly for anything that usually requires a key or password. So I go into my house, my car, log into a computer, that kind of thing*". One participant built an RFID reader into an art installation so that he could "*shut the unit down and walk away*" without fear someone else could turn it on.

For individuals whose workplaces already had an RFID access system, gaining access could be as simple as asking to have their unique chip ID added to the system or, as one participant explained, *"if you know what you are doing and have the right type of hardware you can take office access cards and copy them*". Cloning existing RFID access passes onto chips was a little more involved with one participant, who worked in computing security, explaining: "*for someone who didn't have any technical skills I would consider it would be quite difficult"*. Another participant, a software developer, echoed these difficulties: *"it's one of those things where it's a surprisingly large amount to get set up and get it working*". Participants who did not use their chips for work access either did not have the facilities at their offices, had chips of different frequency, or didn't see the need for the type of job they currently had: "*if I had a lifetime career job I'd definitely consider [it]*".

Enabling home, car and motorbike access for RFID chips was involved but didn't "*require any coding at all. It required a little bit of electronics*." To gain access to his house one participant converted an existing front door lock: "*I built some hardware and modified an existing lock*". Another participant advised for "*anyone who wants to do functional things, it's well worth kind of getting in to the world of microcontrollers because that's the bridge, the glue you need to control the appliances and control the different stuff in your life*". For NFC chips, gaining home access was as simple as buying and installing an NFC-compatible lock and adding their tag to it: "*all I needed to do on the door lock was accept me tagging my hand in, and tap it and go*". Computer access could also be gained easily by buying an external USB reader and adding the chip to it - "*that was pretty much plug and play".*

Insertables for access may seem trivial, but one participant recalled many occasions he "*was super-duper thankful that I went through this small tiny piece of pain for the guarantee that my key would be with me as long as I have my hand, which I've never ever forgotten. It only takes one or two times of making a bullshit trip that's already too long and having to drive the whole way back home, or deal with it for the day, to make you realize like oh a small pinch and this is solved? Yeah, please give me the pinch.*"

Programming an Android phone to unlock, or to launch an app or website, is as simple as downloading an app and placing the chip against the reader to program. One participant used his chip to trigger GPS navigation: "*I set up the GPS coordinates of my lab and I set it so that if I scanned it, it would automatically set my navigator up and immediately have me headed towards my lab, which was kind of cool because it made everything easier, I didn't*

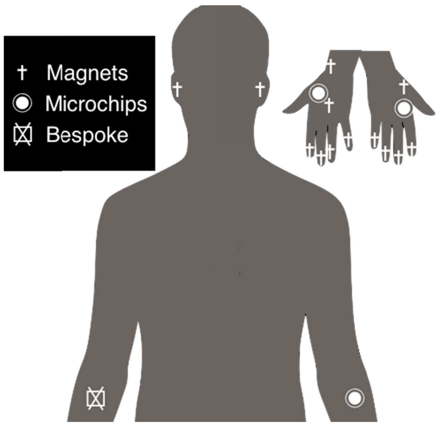

Figure 2. Positioning of Participants' Insertables

have to type things in or interact with the interfaces, I just had to run my hand over my phone and I was on my way."

Storing and Sharing Information

NFC chips were also used for storing and sharing of information. As they are easily reprogrammable, many changed the content regularly: "*I do things like open websites of conferences I'm going to, or write a funny message to prove that I can write to it*".

Three participants used their chips to share contact information with others: "*I can just display my hand and have myself added to their contacts*". Setting this up was also simple: "*I downloaded an app and that's all it took*". Participants who used their NFC chips for this purpose, and were iPhone users, had a secondary Android phone that they used solely for programming and testing their chip.

Temperature Readings

Two participants used their insertables for biometric data, with RFID bio-therm chips that are capable of reading body temperature. These chips have to be interrogated with a reader to get the current temperature, with no data storage.

Use of Bespoke Insertables

One participant inserted a bespoke device, approximately the size of a deck of cards. The device, which included a battery, read and transmitted body temperature to a smartphone every five seconds via Bluetooth. It also had LED lights controllable from an app. This avant-garde device was inserted by a body modification artist with no numbing and took time to heal: "*the first 30 days were really rough, it kept filling up with fluid. At first I was draining it… I'd get worried that this fluid in my arm was just sitting around waiting for bacteria to kill me. And then everything passed, the fluid went and it got flat against the skin and clearly my body had come to terms with it and everything was OK. But for those first 30 days, that was just plain terrifying*". This device was removed after 90 days, as this was a time-boxed experiment like Warwick's [48]. This insertion was a proof of concept that a battery could be inserted into the body and that Bluetooth could communicate through human skin. Through future iterations they hope to make the device smaller and commercially available.

Positioning of Devices

The insertion position selected was generally based on use, with form following function. Figure 2 illustrates the locations of participants' insertables.

Magnets were commonly positioned at nerve endings (11 participants), particularly the fingertips. Magnets in other locations (three participants) were to afford specific interactions: the lovers' magnet, a magnet in the wrist so that a wearable could be positioned over it to digitally interact and magnets in the tragi for audio sensations.

The standard position for microchips was in the webbing of the hand, between the thumb and the index finger (11 participants). The reason for using this position was so that microchips are distant from important anatomy, protected from impact and trauma and for the ease of interactions. The webbing of the hand does not have vital issues or organs; "*you tear away the skin layers and get down to the bone, tissues and nerves…. The webbing is really the best place…there's enough area there to avoid the bones. The radial and medial nerves go around that area; they don't traverse it so it's really, really low risk".*

The webbing also affords maximum protection for the glass chip: "*it doesn't tend to have a lot of trauma or impact in this area of the hand".* The position affords an easy and natural interaction with phones and other devices as "*it's out of the way and harmless while still being in a very accessible position for swiping your hand against a reader*". Another participant echoed this: "*you have to have it in the place that's easy to manipulate. So that made the hand kind of the obvious place. Some people put it just behind the wrist but that doesn't offer as much flexibility in terms of orientation, putting the tag in front of the reader*".

The vast majority put microchips in their non-dominant hand, "*because you use it less*", however not everyone followed this convention. Reasons for getting a chip in the dominant hand included already having a chip in the non-dominant hand and already having "*two things on this arm*" referring to their magnet and wristwatch. Only two participants deviated from this standard position, those using the bio-therm chips, which they placed in their forearms for convenience of reading data: " *I feel strapping a reader to my inner arm would be more convenient*".

Reasons for Choosing Insertables

Participants had a range of reasons for getting insertable devices. These reasons included wanting a new body modification, seeing insertables as the next big thing, extending human functions and capabilities and tiring of wearables. Others could not precisely identify a reason. For these participants it was comparable to asking why someone has a piercing or a tattoo: "*I'm not entirely sure. Partly boredom, partly I'd read about it and partly I was* *going over old thoughts about cyborgs*". For those able to articulate their reasons, we discuss their motivations.

Desire for a New Body Modification

Some participants discovered insertables when looking into other body modifications, as one participant describes: "*I've loved piercings all my life. A friend of mine mentioned that she'd read in Wired that people were getting magnets and were able to pick up some sort of electromagnetic sense around live electronics and detect live wires and that sounded really appealing*". These individuals wanted a body modification regardless of functionality, but enjoyed the concept of a functional insertable once discovered.

Wanting to be a Part of The Next Big Thing

Participants were technology enthusiasts, and early adopters. They consider insertables as the next big thing: "*I guess I'd call myself an early adopter. I've maxed out on wearables and it was just the next step*". One self-professed evangelist enthused: "*because somebody has to figure it out sooner or later, and there's definitely shit we don't know. Why wait? I mean we have the technology, what we're basically waiting around for is for people to be less squeamish. They're not going to get less squeamish unless we start doing it. That's it; it's the only reason, because it's time*". Some identified their current insertables as "*not overly functional…I'll admit it's a bit of a statement to be honest, why get a piercing? I love technology, it's neat*". Others are experimenting with the new technology "*it's something which is relatively new and I want to experiment*" and "*I don't believe that this type of body modification is about functionality. It's about testing the limits; it's about making a statement.*"

Extending Human Function and Capabilities

While some participants discovered the availability of insertable devices when looking into body modifications, "*Oh people are implanting themselves with stuff? Cool, well I'll do that*", their reason for receiving the actual insertable itself was not aesthetic: "*it's all for science rather than artistic expression*". Many explicitly stated "*I prefer to have ones that have a function*" and that they are not interested in tattoos or other aesthetic body modifications. One participant explicitly stated: "*the reason that I chose [a NFC chip] over a tattoo was about permanence and being stuck with something that I'd have forever, whereas this can be removed*". Another expressed an interested in tattoos, despite not having any, and got an insertable as it was "*a tattoo that was useful*".

Many spoke about extending human senses and the experience of "*having something new inside my body*". One participant suffers an eye condition that will likely leave him blind, so he wanted to "*compensate for that and try and use echo-location. I wanted the implant and not a wearable so it is something that I could have at all times*". While he has not been able to achieve this yet, he continues to experiment. Others saw this as "*the next stage of human evolution*": "*we should be able to enhance the senses that we have naturally instead of just improving senses when they're not working as well as we'd like*".

For magnets, individuals spoke about having a sixth sense. This was reflected in some participants with chips: *"I'm not satisfied with the purely biological body. I want to basically have more functional stuff and so [this] is just the very first step. It's what's currently available today, rather than just science fiction*". They noted, "*it's not really a practical skill it's more look at what we can do, science is cool*".

Tiring of Wearables

Participants spoke of the impermanent permanence of insertables. They can remove them but they are also always available. They chose insertables over wearables as otherwise "*it wouldn't be waterproof so you could use it in fewer circumstances*" and as they cannot be forgotten. Others were not excited by the idea of peripheral devices in the form of wearables, while they were excited about "*having it become an actual part of me*". One participant explained: "*the difference is about that permanence and having that more a part of you*".

Another reason for choosing insertables was a dislike towards wearables: "*I don't wear jewelry at all. I don't even wear my wedding ring. I just don't like having things on me…it make my skin clammy underneath and it's uncomfortable*". One participant summarized: "*it really comes down to the fact that we …have these things that we manage in the day…the Tamagotchi effect. We have keys, wallets or purses and our phone. You have to manage those things throughout the day. If you wear glasses then you have to manage them. If you have wearables that you put on and take off every day you…– make sure they're charged and all that. I need a way to just understand it's me and just let me in without needing to mange anything or having a wearable or any other additional devices. I wanted it to be seamless and invisible. You try and minimize the number of things you need to manage in the day because you don't want to spend your time worrying about them*".

For magnets, many spoke having a permanent sixth sense: *I like the idea of having to live with the implant and experience that 24/7 not just selectively adding the wearable…with the extra sense at my leisure*".

DISCUSSION

In 2012, Holz et al [11] predicted devices inside the body could become a reality. In this paper we have shown hobbyists are now indeed voluntarily inserting devices into their bodies. Through 17 interviews we have classified the types of non-medical insertable devices people are voluntarily inserting: magnets, microchips and bespoke devices. Insertables were specifically used to: support human connections; extend sensorial input and act as an alternative digital interface; interact with digital artifacts, including access and authentication inputs, storage and sharing of information; and; to capture biometric data in the form of body temperature. Hobbyists are becoming professional, heralding a consumer market that up to this point has had no professional counterpart [37] that will move towards new professions and the implications for HCI researchers and interaction designers will become a reality.

We will now discuss the implications of our findings and explore possible directions for future use and design of insertables devices, contrasted with novel wearables.

Biometrics from Within the Body

Like wearables, insertables are often used to track personal health information. In our study, three participants used their insertables to garner biometric data in the form of body temperature. Existing wellbeing devices measure biometric data from being worn. Insertable devices used for biometric data capture could address limitations of wearable devices that are often uncomfortable to wear during exercise or unable to be used in some situations, for example swimming [34]. Insertables offer interesting new possibilities for the quantified self (QS) movement, as they stay out of the way of during recreational activities [11].

New Input Devices

Holz et al [11] proved the feasibility of inserted devices by showing traditional interface components could reliably work beneath skin. This was replicated in hobbyists use by one participant, as his bespoke device communicated through human skin via Bluetooth. Our participants have repurposed old technologies, NFC and RFID, for new, input, applications [36] from within their bodies. We have shown that a small, but growing, cohort of individuals are choosing to insert electronic input devices within their body, rather than using wearable alternatives.

The lack of a suitable ecosystem for insertable devices remains an ongoing challenge. NFC and RFID are not currently widespread input options, often requiring additional peripherals or making of specialized devices to receive input. Our participants have gone through considerable effort to modify systems to accept their insertables as valid input. If these formats became popular input technologies, users will be able to access systems more readily. Further, there are technical barriers to use as existing hardware tools are often aimed at developers and involve complex set up. Novice individuals may be interested in insertables but lack the technical ability to configure them. The technological capabilities of components must too be improved for them to become insertable. For example, with regards to the ‘invisible headphones’, individuals cannot currently get the volume loud enough or batteries strong enough to power the transmitting coil for long enough to be deemed useful and usable. Further size and cost reductions and battery life improvements [11] will facilitate insertables as a legitimate category of devices for more widespread use.

Accessibility and Ubiquity

Michael and Michael [23] observe that there are two things always with us: clothing and our actual bodies. As devices are miniaturized they are not only integrated into our everyday experiences, but into our bodies, becoming truly ubiquitous. Accessibility and ubiquity were two important benefits reported by our participants.

Participants associated the capabilities of the inserted technologies as capabilities of themselves. Many spoke of their abilities as *“I can …”* rather than attributing the device. Participants took for granted their capabilities are derived from insertables, as the new abilities become their new norm. In this era of ubiquitous computing there is a blurring of the line between ourselves and the technologies that we use [15]. When this technology is physically inside us, this line is blurrier than ever before. Users of insertables look as ‘normal’ as can be as the devices are often completely hidden within their bodies, with small scars that are only noticeable if pointed out, following Mann [20].

Clearly, insertable devices are ubiquitous devices, small and unobtrusive and comfortable to an extent that participants forgot their existence [15]. Wearables are neither invisible nor unobtrusive as “they are [often] so obviously distinguishable from the human body” [46]. While some novel wearable devices may be hidden or camouflaged in plain sight (e.g. finger nails, hair extensions etc.), they are not truly invisible; only insertables are truly invisible and always available. Some, like SmartWig, are specifically designed to enhance appearances [41]. This too is the case with NailO [15], NailDisplay [40] and Vega and Fuk's work integrating technology into beauty products like make up, fake nails and hair extensions [45, 46]. Our participants were not interested in aesthetics; they wanted something that did not need to be put on and taken off the body, which they could not forget and that was hidden. Certainly, these novel wearables are attractive to users who want devices that are more easily removed.

Usability

Many of our participants claimed that insertables provide increased usability over existing solutions in terms of learnability, efficiency, accessibility and user satisfaction.

Learnability

Insertables have the benefit of proprioception, the bodies’ sense of its position and motion [10, 18], allowing for intuitive interactions. Given the limited functionality of current insertables, it is not surprising that participants had no difficulty learning how to use them: all they had to do to raise their hand to a reader. Use of insertables as input to existing interfaces removes the need for individuals to stop and interact with devices, making them natural user interfaces (NUIs) with intuitive and seamless interactions.

Efficiency

Participants were using insertables as input triggers to automatically and seamlessly launch applications without interacting with devices, other than to hold their hand to a reader. Just like wearables [1], interactions with insertables are efficient, as users do not need to carry devices nor stop what they are doing to interact with one.

Accessibility

In our study those who used insertables for access were, at least partly, inspired by forgetting their keys. As insertables are inside the body users cannot physically forget them, these devices "always stay with the user" [11] therefore are always available . Recent novel, wearable input innovations [15], [49], [1], [45], [41] claim the benefit of being 'always-available'. Once *put* on these devices are always available, however, as they are still wearable devices, they need to be "explicitly put on or removed, either on a daily basis, or for specific activities" [11]. We argue, therefore, insertables are the only truly always-available device available.

User Satisfaction

Our participants expressed frustration with managing wearables; they no longer wanted to be bothered by carrying or wearing objects they could forget and had to manage, recharge and put on. Participants had eliminated keys, dongles and external devices by moving these input and storage functions to insertable devices.

Our participants opted in to insertables. For them, the benefits out weighed any pain or discomfort. As Gasson opines, "demonstrated by cosmetic surgery, we cannot assume that because a procedure is highly invasive people will not undergo it" [8], although for most, insertion is no more invasive than a body piercing. It is true, however, that not all users will be satisfied with inserting devices into their bodies. Gluing RFID tags onto nails is "far less controversial" [47] and threatening for the wider populous. Wearable and insertable devices can coexist alongside one another with users being able to choose whichever they are comfortable with, and what meets their needs.

Extending Senses and Alternative Digital Interfaces

Cybernetics research and neural interfaces shows data input from insertable devices is possible. Notably, Warwick's Cyborg 2.0 experiments where a 100-electrode array innserted into his median nerve was able to control an electronic wheelchair and an artificial hand [50]. However, our participants have also begun to experiment with insertables to receive data in a hands-free manner without having to stop what they are doing. Two of our participants are experimenting with use of insertables for more than a notification that another device needs their attention. They transmit the data itself to magnets, rather than simply a haptic notification. This is a similar technology to the Sensory Vest [30], which used sound-to-touch conversion to relay information to wearers through the skin.

One participant used a magnet to walk around eyes closed - a proof of concept to replace senses in the blind. Leveraging insertable devices in this manner can be used to achieve truly hands-free, eyes-free information receipt for individuals with and without impairments. Receiving and interpreting data from insertables has the potential to give invisible improvements in sensorial parity or extension.

Using insertables for sensory improvement offers new modalities. This is similar to colorblind Neil Harbisson who uses an inserted antenna to 'hear' color [30]. Our participants were also extending their human senses to 'feel' electromagnetic waves, as Harbisson extends his by being able to also 'hear' colors outside of normal human capabilities, into the UV spectrum. Eyeborg, another insertable, has also been used to restore vision [16].

FUTURE WORK

The purpose of this paper is to understand what devices individuals are inserting into their bodies, how they are used and why. We acknowledge this paper presents a mostly favorable view of insertables. This is consistent with findings from participants, none of whom expressed regret regarding insertables. Even those who experienced rejection were positive and were looking to get re-inserted. Questions about privacy, public perceptions and ethical considerations are issues for future research. Michael has written extensively [22-25, 27] about the potential ethical issues that may arise from insertable use, particularly if their use is no longer voluntary. There is much room for future work to address the current issues by: including magnetometers, NFC and RFID readers in existing devices for input, or new peripherals; creating an ecosystem of devices including insertables; designing apps and other peripherals to interact with and transmit data to insertable devices, and; working to create new insertables including addressing power consumption issues with 'invisible headphones'. Extending insertables to receive data will enable interaction designers to create interfaces that are truly invisible, and integrated.

CONCLUSION

This paper has described the current usage of insertables: magnets, NFC and RFID chips and bespoke devices. Individuals are experimenting with insertables and, as acceptance grows, insertables will become a device mode of choice for future NUIs. Designer Jennifer Darmour believes objects should be designed to be seamlessly integrated into users lives [19]. Similarly, Vega and Fuks [47] predict "the use of the body's roughly two square meters of skin as a canvas".

We argue that the body is not just a canvas for devices to go on to, but also a platform for devices to go in, if designed to (miniaturization and encasement in bio-inert materials). Furthermore, the internal body is no longer limited to implantable medical devices. We have shown insertables afford always-on interfaces for voluntary and discretionary interactions. With the advent of insertables as an interaction device of choice there is an impetus for interaction designers to begin to offer insertable versions of devices.

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