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Towards Human Technology Symbiosis in the Haptic Mode

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Abstract: Search and rescue operations are often undertaken in dark and noisy environments in which rescue teams must rely on haptic feedback for exploration and safe exit. However, little attention has been paid specifically to haptic sensitivity in such contexts or to the possibility of enhancing communicational proficiency in the haptic mode as a life-preserving measure. Here we discuss the design of a haptic guide robot, inspired by careful study of the communication between blind person and guide dog. In the case of this partnership, the development of a symbiotic relationship between person and dog, based on mutual trust and confidence, is a prerequisite for successful task performance. We argue that a human-technology symbiosis is equally necessary and possible in the case of the robot guide. But this is dependent on the robot becoming 'transparent technology' in Andy Clark's sense. We report on initial haptic mode experiments in which a person uses a simple mobile mechanical device (a metal disk fixed with a rigid handle) to explore the immediate environment. These experiments demonstrate the extreme sensitivity and trainability of haptic communication and the speed with which users develop and refine their haptic proficiencies in using the device, permitting reliable and accurate discrimination between objects of different weights. We argue that such trials show the transformation of the mobile device into a transparent information appliance and the beginnings of the development of a symbiotic relationship between device and human user. We discuss how these initial explorations may shed light on the more general question of how a human mind, on being exposed to an unknown environment, may enter into collaboration with an external information source in order to learn about, and navigate, that environment.

1. INTRODUCTION

In this paper we present and discuss some preliminary results from an experimental study of *haptic sensing* which feeds into a larger robotics research project which we call ‘REINS’.

The REINS project aims to explore the possibility of designing a robot guide which will aid the user to explore and safely navigate through an unpredictable space without feedback via sight or hearing. The user will therefore be entirely reliant on the *haptic sense* in being guided by the robot and in using it as an exploratory tool.

In the case of the REINS project, the user will make use of the haptic sense in two ways: a) through feeling his or her own bodily movements within the experimental space (commonly known as ‘proprioreception’), and b) through feeling the robot’s movements and behaviour via a stiff hand-held interface – a lead, rein, or handle – connecting the user directly with the robot. In this paper we discuss an initial experimental study relating to b) in which experimental subjects use a simple mobile mechanical device in order to judge the relative weight of objects in the device’s path. This experimental study demonstrates the extreme sensitivity and trainability of haptic communication and the speed with which users develop and refine their haptic tool-using proficiencies.

Drawing on insights from integrationist semiology (Harris, 2009), we argue that such trials show the transformation of the mobile device into a ‘transparent technology’ via an emerging ‘cognitive symbiosis’ of device and human user in the task context (Clark, 2003). Our experimental study, therefore – though relatively modest in its scope – raises fundamental questions about the nature and dynamic of technologically mediated human cognition – or ‘extended cognition’ (Clark, 2009, 2011) which we explore below.

2. THE HAPTIC SENSE

Gibson (1962: 478) notes that the term ‘haptics’ was first proposed by Revesz (1950), following observations of ‘the performances of the blind’, to denote ‘an unrecognized mode of experience ... which goes beyond the classical modalities of touch and kinesthesis'. More specifically, the term is intended to capture 'active touch' as opposed to 'passive touch, or *being touched* (Gibson, 1962: 477). 'Active touch', Gibson emphasises, 'in an exploratory rather than a merely receptive sense' (1962: 477). From this perspective, 'the *hand* is a kind of sense organ as distinguished from the skin of the hand' (1962: 477).

Thus, as Robles-De-La-Torre (2006: 27) notes more recently:

'In experimental psychology and physiology, the word *haptic* refers to the ability to experience the environment through active exploration, typically with our hands, as when palpating an object to gauge its shape and material properties. This is commonly called *active* or *haptic touch*, in which cutaneous and kinaesthetic capabilities have important roles.'

Although relatively under-explored in comparison with sight and hearing, the haptic sense is 'critical for normal human functioning at many different levels, from controlling the body to perceiving the environment, as well as learning about and interacting with it' (Robles-De-La-Torre, 2006: 29). Consequently, there is now intense psychological interest in the cognitive dimensions of haptic sensing generally as well as in the development of haptic proficiency in blind and visually impaired adults and children. Thus, research has highlighted the extraordinary speed and sensitivity of the haptic sense (e.g., Heller & Schiff, 1991) and has also demonstrated, contrary to early assumptions and common prejudice, 'the presence of a comparable set of spatial abilities in people without vision as can be found in those with vision' (Golledge, Klatzky & Loomis, 1996: 232, and see also Ungar, Blades & Spence, 1996; Angeles Espinosa et al, 1998; Ungar, 2000). Understandably, then, there has been growing interest in haptic sensing and its technological applications (for reviews and commentary see, e.g., Hayward & Astley, 1996; Henriques & Soechting, 2005; Robles-De-La-Torre, 2006).

Our own project is inspired by two concrete real-world scenarios which crucially depend on haptic sensing.

The first relates to the challenges faced by fire fighters on entering and exploring a dangerous environment in low or no visibility conditions and often without meaningful auditory feedback. In such cases, firefighters may have to rely solely on their own immediate haptic feedback in order to make their way in and out of burning buildings and to locate survivors. In working in such conditions, firefighters make use of a number of basic haptic feedback strategies, including wall-following – i.e. running their hand along the wall as a means of navigation – and kicking out in front of them as they move in order to feel or remove possible obstructions.

The second scenario is the relationship between visually impaired person and guide dog. Many blind and partially sighted people have developed highly effective navigational and exploratory partnerships with their specially trained guide dogs. In walking along the street to a destination, the visually impaired person is linked directly to the guide dog via a stiff metal interface known as a 'handle', attached to a harness on the dog's back and shoulders. This simple device is the main conduit for the necessary reciprocal haptic feedback between the partners. The handler feel's the dog's movements and direction while the dog monitors the handler's walking as they proceed together.

As person and dog get to know one another and their working relationship develops, they become –via the handle - extraordinarily sensitive to the behaviour and disposition of their companion. N.G, an experienced guide dog handler in Sheffield, told us that she senses all her dog's reactions through the handle. She reads his overall 'body language' and can feel all kinds of attitudinal states in her dog in addition to the behaviours more obviously focussed on navigational functions. At the same time, this ability to sense the moods and disposition of the dog also affords additional information to the experienced handler about both immediate and distant environmental circumstances through the medium of the dog's responses to those circumstances. In return, her dog reads N.G's overall state ('he's picking up whether I'm all right', as she told us), feeling whether she is nervous, upset, anxious etc. In short, the handle allows constant two-way monitoring of behaviour as a result of which the handler and dog constitute a single, purposeful navigational 'system'.

Moreover, this haptic reciprocity between dog and handler begins to emerge very rapidly. In initial work on the project, one of our (sighted) colleagues reflected on his first ever street trial with a guide dog and noted:

‘I walked blindfolded with the dog along a busy walkway outside. Pretty soon I began to feel even the slight changes of speed and direction. The trainer who walked with me said that it is important to swing your hands so that the dog also gets some feedback on your active participation of walking’.

The REINS project, then, aims to explore a design which integrates active haptic exploration of the immediate environment with haptically guided locomotion and navigation. In this paper we report and discuss only the first of these topics, that is, our initial exploration of haptic sensing of the environment, concentrating specifically on the ability to perceive and discriminate objects of different weights positioned in the immediate path of the mobile device.

4. HAPTIC DISCRIMINATION

Haptic sensing of weight and force, as well as other object properties such as size, volume and texture, has been extensively studied since the early 19th century (e.g. the pioneering work of Ernst Weber, see Jones, 1986). In general, haptic discrimination abilities have been shown to be extraordinarily acute and easily trainable. Indeed, in a study of haptic discrimination of textured surfaces, Lamb (1983: 562) concluded that:

‘Any incremental change in the period of the dots produced *d’* values greater than zero; in other words, the subjects could detect to some degree any change in the period of the dots, no matter how small. There was no evidence of “threshold” behaviour in this discrimination task’.

In terms of the discrimination of weight more specifically, studies have differentiated between the perception of ‘inertial mass’ (the feeling of the force needed to move an object) and ‘gravitational mass’ (the feeling of holding an object in the hand), showing that ‘gravitational mass’ generally feels heavier (Bergmann Tiest & Kappers, 2010). Studies have also shown the inter-relation between perceptions of weight and perceptions of size, volume, colour and texture (Jones, 1986; Kahrimanovic & Bergmann Tiest, 2011).

Our own study involves asking subjects to make judgements of ‘inertial mass’, experienced by using the mobile mechanical device to collide with, and push, objects of various weights. However, the weight discrimination studies referred to above have all involved *direct* touch contact with objects. In contrast, our own study involves *indirect* haptic sensing in that subjects can only ‘feel’ the weight of objects through the mediating presence and role of the mobile device. In effect, the robot plays the role of a glorified blind person’s cane – a ‘robot-on-a-stick’, as it were. Thus, the robot’s own ‘body’, controlled by the human user by a rigid ‘handle’ or ‘rein’, is used as an exploratory tool with which to interact with objects in the vicinity and give feedback on their inertial weight. We were interested in the extent to which users would be able to discriminate in this way between objects in terms of weight and how quickly such mediated haptic powers would develop and improve over a short period of time. Furthermore, our study eliminates the influence of the perception of other object properties (size, volume, texture, etc) on the perception of weight, since no tactile manipulation of objects is possible and subjects are deprived of both visual and auditory feedback (by blindfold and headphones).

5. THEORITICAL PERSPECTIVE

In designing and interpreting our experimental study, we were guided by two main theoretical perspectives: 1) the integrationist perspective on language and communication developed by Roy Harris (see particularly 1996, 2009), and 2) the concept of ‘transparent technology’ as discussed and developed in the work of Andy Clark (2003, 2011).

5.1 Integrationism

The integrationist perspective on communication – or ‘integrational semiology’ (Harris, 2009) – rejects any hard-and-fast compartmentalization of our communicational experience into ‘linguistic’ and ‘non linguistic’, or ‘verbal’ and ‘non-verbal’ processes or phenomena. For the integrationist, all communication of whatever kind involves the *creation of signs* whose meaning, or value, lies in the role these signs play in the integration of human activities in context. From this perspective, *feeling* or *sensing* our environment in the course of a task means *making sense of* our environment, and 'making sense' of something is an act of making meaning, hence a semiotic, or semiological act.

In going about our daily business of interacting with other people and the world, then, we are not mere *sign users* but *sign makers*. We actively 'read' our environment as we act on it and there are no restrictions in principle on what aspects of our experience might, in the context of our activity, become relevant cues or signals for us. In acting in and on the world, we can therefore make signs out of anything that is to hand, including, and most basically, our immediate sense experience. While our sensations and perceptions are not signs themselves, one may 'treat them as signs for purposes of some further activity' (Harris, 1996: 177). As Harris explains:

'There are indeed cases where my sensations become signs. Groping my way through a familiar room in the dark (because the lights have fused), what my fingers feel and my feet encounter become signs of chairs, tables, walls, doors, etc. There is no semiological mystery here. These sensations become signs because – and insofar as – they integrate past memories with a current programme of action – i.e. crossing the room in the dark' (1996: 176).

In the effective working partnership between guide dog and handler, then, both partners have become skilled sign makers, able to 'read' – or 'feel' - the behaviour of their partner and the immediate environmental context through the handle. In our own study, our experimental subjects were asked to 'read' the physical environment through the rigid 'rein' attached to the mobile device. But, as we shall detail below, such a task is an extremely complex communicational challenge involving different types of semiological integration.

5.2 Transparent technology

As Clark (2011) explains, the concept of 'transparent technology' derives from the Heideggerian notion of 'transparent equipment' – 'equipment ... that is not the focus of attention in use' (Clark, 2011: 10), a 'classic example' being 'the hammer in the hands of the skilled carpenter'. As Clark argues, the user does not 'feel' the equipment in his or her hands:

'Instead, the user "sees through" the equipment to the task in hand. When you sign your name, the pen is not normally your focus (unless it is out of ink etc.). The pen in use is no more the focus of your attention than is the hand that grips it. Both are transparent equipment' (2011: 10).

A 'transparent technology', then, 'is a technology that is so well fitted to, and integrated with, our own lives, biological capacities, and projects as to become (as Mark Weser and Donald Norman have both stressed) almost invisible in use' (2003: 37). In contrast, an 'opaque technology' is 'one that keeps tripping the user up, requires skills and capacities that do not come naturally to the biological organism, and thus remains the focus of attention even during routine problem-solving activity' (2003: 37).

'Transparent' tools are those 'whose use and functioning have become so deeply dovetailed to the biological system that there is a very real sense in which – while they are up and running – the problem-solving system just *is* the composite of the biological system and these nonbiological tools' (2003: 38).

The classic illustration of 'transparent technology' in this sense, and of particular relevance to our own study, was the use of a cane by a blind person (or 'cane traveler') for navigational purposes (Clark, 2003: 38) as described by Bateson (1973: 434):

'But what about "me"? Suppose I am a blind man, and I use a stick. I go tap, tap, tap. Where do *I* start? Is my mental system bounded at the handle of the stick? Is it bounded by my skin? Does it start halfway up the stick? Does it start at the tip of the stick? But these are nonsense questions. The stick is a pathway along which transforms of difference are being transmitted. The way to delineate the system is to draw the limiting line in such a way that you do not cut any of these pathways in ways which leave things inexplicable. If what you are trying to explain is a given piece of behaviour, such as the locomotion of the blind man, then, for this purpose, you will need the street, the stick, the man; the street, the stick and so on, round and round. But when the blind man sits down to eat his lunch, his stick and its messages will no longer be relevant – if it is his eating that you want to understand'.

If I am conscious of the world via a stick, then the stick is not simply a tool that 'I' use, but part of 'me', a limb of my extended body and a sense organ of my extended mind. User and tool thus become 'human-technology symbionts' - 'thinking and reasoning systems whose minds and selves are spread across biological brain and nonbiological circuitry' (Clark, 2003: 3).

Clark offers a remarkable illustration from the work of Berti and Frassinetti (2000) with neurologically impaired human subjects. The subjects in question suffered from 'unilateral neglect' within the visual system with the result that areas within the visual field were inaccessible to them. But when subjects were given a stick to reach objects with, it was found that 'the use of a stick as a tool for reaching actually extends the area of visual neglect to encompass the space now reachable with the tool' (Clark, 2011: 38). He quotes from Berti and Frassinetti:

"the brain makes a distinction between "far space" (the space beyond reaching distance) and "near space" (the space within reaching distance) ... simply holding a stick causes a remapping of far space to near space. In effect the brain, at least for some purposes, treats the stick as though it were part of the body" (2000: 415).

As Clark explains, this human ability to render our technological aids 'transparent' in this way has profound consequences for how we understand not simply our physical and mental abilities but, more fundamentally, how we understand what it is to be human. In broad terms, it means that we need to 'foreground embodiment, active sensing, and temporally coupled unfoldings' in our perspective on human action and cognition (2011: 23). But more specifically, it involves a view according to which tools are not so much 'used' by people but 'incorporated' (Clark, 2011: 37) into novel dynamic systems of embodied activity and interaction to form part of the users themselves.

In our studies of object discrimination using the device-on-a-stick we were interested in witnessing and analysing the emergence of such a human-technology symbiosis or 'synergism that can develop between artifacts and human agents' (Neuman & Bekerman, 2000). More specifically, then, this involved providing a suitable task context in which the mobile device would be transformed in use into 'transparent technology'.

6. THE HAPTIC DISCRIMINATION STUDY

6.1 Overview of experimental task

Five subjects took part in our experimental study of haptic discrimination. Each subject underwent two sets of trials, during which their behaviour was monitored and recorded.[1] The subjects were given the task of pushing the mobile device by means of the fixed rein while blindfolded and wearing headphones. On each push the subjects were asked to report on whether they could feel anything in front of the mobile device and, if so, how heavy it was (see below for exact instructions).

The task as outlined requires the subjects to develop communicational proficiencies which involve a number of different types of semiological integration (Harris, 2009: 72), including:

1. 'environmental integration' – 'The integration of an individual's activities with objects and events in the physical world' (Harris, 2009: 72).
2. 'transmodal integration' – 'The integration of verbal with non-verbal communication', visual with oral communication, etc.' (Harris, 2009: 72). Here, the subjects had to integrate verbal descriptions of weight ('light', 'medium', 'heavy') with haptic feedback from the device. In fact, using such terms represents a complex integrational challenge. It is neither simply to do with 'linguistic' knowledge – in this case, knowledge of 'English' vocabulary - nor with the 'psychological' ability to make perceptual discriminations. As Harris argues:

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[1] One subject preferred not to be videoed, leaving 4 subjects whose performance was captured on film.

‘Even the use of ordinary grading words, like *heavy*, *good*, *unusual*, typically involves a simultaneous assessment of facts and terminological appropriateness, correlated in such a way that when doubts arise it often makes little sense to ask whether they are factual doubts or linguistic doubts. They may in one sense be a mixture of both, but not necessarily a mixture that could even in principle be sorted out into two separate components’ (Harris, 1981: 180-1).

Clearly, then, the same object may be ‘light’ for the purposes of one task but ‘heavy’ for the purposes of another. In practice, then, subjects had to create from their own experiences what appeared to them to be an appropriate integration of their own feelings with the words given. Thus, subjects would have to introduce some semantic order into their understanding and use of these terms as an inseparable dimension of developing the haptic discrimination skills themselves. In effect, then, the *words used to describe weight*, no less than the mobile device for ‘feeling’ weight, would need to be transformed into ‘transparent technology’ in order for successful task performance.

6.2 Description of Experiment

Experimental apparatus

Fig 2 shows a schematic view of the mobile device and its functional components. The mechanical device consists of a fixed handle (henceforth ‘rein’) attached to a wooden trolley (A). The wooden trolley rolls on four wheels, two at the sides (radius 7cm), one at the back (3cm) and one (3 cm) in the front (B). The trolley is designed to have two degrees of freedom, moving only forward and backward. The trolley is surmounted by a smooth, rigid skirt (C) which envelops the body and wheels of the trolley (A). The skirt is designed to yield to force exerted from objects with which it comes into contact in order to absorb force of impact and thereby protect the user.[2]

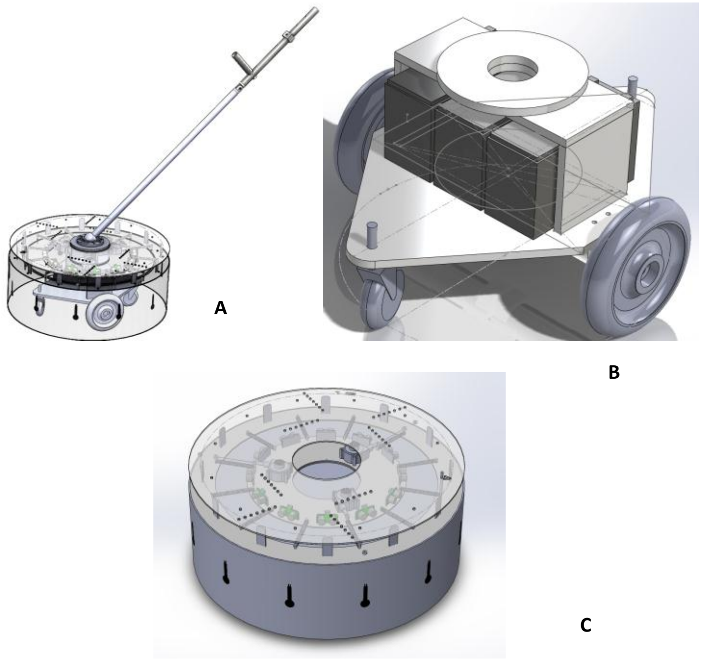

Fig.2. Mobile device consisting of a wooden trolley, a rigid handle and a skirt

Target objects

In our simplified setting for haptic discrimination, a hollow wooden box, measuring 30.48x30.48x29.21 centimeters and weighing 3.2 kilograms empty was used as the basic target object. The weight of the box

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[2] The skirt is also fitted with force sensors, signals from which are received and recorded by computer. This data will be used during the second stage of the REINS project in which a wireless communication device – a wireless ‘rein’ – will be substituted for the ‘fixed rein’ used during the present experiments.

was altered during the experiment by adding pre-arranged weights, giving the following set of weight values for the target objects:

- 3.2 kg (the empty wooden box)
- 5.2 kg (the box plus 2 kg weight)
- 10.2 kg (the box plus 7kg weight)

6.3 Testing Protocol

Each subject was asked to undergo two trial sessions with twelve trials in each session with a short break between sessions. The whole trial period lasted for approximately 20 minutes. At the start of the first session, subjects were instructed on how to perform the task. Subjects were allowed to see the mobile device (but not the box or weights) and to push it several times before blindfold and headphones were put on. Subsequent communication with subjects was conducted via pre-arranged haptic signals.

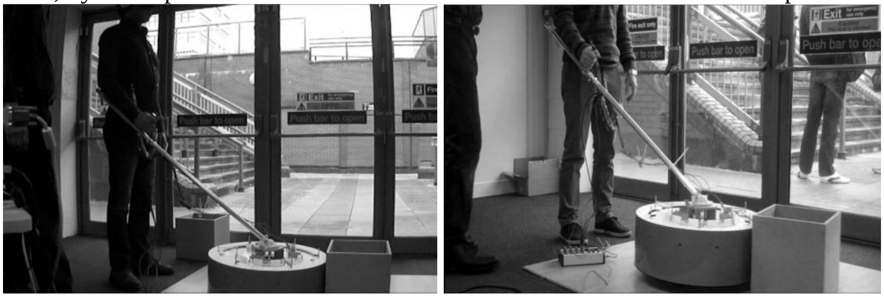
Subjects were asked to grasp the fixed rein and to gently push the mobile device away from them a short distance without stepping forward (Figure 3). On each of the twelve trials in each session, subjects would encounter one of the following four randomly assigned target states:

a. No object in front.
b. Wooden box (3.2 kg)
c. Wooden box plus 2 kg (5.2kg)
d. Wooden box plus 7 kg (10.2 kg)

For states (b-d), the wooden box was placed in direct contact with the skirt before the trial began (as in Figure 3) in order to eliminate (or at least reduce the chance of) perceptible collision cues. Subjects were asked to report what they could feel on each trial using, as far as possible, the verbal expressions below:

A. *Nothing*: meaning no object could be felt in front of the device.
B. *Light*: meaning there was a light object in front of the device.
C. *Medium*: meaning there was a medium weight object, quite easily movable, in front of the device.
D. *Heavy*: meaning there was a quite heavy object, possibly not movable, in front of the device.
E. *Not sure*: meaning the subject was not sure if there was any object in front of the device or not.
F. *Not sure which*: meaning the subject could feel an object but was not sure of the weight.

Before the commencement of every trial, the fixed rein was gently placed in the subject's hand – this was the pre-arranged haptic signal for the subject to push and report. After each report, the rein was taken back, by the experimenter for a few seconds while the next trial was set up.



A **B**

Fig. 3 Subject pushes the device with target object in front.

For each trial we recorded the following:

- response time in seconds (from push to report)
- verbal report

Each verbal report ('Nothing', 'light', etc) was noted against the relevant target object state (No object, wooden box, etc) so that we could examine the accuracy of the verbal report.

6.4 Experimental Results

6.4.1 Response times

Figures 4-6 show the average response times of every subject for the first and the second trial sessions. The mean response time for the second set is less than the first set in each case, indicating that the subjects have already learnt from the first trials and responded with more confidence in the second session of the trials.

	Trial Set 1	Trial Set 2	Overall
Subject 1	5.93	5.00	5.465
Subject 2	7.72	6.02	6.87
Subject 3	6.13	3.83	4.63
Subject 4	3.93	2.9	3.415
Subject 5	4.34	2.21	3.275

Figure 4 Mean Response Times

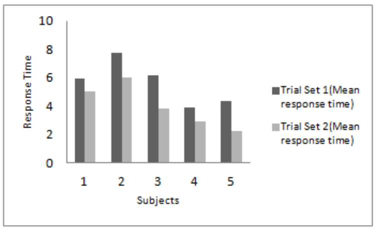


Figure 5 Bar-Graph showing the Mean Response Times for two sessions

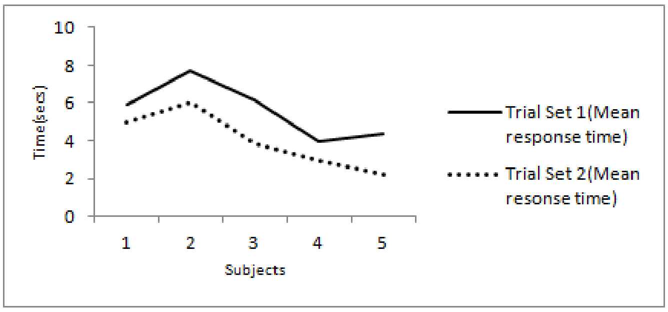


Figure 6 Line-Graphs showing the Mean Response Times of the subjects for two sessions
Normal line represents the first session and dotted line represents the second session.

6.4.2 Accuracy of verbal report

We took a verbal report to be accurate if there was a match between target state and verbal expression as follows:

Target state	Verbal expression
a	A
b	B
c	C
d	D

We counted verbal responses E and F as inaccurate for the purposes of calculating the accuracy rate.

The accuracy rate for each subject was calculated on the basis of the number of accurate reports per trial set. Figure 7 shows that the accuracy rate improved from the first trial set to the second trial set for each subject.

Figure 8 shows accuracy rate by each target state (a)–(d) for each trial session. Accuracy increases over the two trial sessions for all target states. However, accuracy rates for states (a) (No object) and (d) (Heavy object) are very high indeed, with rates for states (b) (Light object) and (c) (Medium object) being lower but improving in the second trial. Figure 9 shows mean accuracy rate for each target state over all trials, indicating that the general accuracy for each target state is over 60%.

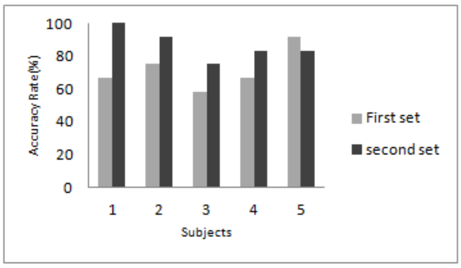


Fig. 7: Percentage accuracy for all subjects

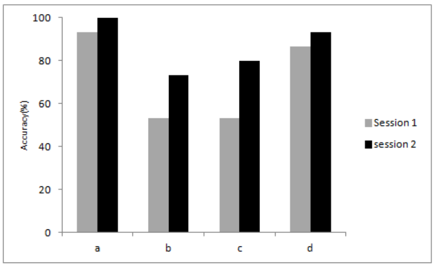


Fig 8: Mean accuracy by target state (a)-(d)

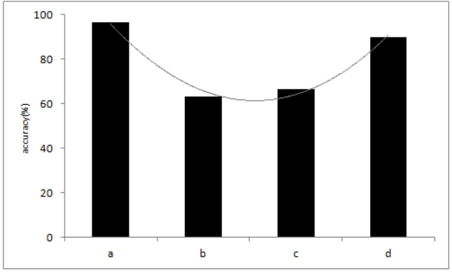


Fig. 9: Mean overall percentage accuracy for each target state.

6.5 Discussion

Prior to the experimental trials, we had no idea of the level of difficulty that our task would pose for our volunteer subjects. However, as the results clearly show, the subjects found the task to be manageable and made rapid strides in task competence over the two trial sessions. Subjects were able, by and large, to make use of haptic feedback from the mobile device and to coherently and successfully integrate verbal descriptions with haptic perceptions of different object weights as represented in the four target states. The results overall, then, appear to demonstrate quite unequivocally that haptic proficiency develops very rapidly, even under very unfamiliar and difficult task condition and, consequently, that skills of haptic discrimination are easily trainable. In other words, our subjects were learning fast in a very unfamiliar environment. They are, as one would ordinarily say, 'familiarizing themselves' with the task and task environment. But what are the ingredients of the learning process that we call 'familiarization' in this case?

In integrationist terms, familiarization of this kind is a communicational (or semiological) process since it has to do with the development of sign-making capacities in the human subject. To familiarize yourself with an environment or set of circumstances means getting better at 'reading' the environment for meaningful cues relevant to your 'current programme of action' (Harris). It means being able to discard or ignore those environmental properties which are currently irrelevant or insignificant. In the case of our subjects, the increases in speed, confidence and accuracy of their verbal reports is only explained, we would argue, by an increasing capacity to 'read' the environment for relevant cues in this way via the fixed rein. We are witnessing here a growing 'integrational proficiency': a capacity for creating contextually meaningful verbal signs through the simultaneous integration of haptic perception via fixed rein ('environmental integration') with verbal labels for weight discrimination ('transmodal integration'), all the while in a communicative relationship with the experimenters ('interpersonal integration').

But the process as described is just the process of development of 'transparent technology' in the sense of Clark (2003, 2011). Improved accuracy in discrimination of target weights, in the absence of any other factor being changed, can only mean that the properties of the mobile device itself are become invisible – literally *intangible* – against those of the target object. The fixed rein becomes haptic *background* as the object environment becomes haptic foreground. In other words, our results show the fixed rein being transformed by active subjects, over a few minutes, into 'transparent technology'.

But as they 'feel' the different target states, where, one may ask, do our subjects end and where does the mobile-device-on-a-stick begin? Since our subjects have no direct physical or perceptual contact with the target objects, then it is only the system *human agent - rein - mobile device - target object* which includes all the 'pathways' (Bateson) necessary to the action of the system, i.e. feeling and discriminating accurately between object weights. In making themselves aware of their environment via the fixed rein, then, the 'partnership' of human subject and technology in this case is an emerging symbiotic system of acting, feeling, and thinking. Tool and tool user are becoming 'human-technology symbionts'. At the same time, the subjects are creating novel semantic values for the weight words via their integration in context with haptic feedback from the rein. The 'verbal technology', as much as the mechanical, must also, then, become 'transparent' to the task.

7. CONCLUSION

In this paper we have reported on a small scale experimental study in haptic discrimination using a mobile device with a fixed rein interface. We have demonstrated the sensitivity and trainability of the haptic sense. We have also argued that the development of haptic proficiency involves a process of development of 'transparent technology', a process in which a human-technology symbiosis emerges. We have also argued that the development of transparent technology is understandable, in semiological terms, as a growth in integrational proficiency on the part of the human agent.

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