Empathy over Distance: Wearables as Tools for Augmenting Remote Emotional Connection.

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This paper reports on the development and testing of a range of garments that conduct presence information between remotely located people. The garments detect, process, transmit and receive the heartbeat signal - electrocardiogram (ECG). They are enabled with ECG sensors, signal processing equipment, small vibration motors, and radio transceivers which allow users to 'feel' the heartbeat of a remote friend/lover/relative as vibration through their garment. The prototypes aim to enrich the remote communications experience through reintroducing an embodied, tactile dimension that is present in face-to-face communication. A range of user testing trials will be discussed which have been undertaken to assess the impact of the garments at a conscious and a non-conscious level. Conscious experiences were gauged through qualitative testing, by way of unsolicited written responses while non-conscious physiological reactions were assessed by recording ECG throughout user-testing periods. This data has been processed using HRV (heart rate variability) analysis software [1] running on MatLab [2] for Windows.

Introduction
Mainstream communication modes emphasise network speed, connection access, resolution, portability, and aesthetic design as primary to the success of their products. Within this vision a three by four centimetre screen and high resolution display are deemed adequate to emulate the intensities and complexities of face-to-face connection with loved ones. They allow us to 'be there with you' from wherever we might be. Yet interpersonal communication is a massively complex phenomenon. It involves a plethora of micro-activities which occur at a physical, physiological, and psychological level allowing us to recognise at a cellular scale intention, motive and emotional authenticity. Our conscious and non-conscious involvement in spatially collocated communication is substantial due to these myriad channels of real-time bi-directional information transfer. While contemporary communications technologies have the capacity to mediate our relationships, they fall short of encouraging the richness of spatially co-present interaction.

The research discussed in this paper investigates the potential expansion of remote connection when electronically enhanced apparel is incorporated into the communications mix. This research has generated a range of biosignal sensing garments that have been in development and testing since June 2004. The prototypes investigate remote empathy through the real-time exchange of heartbeat. A range of quantitative and qualitative experiments have been designed to test the effectiveness of the prototypes. Preliminary results suggest that users have strong conscious and non-conscious reactions to the experience of wearing the electronic garments. The paper will describe the prototype development, testing methodologies, data processing techniques, and preliminary findings of the user testing trials.

Objectives
The research aimed to develop electronically enhanced garments that facilitated the type of implicit understanding, between remotely located individuals, as occurs in face-to-face communication. Inspired by remote presence research the prototypes foreground ideas of action at a distance and aim to enrich remote connection through the real time transference of biosignal information. Enacting change in a remote location allows our presence to be registered physically at a distance transcending spatial and temporal restrictions. Thus, remote interaction steps beyond a representation of presence toward an embodied experience

of co-presence. Introducing biosignals as the communication language through which this presence is expressed questions our bodies' capacity for semantic understanding of like signals. The heartbeat is the first sound that we are exposed to, mediated by amniotic fluid. Within the context of this research the heartbeat is repositioned as an actively extended communication media. Thus the garments externalise internal processes to facilitate a unique sense of empathetic understanding.

Development

Within the scope of this research 'Ether Beat', a range of electronically enabled garments, were developed to facilitate an embodied sense of remote presence. The methodology employed within the research project was threefold: the development of a conceptual framework that drew from a range of relevant fields; the creation of a range of prototypes inspired by this theoretical basis; and the evaluation of these prototypes through qualitative and quantitative means.

Image 1

Ether Beat encompasses a range of compatible garments that sense, process, transmit and receive the heartbeat wavelength (ECG). The collection is made up of two sets of garments comprising: a singlet 'Under Beat' (Image 1) that houses the ECG electrodes and which connects to either of the outer garments: 'Ether Scarf', a scarf (Image 2), or 'Ether Beat', a blouse. The under garments are enabled with ECG sensors while the outer garments house signal processing equipment, small vibration motors, and radio transceivers. The sensation provided by the garments is of wearing the heartbeat of your remote friend/lover/relative as vibration through your garment. The garments utilise simple technologies, which have been 'rejigged' to suit the prototype, combined with specifically designed processing equipment. From a design perspective, the garments have been drafted from the initial stages using traditional construction techniques in non-traditional ways to accommodate electronic pathways, processing equipment, and battery power. The challenge has been to utilise the structure of the requisite technologies to inform the development of the apparel, rather than retrofitting an existing garment. In this foregrounding of the physical properties of technology, including the structural boning capabilities of wiring and the weight of the vibration motors, new opportunities for garment design arise.

Image 2

The Ether Beat outer garments are essentially the 'brain' and 'heart' of the system. The garments house signal processing equipment, radio transceivers and small vibration motors. The electrical current detected by electrodes in the Under Beat garment is processed and converted into a square wave signal by equipment housed in the Ether Beat outer garment, and transmitted via FM radio wave to the partner device. When the waveform is received by the remote garment it is amplified and used to pulse the four 6 volt vibration motors situated over the left chest, simulating the remote heartbeat. The garments have been developed in collaboration with a fashion designer utilising traditional pattern making and construction techniques in connection with 3D modelling processes. Their design aim is to create garments that derive their structural stability from the electronics that they house. The use of highly transparent materials consciously juxtaposes the materiality and the functionality of the garments. In this way the projects suggest the potential for articles of clothing that are both aesthetically engaging and imbued with communications functionality. The materiality actively questions the idea that the success of an electronic garment be contingent solely on technical issues, wearability, washability and cost. Rather, the projects are situated between art, technology and design and aim to raise questions about futuristic ephemeral ways of connecting with others.

User Testing

User testing of the prototypes took several different forms and ran over a number of months. Testing aimed to assess the impact of the projects at a conscious and a non-conscious level. The conscious experience was evaluated through qualitative assessment, primarily written responses. Non-conscious physiological reactions were evaluated through ECG readings taken throughout user-testing periods. This data has been processed using HRV

[1] [3] (heart rate variability) analysis software, running on MatLab [2] for Windows. The initial round of testing for the wearable apparatus' involved a situated methodology located in a gallery setting. Subsequent testing was conducted in laboratory conditions.

The first round of user testing took place in an exhibition environment. Members of the public were invited to interact with the prototypes and record their feelings about the experience on small cards. They were informed that the prototype was vibrating in response to a heartbeat being synthetically generated by an ECG machine which was located on the opposite wall of the gallery. The responses are very broad, some highly emotional in content while others focus on technical details. The responses roughly fell into five categories: tactile memory cues, looking outwards, looking inwards, affective, and technical responses.

Within the first range of responses 'tactile memory cues' users were reminiscent of childhood memories. The memories recollected were highly tactile in nature and included such responses as: "Smoothly took me back to a symbolic memory of freeing a sparrow from our chicken fence…a memory of feeling for one of the first times the difference and magic of living beings." Within the second group of responses, looking beyond the self, users relayed a sense of looking outward, beyond the self. For instance: "Quite an unusual experience. Makes one understand the connecting thread between us all and the fragility of the thing keeping us alive in this world." The third group of user reactions are concerned with introspection. These are particularly interesting as they suggest that through interaction with the technology, which is designed to encourage interpersonal connection, the user's attention is turned inwards, to the intrapersonal. Such responses included: "I thought it was my own heartbeat...at first and it made me a bit stressed - I think I actually picked up (speed) and tried to match it." The fourth group of responses which were primarily affective reflected purely on the intensely emotionally impact that the interaction inspired. Irrespective of the knowledge that the heartbeat was synthetically generated the emotions elicited are quite powerful. They include such feedback as: "It was quite an extreme sensation…and you kind of feel a bit emotional somehow…quite powerful…a bit overwhelming." The last group of responses focused on the technical aspects of the work. Several reflect on the physical intensity of the experience while others bring up the bionic nature of the prototypes. They included such responses as: "Clockwork or bionic themes also come to mind."

The second round of user testing for the Ether Beat garments was undertaken in laboratory conditions. The aim of this phase was to establish whether interaction with the garments would cause a physiological change in users. The studies hoped to demonstrate that by communicating in a non-conscious way through the agency of the garments, a change in the user's ECG readings would be registered. This phase of testing was undertaken in collaboration with an expert in the field of biosignal engineering. Whilst the results of the testing can be examined in highly technical ways, the investigation focused on locating general trends that suggested physiological responses to the prototypes under review. Detection of emotions from somatic states is a highly contested area of research that requires extensive testing and specific knowledge [4]. The physiological component of this research sought to detect changes consistent with the use of the prototypes but not distinguish particular emotional states within the data.

Testing for non-conscious user reactions to the prototypes involved measuring and recording the ECG signal of the sender and receiver during interaction sessions and processing this data with HRV analysis software. The users were connected to a portable ECG machine via three electrodes which generated real-time displays of the two heartbeats. The individual whose heartbeat was being 'sent' was wearing a garment that sensed their ECG signal and transmitted this via FM radio wave to the receiving device. The signal was then felt by the 'receiver' as a heartbeat vibration through their garment.
The raw data was analysed using free-access Heart Rate Variability (HRV) [1] software developed by Niskenen et al [3], run on Matlab [2] for Windows. HRV basically measures the variations between successive heartbeats. The smaller the deviation in the RR intervals (distance between each 'beat') the lower the HRV figure. Heart rate activity is controlled by the Autonomic nervous system (ANS) which regulates involuntary organ function. The ANS is broken into the sympathetic nervous system, which causes heart rate to increase and the parasympathetic nervous system, which causes heart rate to decrease. Rainville et. al. suggest that "rapid changes in heart rate are mediated by parasympathetic activity while slow changes can result from either sympathetic or parasympathetic activity." [4] For the purposes of this research the following four readings were assessed: Frequency ratio; changes in power spectral density; RR interval change; and mean heart rate per minute.

Within the quantitative analysis there were some suggestive data trends. Firstly, in all four cases the Mean HR followed the pattern of increasing when the user first interacted with the prototype then decreasing in subsequent sessions. In all cases the receiver's Mean HR was lower in the final control session than in the original session. These results suggest that there are palpable impacts of utilising the prototypes yet require further testing and data analysis to corroborate these findings and ascertain implications of such technologies for enhancing remote connection.

The final round of qualitative testing was designed to establish responses to the prototypes over longer time periods. In this way, the novelty factor of interacting with the garments started to dissipate and allowed users to relax into the rhythm of the received heartbeat. Users were asked to write about their experiences after wearing the prototype garments for a ten minute session. The responses suggested that while some users found the experience meditative in nature others had a slightly anxious reaction to the implicitly foreign experience. An example of this mild anxiousness was recorded by a user who was receiving the real-time heartbeat of a close friend, she wrote: "Sleepy, anxious in parts at feeling the heartbeat. Kind of lulls you into deeper recesses of your mind, not really flashes, you don't always realise what you are thinking and are then drawn back to the heartbeat and there is a buzzing feeling of anxiety before lulling you again into a kind of sleepy state. Remember childhood moments of laying on my father's chest, next to lovers. A warmth but more overwhelming anxiousness."

Conclusions

The creation of prototypes has raised many issues, above and beyond theoretical concerns. Such issues include the critical role of collaboration in developing multidisciplinary projects; the importance of design, in tandem with usability and functionality, in the development of wearable electronics; and the need for adequate user testing models to assess the success of wearable projects. Through reframing biosignals as active communications modalities the act of control becomes eminent – how does one control one's heartbeat to transmit the appropriate message?

The user testing has provided preliminary data for considering the effectiveness of the projects. The initial testing session generated interesting feedback with many responses indicating strong emotional reactions to the work. The second set of user trials, which measured the ECG signals of users while interacting with the prototypes, suggested certain emergent patterns in the physiological responses of participants. In order to provide enough information for greater generalisation of results, future tests would benefit from having larger sample groups, longer trials, and possibly investigation of different methods of signal processing.

The development of the Ether Beat range of garments has illuminated a range of areas where the technology and testing could be refined. With regard to the prototype design alternatives to radio frequency such as Bluetooth are being investigated to facilitate truly remote experiences. Similarly, there are a range of changes within the user testing process that are being investigated to garner a broader range of results. Within the realm of user testing larger sample groups and longer trials in truly remote circumstances are required to establish the effectiveness of the prototypes as peripheral awareness media.

Acknowledgements

The results were analysed with HRV Analysis Software 1.1 for windows developed by The Biomedical Signal Analysis Group, Department of Applied Physics, University of Kuopio, Finland.

References

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Keywords

Wearable Technology, Social Cohesion, HRV Analysis, Augmented Communication, Biosignal Transmission.