Investigating the Potential for Shared Agency using Enactive Interfaces

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ABSTRACT

Human agency, our capacity for action, has been at the hub of discussions centring upon philosophical enquiry for a long period of time. Sensory supplementation devices can provide us with unique opportunities to investigate the different aspects of our agency by enabling new modes of perception and facilitating the emergence of novel interactions, all of which is impossible without the aforesaid devices. Our preliminary study investigates the non-verbal strategies employed for negotiation of our capacity for action with other bodies and the surrounding space through body-to-body and body-to-space couplings enabled by sensory supplementation devices. We employed a low-fi rapid prototyping approach to build this device, enabling distal perception by sonic and haptic feedback. Further, we conducted a workshop in which participants equipped with this device engaged in game-like activities.

Keywords

Human agency, sensory supplementation, distal perception, sonic feedback, tactile feedback, enactive interfaces

1. INTRODUCTION

The concept of agency is defined in its simplest sense as the "capacity for action" or "transformative capacity"[6]. Yet, there has been ongoing debate surrounding definition, emergence and possession of agency in artificial intelligence, cognitive science, philosophy and many other fields. One particular point of controversy is related to the attribution of agency to entities. As opposed to 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 but is "the ongoing reconfigurations of the world, an enactment" [2]. Agency emerges out of the dynamism between entities.

The extended mind perspective advocates a view of mind not confined to the head [4]. According to this view, the external environment and the mind are considered as a coupled system constituting a hybrid cognitive system in which environmental objects and tools enable extended mental processes. This coupling involves ongoing interaction and reconfiguration of the world and consequently it shapes our perceptions, cognition, actions and, by extension, agency. De Jaegher and Froese, who investigated the interpersonal dimension of this coupling by employing an enactive approach, examined the interpersonal coordination and interaction processes and the interplay between them [5]. Their perspective suggests (a) that the interpersonal coordination of movements can lead to the emergence of an interaction process, which in turn can affect the constitution of agency of individuals; and (b) that individual cognition and interpersonal interaction - as two linked aspects of our agency - mutually enable and constrain each other.

This paper, in which we present an initial study, represents the first stage of our long-term investigation of enactive ways of negotiating our capacities for shared action with other bodies and surrounding spaces.

2. BACKGROUND

Sensory substitution systems cover whole range of devices that transform stimuli characteristic of one sensory modality into stimuli of another sensory modality [8]. Sensory substitution systems can be categorised as enactive interfaces, a term used for interfaces that are predicated on enactive knowledge. Enactive knowledge [12] is acquired primarily by "doing" and constructed on motor skills; for example, playing a musical instrument.

TVSS (Tactile Vision Sensory Substitution), one of the very early sensory substitution systems designed to help visually impaired people, was a vision-to-tactile system converting the image of environment captured by a video camera into tactile stimulation produced by a matrix of 400 activators [1]. Participants experimenting with this system were able to interpret this tactile stimulation, when they were asked to bat a ball as it rolled off a table. Although sensory substitution systems enable visually impaired people to carry out certain tasks like recognising locations of objects, which would hitherto have been impossible for them, they are not able to provide the experience and joy of actually seeing [8]. In this respect, sensory substitution systems may be considered as additions or supplements to an individual's sensory modalities rather than substitution. Despite the fact that sensory substitution systems were originally designed for visually impaired people, they have also facilitated research into perceptual and cognitive studies and philosophy. The features that make sensory substitution systems a suitable tool for performing practice-based research in these areas include the provision of a novel perceptual modality and a "new space of coupling between humans and the world" [8].

Sensory supplementation devices can provide us with unique opportunities to investigate the different aspects of our agency by enabling new modes of perception and facilitating the emergence of novel interactions, which are not possible without their inclusion.

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Bird et al. [3] investigated the potential of extended mind perspective through experimentation with sensory substitution systems. Employing a low-fi rapid prototyping approach to building a minimal TVSS system, they demonstrated that prototyping and experimenting sensory substitution devices facilitate "an understanding of agent-environment interactions by reducing abstraction load" and revealed the salient relations between them.

Similar minimalist approaches have been employed by other researchers: Lenay and Steiner, who demonstrated that localisation of objects is possible using a simple sensory supplementation device composed of a photoelectric cell triggering a vibrotactile actuator, argued that minimalism of the device forces "a spatial and temporal deployment of the perceptual activity"[9]. Similarly, Grespan et al. [7] used a distance-to-tactile sensory supplementation device, the Enactive Torch (ET), to investigate the role of embodied action in the perception of external spatiality. When the ET detects an object within a range of 60cm, it vibrates. Grespan et al. [7] designed an experiment consisting of two simple tasks related to determining the location of objects and the distance to and between them; as well, they examined the different types of perceptive strategies that allowed participants to carry out simple tasks.

3. METHODOLOGY

Similar to the studies of Bird and colleagues, we have employed a rapid prototyping approach to investigate our shared capacities for action and explore enactive ways of adding new dimensions to this capacity. This research is comprised of two main stages involving experimentation vis-à-vis (a) different physical configurations, and (b) different sensory supplementation device capabilities.

The work of Lenay and Steiner [9] and Grespan et al. [7] inspired the design of our workshop experiment in which we use minimalist interfaces to understand the different characteristics of perception. We started by building a small, mobile, sensory supplementation device called the Enactive Coupler (EC) (see Figure 1). Equipped with one ultrasonic range finder sensor and two vibration motors, it is similar to the Enactive Torch in terms of distance-to-tactile functionality. However, unlike the Enactive Torch, the EC can be attached to different parts of the body or placed onto different surfaces in the environment. This flexibility enabled us to experiment with different configurations between the body and space. The EC also features sonic output, which is produced mechanically by an additional vibration motor. Whereas the first vibration motor attached to the bottom of the EC is responsible for generating tactile output to be felt directly by the skin, the second vibration motor is responsible for generating sonic output.

The EC is composed of one Arduino[1] controller board, one Parallax PING))) ultrasonic rangefinder sensor, two 10mm shaftless vibration motors and one plastic amplifier cube.

Figure 1: The Enactive Coupler (EC)

[1] Arduino open source microcontrollers: http://www.arduino.cc

3.1 Mapping

The mapping of input acquired by sensors to the output generated by the actuators plays a significant role in the body-to-body and body-to-space couplings mediated by the EC. Put simply, when the EC's distance sensor detects an object within a range of 60cm, two motors vibrate. Although it was found that human subjects are able to discriminate between three and five intensities of vibration [3], in this first experiment, we used simple on/off modes for mapping the distance information to sonic and tactile feedback. This was done to reduce the number of the experiment parameters and to investigate the minimal amount of information required to accomplish the tasks.

4. EXPERIMENT

We conducted two preliminary workshop sessions with 4 participants. These were intensive sessions comprised of 4 activities lasting approximately 3 hours in total. The participants performed each activity in pairs, only one pair at a time. By organising the participants into pairs, we could examine their interpersonal enactive interaction constructed on body-to-body couplings. Participant 1 was an architect aged 24: Participant 2 was a visual artist aged 26; Participant 3 was a psychologist aged 25; and Participant 4 was a musician aged 23.

4.1 Activities

All the activities were designed in the form of a game, with the same 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). In the interests of making the task simpler, the angle of turning points on each track was always 90°. There were four main activities (see Figure 2) during which the same pair of participants performed each activity twice by switching the roles of BP and GP.

Activity 1*: GP guides BP with a rope extending from GP's back to BP's stomach.*

Activity 2*: GP guides BP with EC attached to BP's stomach.*

Activity 3: *GP guides BP with EC attached to GP's back.*

Activity 4: *GP guides BP with EC attached to BP's hand.*

The participants were not allowed to talk to each other. They were only able to communicate through the tools provided and by using non-verbal communication without touching each other. Their footsteps were not audible to each other. There were two tools utilised to gauge each individual's perception of distance: a simple rope approximately 60cm long and the EC. We considered the rope as an "enabling constraint" [10] for making analogies to arrive at ways to coordinate the movement between bodies when the participants were asked to use the EC. Although the functionality of the device remained the same in activities 2, 3 and 4, the meaning of the feedback and consequently the strategies using the feedback needed to be reappropriated due to the changing physical configurations.

After the completion of each activity, we delivered response cards and interviewed the participants. We used the answers on the response cards, follow-up interviews and video recordings to analyse the activities.

At this stage, our goal was to gain a practice-based understanding of the emergence of a shared capacity for action between bodies. In particular, we were interested in the enactive ways in which body-to-body couplings were established and maintained.

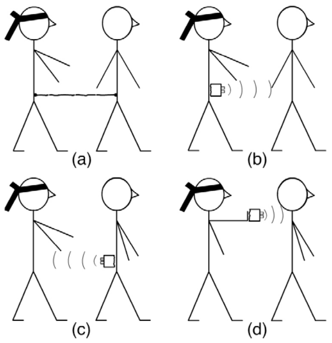


Figure 2: Configurations for activities: (a) Activity 1- guiding with rope, (b) Activity 2 – guiding with EC attached to BP's stomach, (c) Activity 3 – guiding with EC attached to GP's back, (d) Activity 4 - EC attached to BP's hand

4.2 Findings

Table 1 summarises the results from the four activities according to three perspectives: perceptive coordination of strategies, interpretation of sonic and tactile feedbacks, and awareness of partner and space.

4.2.1 Perceptive Coordination Strategies

The strategies the participants employed when carrying out the tasks revealed important aspects of negotiation and evolution of mutual intentions and influences, which were important dimensions of our shared agency.

The participants pointed out that Activity 2 was the most complicated one for them as they needed to simultaneously both control the device and search for their partners. Participants considered activity 4 as a hybrid of Activities 2 and 3 and hence employed a hybrid strategy of the previous two activities based on the principles of *following a signal* and *confirming the rightness of their body elements, movements and orientation*.

The first activity with the rope clearly influenced the negotiation of the coordination strategies developed in the later activities. In a few cases, the GPs were able to find alternative ways of coordinating with their partners, even though they were still acting in accordance with the rope model of coordination. Each faced his/her partner and detected the signals of the EC with their hands. In the last activity, one GP went beyond the rope model by directing the BP while s/he was not moving over the track. This was a significant deviation from all of the other strategies, which were based on the proposition of having both partners moving together over the track. Here, the GP was performing at another level of agency, using the same interface for communicating with the BP but able to act in a different way. The GP knew what the BP was expecting, based on their previous model of interaction: s/he provided appropriate inputs while acting according to another new model of "coupling" evolved from the base rope model of coupling.

4.2.2 Interpretation of Sonic and Tactile Feedback

The role of sonic and tactile feedback changed within and across the activities. These changes gave rise to two important aspects: the importance of different placements of sensory substitution devices in meaning generation and fluent transition of participants from one feedback model to another one. Participants were able to adapt to these changes at three levels: (1) they adapted their perception of distance with respect to changing the places and influences of sonic and tactile stimuli; (2) they adapted their movements to this new coupling by negotiating this new space of possibilities for action with their partner; and (3) the meanings of the feedbacks were determined and reappropriated mutually during this negotiation process.

4.2.3 Awareness of Partner and Space

The BPs all agreed that they felt the presence of their guiding partner most in Activity 1, then in Activity 3, then in Activity 4 and least in Activity 2. There was no common pattern of awareness of space. But, the BPs all said that it was at its lowest level in Activity 2.

Table 1: Summary of the Results of the Activities

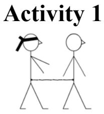
	Perceptive Coordination Strategies	**Interpretations of Feedback**	**Awareness of Partner & Space**
Activity 1 	Participants developed common perceptive strategies, e.g., keeping the tension of the rope constant and pulling the rope from different angles.	Common interpretation of tactile feedback was the confirming role of the rope tension and orienting role of directional pulling of the rope.	All BPs found this configuration to be the one most connected to their partner: their sense of direction was the highest for most of them.
Activity 2 	Two GPs guided BP as if connected by rope and failed to negotiate coordination strategies for the EC. The others were able to use methods based on the changes in the EC's on/off signals in a consistent manner.	Both sonic and tactile feedback were considered to be confirmation of: - *the rightness of orientation of body* - *the rightness of the body movement* - *the time to stop the movement*	All BPs found this configuration to be the one least connected to both partner and space. They had very little sense of directionality. On occasion, the BPs could not differentiate the GPs from the walls of the space.
Activity 3 	Although the roles were different, the participants easily adapted to the new feedback structure. All of the participants used the step-by-step procedures of coordination consistently. All of the BPs used their arms and hands actively.	Sonic feedback was considered as: - *a signal to follow* - *degrees of proximity to partner* Tactile feedback was considered as: - *an indication of their partners following behind them correctly.*	This configuration provided the highest awareness of partner among the activities with the EC. The sense of directionality was also very high. BPs were able to perform 90 degree sharp turns.
Activity 4 	The feedback structure was basically the same as that of Activity 2, but the participants' strategy was a hybrid of Activities 2 and 3. Their movement patterns were quite similar to those of Activity 3.	Both forms of feedback were considered as confirmation of: - *the rightness of orientation of hand* - *the rightness of body movement* - *time to stop the body movement* - *a signal to follow*	All BPs were highly aware of their partners. But, their sense of directionality failed to demonstrate any common patterns.

Figure 3: Workshop participants engaged in their task

The awareness of the presence of the GP was directly affected by the placement of the EC. When the EC moved physically closer to the GP's body, the BP's awareness of the GP increased. In general, the EC provided a proximity-based representation of entities to the BPs; however, the association of this representation to individual entities depended on the physical distance between the entity and the EC. The association of a representation with the entity was at a maximum when the EC was physically attached to said entity and at a minimum when the EC was carried by the BPs. From this point of view, distributing ECs could increase the participants' awareness of space and of the other entities in that space.

Due to the turning points on the tracks, the participants had to release the connection between them for a while, then re-establish it. Thus, there was a cycle of decoupling and re-coupling during the activities. While the participants were connected, they constituted a single unit, which had to move in accordance with shared capacities of action. When they were physically decoupled, they were still coupled at a higher intentional level, which rendered them not a single entity but something akin to an extended mind.

5. DISCUSSION AND FUTURE WORK

This experiment showed 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 sensory substitution devices were attached. This may have significant implications for the design and evaluation of similar sensory substitution devices, and perhaps more generally for wearable devices using enactive interfaces.

The participants developed different strategies in each activity to coordinate their movements, based on different couplings. The couplings were not predetermined but emerged from the process of negotiation between the participants, supported by the EC. However, these couplings were not completely unexpected. The grounding experience of the rope activity, as well as the different placements of the EC, served as enabling constraints. While these constraints allowed movement to remain predictably connected to a desired model of coupling, they also enabled new possibilities [10]. The first activity with the rope provided **a** useful basis, flexible enough for constructing new couplings yet specific enough for developing and sustaining a shared understanding of their mutual intentions and influences.

Although this preliminary study supports the idea of attribution of agency not to entities but to relations and ongoing configurations, it also highlights the vital role of action in perception: when the BPs stopped moving, due to the loss of feedback their perception of GP disappeared. This is in line with an enactive approach to perception, which claims that: "Perception is an activity that requires the exercise of knowledge of the ways action affects sensory stimulation" [11]. However, this contradicts our understanding of 'dynamic' agency. In this particular case, we need to act in order to perceive. This requires an action before perceiving and thus before any couplings of our body with other external entities. There needs to be an immanent capacity, *agency* independent of our coupling with the world to make the initial act without perceiving. This agency needs to comprise at least two parts: one an independent core part and the other a dynamic part. Here, the ways in which this independent part evolves into another space of possibilities through various couplings - and the conditions for its transition from one coupling to another - become critical.

We will continue to investigate these ways and conditions to establish and sustain various couplings by a series of case studies involving EC-like devices. Ultimately, we are planning to produce an assemblage of networked EC-like agents that communicate with each other to facilitate further novel modes of perception and action and evolving dimensions of agency.

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