Enabling New Forms of Agency using Wearable Environments

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ABSTRACT
Technological artefacts can mediate the relations between humans and the environment: mediation changes our agency, which can be defined as our capacity for action. There can be different types of technological mediation and each type shapes our agency differently. Our model of wearable environments, which combines wearable computing and smart environment approaches, is useful for exploring new types of relations and, by extension, new forms of agency. In this paper, we present the first stage of developing a wearable environment system involving a series of workshops using two prototype devices. We evaluated the workshop activities according to a post-phenomenological account: this has allowed us to analyse the transformation of machine-mediated agency vis-à-vis two dimensions: perception and praxis. Our findings showed that interpretations of sonic and tactile feedback were highly dependent upon the placement of the sensing and effecting capacities of the system.

Categories and Subject Descriptors
H.5.m Information interfaces and presentation: Miscellaneous; H.5.2 User Interfaces: Haptic I/O

Keywords
Agency, mediation, wearable computing, smart environments, sensory substitution, post-phenomenology.

INTRODUCTION
The philosophy of technology has explored the roles of technological artefacts in people's lives and society over a period of time. One of the main roles played by technological artefacts is mediation: they can mediate the relationships between humans and the environment, our perceptions of world, and our actions in the world [5] [7]. These two main types of technological mediation can take different forms and thus shape our agency differently. Agency may be described as either "capacity for action" or "transformative capacity" [3]. Agency can attract different conceptualisations across and inside its different domains. Unlike the traditional humanist view of agency as a property of individual entities, Barad suggests that agency is not an attribute of subjects or objects or systems; rather**,** it is "the ongoing reconfigurations of the world, an enactment" [1]. Based on this view, we model agency according to a design perspective [10] considering two dimensions: perception and praxis.

Our aim is to find ways of enabling new forms of machine-mediated agency between humans and the environment, and to develop a framework of agency for designing multi-agent interactive systems distributed over bodies and space. Our wearable environment system will be a typical example of this kind of system, to be designed and evaluated according to this framework. This paper presents the first stage of developing the wearable environment system involving a series of workshops.

BACKGROUND
Ihde [5] distinguishes three main types of human, machine and environment relations (see Table 1). The first is called embodiment relations, in which the particular machine in use becomes transparent or "ready-to-hand" (in Heidegger's terms). A typical example of this type of technology is a pair of glasses. When you use your glasses, they become an extension of your body and are incorporated into your body. You do not see the glasses; rather, you see *through* the glasses. The second type of relation is the hermeneutical relation, based on the interpretations of reality provided by a machine. For example**,** a thermometer represents a state of reality as a number without providing the actual experience of heat. The third relation is the alterity relation, in which we interact with machine itself and the machine is considered as "quasi-other to which I relate" [5] or "present-at-hand". Typical examples may include ATM machines or intelligent software agents.

Ubiquitous computing technologies can facilitate new types of relations by providing opportunities for new couplings between humans, machines and the environment [11].

Embodiment relation	(human – technology) → world
Hermeneutic relation	human → (technology – world)
Alterity relation	human → technology (– world)

Table 1. Human, technology and world relations [5]

Wearable computing [9] and smart environments [2] are two important approaches to developing ubiquitous computing technologies. While smart environments embed sensors and computing capabilities into the environment, wearable computing technologies place them onto the body as wearable garments or portable accessories. Wearable computing technologies mediate the relations between humans and the world, primarily through embodiment relations. However, smart environments mediate these relations mostly through hermeneutic relations. We employ a model of wearable environments using the approaches of both wearable computing and smart environments in our attempt to establish new hybrid types of human-machine-environment relations.

Wearable Environments

Our model of a wearable environment involves an assemblage of networked, multiple agents, distributed over a continuum from bodies to space. This assemblage, that is, this machine, extends from the body to the environment, interfacing both sides. While machine interfaces humans like wearable computing, it interfaces the world or the space around us like a smart environment. The merging of two polar interfaces enables a new type of relation, a *hybrid* of embodiment and hermeneutic relations, which can reveal new forms of machine-mediated agency by taking advantage of the new physical associations and configurations between the human, machine and the environment (see Figure 1).

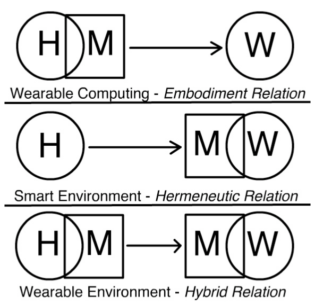

Figure 1: Ubiquitous computing and Human (H) – Machine (M) – World (W) relations

METHODOLOGY

Our approach to developing wearable environments involves two main, design-based, research stages. While the first stage investigates the effect of the various physical configurations between human, machine and environment on agency, the second investigates the effect of the different reasoning capabilities of machines.

In this paper, we presented two workshops, which we conducted as part of the first stage. After conducting the third workshop, this stage will be completed. Table 2 explains the configurations to be experimented in each workshop. Configurations were determined according to two fundamental capacities of the machine: sensing and effecting. These are capacities flexible enough to distribute separately over space and uniform, sufficient to establish a tight coupling between humans and the environment. The

Configurations	Body 1		Body 2		Space		Workshops
Config. #1	*S*	*E*					Ws1, Ws2
Config. #2			*S*	*E*			Ws1, Ws2
Config. #3	*S*					*E*	Ws2
Config. #4			*S*			*E*	Ws2
Config. #5	*S*			*E*			Ws3
Config. #6		*E*	*S*				Ws3
Config. #7		*E*			*S*		Ws3
Config. #8				*E*	*S*		Ws3
Config. #9					*S*	*E*	Ws3

Table 2: Configurations of the sensing (S) and effecting (E) capacities of machines across the workshops (Ws) 1, 2 and 3

wearable environment systems can contain various configurations of sensing and effecting capacities of machines distributed over bodies and space. At this stage, we developed a minimal system involving two humans and simple sensing and effecting capacities. We determined a total of 9 configurations between them as constitutive parts of the wearable environment. Our objective is to gain an understanding of how to develop a wearable environment system by means of different configurations.

We built two lo-fi sensory supplementation devices to meet the requirements of the configurations. Sensory supplementation devices transform stimuli characteristic of one sensory modality into stimuli of another sensory modality [8]. They are particularly useful for providing novel perceptual modalities and "new spaces of coupling between humans and the world"[8]. Grespan et al. [4] used a distance-to-tactile sensory supplementation device, the Enactive Torch, to investigate the role of embodied action in the perception of external spatiality. Similar to the above researchers, we built a sensory supplementation device called Enactive Coupler (EC). When the EC's distance sensor detects an object within a range of 60cm, two motors vibrate. The EC can be attached to different parts of the body or placed onto different surfaces in the environment. The EC also features amplified sonic output, which is produced mechanically by the second vibration motor. While the first version of the EC (ECv1) contained sensing and effecting capacities in the same "body", i.e., box, the effecting capacity was separated from the sensing in the EC version 2 (ECv2) (see Figure 3). This means that ECv2 does not provide any feedback from the white box: the feedback in the form of sound is provided from the black box somewhere in space.

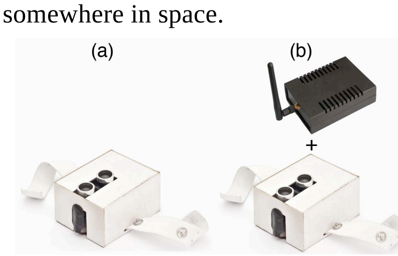

Figure 3: Enactive Coupler (EC) version 1(a) and version 2 (b)

WORKSHOPS

We conducted two workshops involving a total of 10 participants. In the first, participants working in pairs, one pair at a time, performed 4 activities. The activities were designed in the form of a game, with the objective of guiding a blindfolded partner over the randomly established tracks using different tools or configurations. For each activity, there was a guiding participant (GP) and a blindfolded participant (BP). They were only permitted to communicate with each other using the tools provided in non-verbal ways. There were two tools to gauge each individual's perception of distance: a simple rope approximately 60cm long and the EC.

The GP guided the BP using a rope extending from the GP's back to the BP's stomach in the first activity. The rationale behind including an activity using a rope was to provide a grounding experience for the participants; that is, to coordinate the movement between their bodies when they were asked to use the EC. In the second activity, the GP guided the BP with the EC attached to the BP's stomach; in the third activity, the GP guided the BP with the EC attached to the former's back. The first workshop demonstrated that the perceptions and interpretations of sonic and tactile feedback, and the strategies of the subjects, were highly dependent on the places to which the EC was attached. This confirmed our assumption regarding the important role of different physical configurations in shaping our agency. Please see [6] for a detailed presentation of the findings of Workshop 1.

In the second workshop, we investigated how sensing and effecting capacities might separately affect the ways in which participants perceive and act. The participants performed the same task as the participants in the first workshop, using two new configurations in addition to those used in the first workshop (see Figure 4). We changed our previous visual representation of human-machine-world relations by adding another human. This representation allowed us to experiment with new forms of couplings between humans and to challenge the boundaries of our perceptions of other humans and the space around us. This time, we omitted the activity in which participants used a rope: we did this to allow the natural emergence of interaction metaphors.

Activity 1: *GP guides BP with ECv1 attached to BP's stomach*

Activity 2: *GP guides BP with ECv1 attached to GP's back*

Activity 3: *GP guides BP with ECv2 attached to BP's stomach*

Activity 4: *GP guides BP with ECv2 attached to GP's back*

We used response cards, follow-up interviews and video recordings to analyse the activities.

FINDINGS

We examined the workshop outcomes according to a post-phenomenological account. Verbeek [10] provides a post-phenomenological vocabulary derived from the works of Ihde [5] and Latour [7] to analyse the transformation of agency enabled or mediated by machine (or *machine -*

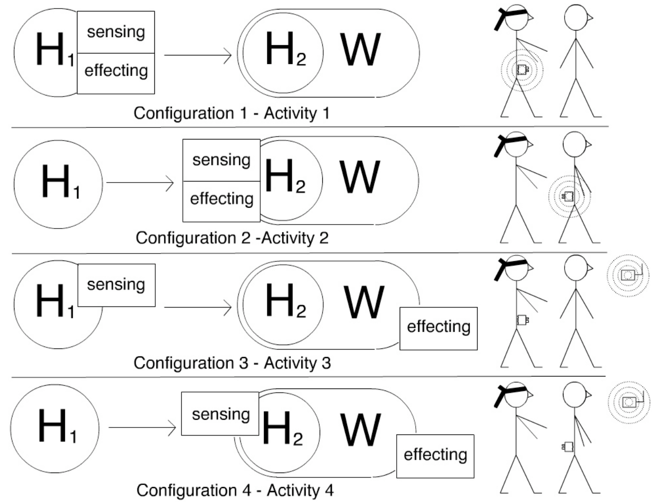

Figure 4: Human ($H_{1,2}$) – Machine – World (W) configurations and corresponding activities

mediated agency) with regard to two dimensions: perception and praxis. This perspective allowed us to evaluate the influence of technologies on humans' perception and actions in terms of two structures. While transformation of perception has a structure of amplification and reduction, the translation of action has a structure of invitation and inhibition [10].

Changes in Perception

One important finding was the lack of difference between the BPs' awareness (1) of their partners; and (2) of space. The participants indicated that the two meant the same for them across the activities: they did not - or needed not to - differentiate between their partners and space.

Changing the place of sensing capacity resulted in radical changes in the BPs' perceptions of their partners and space. The BPs' awareness of the GPs was higher in the activities in which the GPs carried the EC, i.e., Activities 2 and 4. This outcome, which was also supported by the findings of the first workshop, suggests a strong relation between the level of awareness and the place of sensing capacity. But, changing the place of effecting capacity did not make any difference to the BPs' awareness of their partners and space. We were expecting an increase in perceptions of space when we placed the effecting capacity somewhere in space. However, employing this strategy did not bring about any difference in their awareness of space. Changing the place of effecting capacity affected only the cognitive effort expended by the participants on Activities 2 and 4. Both the BPs and the GPs stated that they had to put much less cognitive effort into Activity 2 than Activity 4.

Changes in Praxis

The participants interacted with each other using two main types of interaction models based on metaphors of a rope and an obstacle. While eight participants used the rope metaphor, considering the feedback as confirmation of right direction, one pair of participants used the obstacle metaphor, considering the feedback as an indication of wrong direction. This basic difference in interaction models totally changed the ways in which the participants communicated and moved.

When the place of sensing capacity changed, the strategies that were employed to coordinate the movements also changed. The participant who carried the EC, in particular the sensing capacity, felt more responsible for controlling the flow of activity. In other words, the sensing capacity required the participant who carried this capacity to be more active and the other participant to be more passive. Being 'more active' means that one participant takes the major initiative to communicate with her/his partner, especially when the connection between the two is lost.

Modes of Engagement

The BPs interaction with the EC across the activities can be placed on a continuum of engagement spanning from transparent (ready-at-hand) to reflective (present-at-hand). The mode of engagement for each activity represented the dominant mode of engagement during the activities: it was most transparent in Activity 1, then Activity 3, then Activity 2, and finally in Activity 4. This order is in accordance with the statement made by the BPs vis-à-vis the high level of cognitive effort spent on Activity 4, which showed the most reflective mode of engagement. As a result, we categorised the relations in Activity 4 as alterity relations and those in Activity 1 as embodiment relations. In this respect, Activities 2 and 3 can be considered in-between relations, in which frequent transitions between modes of engagement occurred.

One interesting aspect of Activity 1 was the appearance of two modes of engagement simultaneously. While the vibrations of the EC were reflective for the BP, the sound of the EC was transparent. This was an interesting case in terms of showing the possibility of interacting with a device in both modes of engagement at the same time.

DISCUSSION AND FUTURE RESEARCH

The findings from Workshops 1 and 2 showed that the perceptions and interpretations of sonic and tactile feedback, and the strategies of the subjects, were highly dependent upon the placement of the sensing and effecting capacities of the system. This may have significant implications for the design and evaluation of similar sensory substitution devices, and perhaps for any wearable computing systems involving sonic and tactile modalities.

While most of the participants used the rope interaction metaphor, some used the obstacle metaphor. One possible direction for research could be to investigate the relations between emerging metaphors and the physical configurations of distributed machines.

Changing the place of effecting capacity failed to increase the awareness of space. This may have been caused by usage of only one source of sound in space. While the use of more sound sources, that is, effecting capacity in space may prove useful for participants in that it would enable them to develop a sense of directionality, the placement of the sensing capacity into the environment can provide participants with an increased awareness of space.

The in-between relations exhibited in Activities 2 and 3 are types of relations with frequent transitions between the modes of engagement that we aim to facilitate in future wearable environment systems. In the next stage, we will increase the role of space by implementing the remaining 5 configurations listed in Table 2. Ultimately, we aim to have an assemblage of smarter EC-like agents that can communicate with each other to facilitate further novel modes of perception and action, and evolving dimensions of agency. As well, we aim to establish a framework of agency for designing these kinds of multi-agent interactive systems distributed over bodies and space.

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