Interpersonal Recognition Through Mediated Tactile Interaction

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ABSTRACT

For several years, we have been developing a system of perceptual supplementation (Tactos) so as to render spatialized digital information accessible to users with visual deficiencies. After having validated this device in experimental situations and in practical use, we now propose to connect several Tactos systems in a network, so as to allow for access to shared digital spaces via technical mediation calls upon a tactile modality (Intertact). This opening up of previously individual use to collective use makes it possible to conceive digital spaces designed for tactile interaction, by proposing practical, pedagogical and gaming functionalities. This new possibility of tactile interaction opens the way to the production of a technical aid for visually impaired persons with a social dimension. At the same time, the design of shared tactile spaces goes together with a fundamental reflection concerning perceptual interactions. We therefore propose an experimental study in order to characterize the processes of mutual engagement in the interactions. These processes seem to constitute a mutual dynamics, which is the basis for an active co-construction of meaning.

KEYWORDS: Perceptual supplementation, Visual impairment, Accessibility, Interaction.

INDEX TERMS: H.5.2 [Information Interfaces and Presentation]: User Interfaces—Evaluation/methodology, Haptic I/O, Theory and methods; K.4.2 [Computers and Society]: Social Issues—Assistive technologies for persons with disabilities

1 TACTOS: AN HAPTIC DEVICE FOR DIGITAL INFORMATION ACCESSIBILITY

Tactos is a perceptual supplementation device which makes it possible to explore and read digital shapes on the screen of a computer, by means of tactile stimulations [1]. It works by controlling the activation of piezoelectric Braille cells as a function of the movements of the cursor in the two-dimensional space of the screen (Fig. 1).

Two peripheral elements, an effector and a tactile stimulator, are connected to a computer. The effector constitutes the means of action in the two-dimensional space of the screen. In this example, the effector is a stylus on a graphic tablet; but other effectors can be used, on condition that the space of action holds a bijective relation with the space of the screen (the command can relate to absolute position or to movements).

The effector makes it possible to move at least an elementary receptor field. When the latter crosses at least one black pixel on the screen, a tactile stimulator is activated, in this case a single pin of a piezoelectric Braille cell (this is the minimal version of the device). In this case, the user only receives a succession of very poor stimuli: the sensory feedback provides only one bit of all-or-none information at each moment, and this information has no intrinsic spatiality. Even under these minimal conditions, the user succeeds in recognizing and discriminating two-dimensional shapes [1]. Thus, the capacity to recognize shapes does not require a global access to the shape being explored, as if it were sufficient to “capture” an image passively in order to perceive. The counterpart to this is that the user must actually deploy an external exploratory activity, in space and in time, in order to establish a minimal sensory-motor coupling [2]. It is thus through active exploration that the subject can recognize a shape. In other words, there is no perception without action, just as the users of the classical Tactile-Vision Substitution Systems (the TVSS) only feel local stimuli on the skin but do not perceive shapes unless they are able to move themselves the camera [3].

An advantage of the Tactos system described here, connected to a computer, is that it is possible at virtually no extra cost to record the perceptual trajectories produced by the subjects, and so it is easy to observe in fine detail the way in which the subjects explore the two-dimensional shapes. It appears that the constitution of percepts via technical mediation calls upon a characteristic sensori-motor repertoire [1]. Thus, the analysis of the exploratory strategies reveals emergent dynamics between the actions performed and the sensory returns which result, which makes it possible to study in fine detail the micro-genesis of the perceptual act.

Following these observations, we have undertaken a progressive enrichment of the action possibilities and/or the richness of the tactile stimulations. Indeed, previous studies have shown that an increase in the number of receptor fields employed conjointly made it possible to improve the perception of the

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The use of this parallelism in the context of mediated perception devices can thus improve the richness and the quality of perception in a digital space [5]. In order to verify this hypothesis, a study was carried out concerning the effects of variation in the properties of the coupling device [6]. In this study, the size and the number of the receptor fields were varied, as well as the number of associated stimulators. The best performances were obtained when the user moved a square matrix of 16 elementary fields (4×4 receptor fields of 2×2 pixels each), each of these fields being linked to the corresponding pin of a matrix of 16 tactile stimulators (4×4 points, realized by juxtaposing two piezoelectric Braille cells) [6]. In this way, the parallelism between the receptor fields and the stimulators made it possible to render accessible a “movement already done”, present right from the level of the sensory input (Fig. 2). Thus, it produces an economy of movement and memory which makes it possible to increase the perceptual speed, notably improving the quality of the exploration and recognition of forms present on the screen [5].

Thus, the various experimental situations and the observations in context have shown that the user of Tactos is able to discriminate and to recognize shapes encountered in the digital space [7-8]. Moreover, the device gives an access to the spatial configuration of information present on the screen, which makes it possible to localize digital objects (icons, buttons, frames, etc.) – and thus to navigate in the graphic interfaces – as well as to read spatialized objects such as tables, graphs or pictures. In this way, coupled to “screen-readers”, the Tactos device makes it possible to overcome their limits of linearity [9], and opens the possibility of an effective access to digital environments.

2 INTERACT: MAKING DISTAL TACTILE INTERACTIONS POSSIBLE

After validating the Tactos device in a context of longitudinal following of visually impaired users [10], we turn now to study the conditions for tactile interactions in shared digital spaces. Indeed, when several Tactos systems are connected in a network, the users can interact via the tactile modality: this corresponds to the Intertact setup (Fig. 3).

Each user, by means of his effector, controls both: i) the movements of a matrix of receptor fields, i.e. a perceiving body that is coupled to the same number of tactile stimulators; and ii) the movements of an avatar, i.e. a body-image that the other user can perceive with his own receptor fields. In this way, when one user “touches” the other, he is also “touched” by him, which is what we call a perceptual crossing or mutual touching at a distance [11].

Each user explores his tablet and enters into contact, either with objects which exist in the shared environment, or with the body-image of the other user. We thus allow the constitution, by each partner, of a common space where their perceptual actions can be co-ordinated and where digital objects can be explored in a mutual fashion. Thanks to this device, we make it possible to pass from a system of strictly local use (GUI navigation and individual exploration of digital objects) to a system where the use opens onto the sharing of tactile digital spaces dedicated to practical, educational and playful applications [8], [12]. Thus, in addition to a more complete access to “World Wide Web” offered by the Tactos device, Intertact aims at being a platform dedicated to the hosting of a set of contents with practical aims (geographical maps, town plans, transport plans, etc.), and allowing for sharing and mutual help between users at a distance. In this way, the mutual exploration of contents is made possible, such as collaboration or tutoring, via an original mode of communication and the sharing of a common digital world.

In order to allow for the relevant elaboration of shared tactile spaces, the question of the interaction process appears to be central. Thus, it is a question of properly understanding how two subjects in interaction manage to recognize each other, and to distinguish their mutual presence from the static or dynamic content of the environment they are exploring. In this perspective, one of the main axes of the present project concerns the fact of “presence” (active interaction with the other), which seems to us a crucial point for the elaboration of a technical and social device aiming to help persons who have a visual impairment.

3 AN ORIGINAL PARADIGM FOR THE STUDY OF INTERACTION

The conception of this kind of device, besides the technical and practical aspects, has lead us on one hand to rethink the shared digital spaces proposed to users, and on the other hand to reconsider certain fundamental questions. Thus, the shared digital spaces open the way to original experimental studies concerning the processes of interaction. In the same way that Tactos made it possible to study the micro-genesis of the perceptual act, Intertact seems to us to offer a paradigm for the study of the micro-genesis of interactions between users. We have already shown that the perceptual crossing via Intertact gave rise to the feeling of being in the presence of another subject: the subject recognizes the other person by means of the conjoint dynamics of the two perceptual

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1 This is the ITOIP project (Tactile Interactions for Orientation, Information and Presence, carried out at the Technological University of Compiègne and financed by the Picardie region from 2011 to 2014.)
activities [13]. We propose an experimental situation to try to characterize these processes of mutual engagement in perceptual interactions.

4 EXPERIMENTAL PROTOCOL

We have taken inspiration from the famous “imitation game” of Turing [14]. 54 subjects, divided into three independent groups of 18 subjects, were invited to interact via the Intertact setup. We constituted shared one-dimensional spaces of 200 pixels long: each subject moves from right to left by means of a mouse (up and down movements are not taken into account), and receives an all-or-none tactile stimulation if his cursor encounters another cursor. The cursors in question are 2 pixels long, with a strict geometrical torus, and is thus theoretically infinite without any edges: from the point of view of an external observer, passing the boundary at one end results in a simultaneous reappearance at the other end. Each subject passes 16 trials of one minute each. In each trial, the subject is connected either with another subject, who, like himself, is participating in the experiment in real time; or else with a robot which is supposed to imitate a human behavior. The groups are constituted as a function of the complexity of the robots. The robots in group 1 have regular speed and amplitude of movement, with zero probability of stopping (simple robots); the robots in group 2 have variable speed and amplitude of movement, with zero probability of stopping (intermediate robots); the robots in group 3 have variable speed and amplitude of movement, with a certain probability of stopping randomly (complex robots).

For each group of subjects, two types of robots are constituted: robots with a closed programme (a certain pattern of movement in space is deployed independently of the movements of the human subject); and robots with an interactive programme (the pattern of movement is triggered by the encounter with the human subject). Thus, each subject encounters two other human subjects and two robots with a given level of complexity (a closed programme and an interactive programme), each being encountered four times in a pseudo-random order. At the end of each trial, the subjects indicate whether they consider they interacted with a human subject or with a robot.

4.1 Results

Overall, we observe that the group of subjects interacting with complex robots obtain a frequency of correct responses which is lower than that for the other two groups of subjects (respectively 47.56 %, 61.45 % and 62.84 %). This difference is statistically significant (F(2, 51) = 9.1297; p = 0.0004).

If we consider just the robots, we observe that paradoxically the subjects obtain a higher frequency of correct responses in the trials where the robots are interactive programmes (56.94%) than in trials where the robots are closed programmes (44.44%). However, this tendency is only expressed for the subjects interacting with simple robots (43.05% of correct responses for closed programmes versus 77.77% of correct responses for the interactive programmes); subjects confronted with intermediate and complex robots do not exhibit significant differences between the two types of robot. The interaction effect between the factor “Complexity” and the factor “Type of robot” is statistically significant (F(2, 51) = 4.2703 ; p = 0.0193).

Whatever the type of robot, we observe that the frequency of correct responses is higher in the trials where the subjects encounter other human subjects (63.88%) than in trials where the subjects encounter robots (50.69%). This difference is statistically significant (U(2, 51) = 4.0868 ; p = 0.0002), and it increases as the complexity of the robots increases (Fig. 4).

In addition, if the difference between Robots and Humans is not significant for groups 1 and 2, it is significant for the group 3 (t(17) = 4.6050; p = 0.0003) and can even be considered as noteworthy according to a Bayesian analysis2 (Pr[δ/σ] > .66 = .91).

Finally, even in the total absence of feedback concerning the quality of their replies right through the experiment, the subjects definitely improve their performances between the first eight and the last eight trials (48.37 % vs 66.20%). This global learning effect is statistically significant (t(51) = 5.1107 ; p < 0.0001), and it occurs in all groups of subjects. However, this effect cannot be considered as noteworthy (Pr[δ/σ] > .66 = .57).

If we look at this result in more detail, we observe that the learning seems more stable for trials where the subjects encounter other human subjects than for trials where they encounter robots: the increase in the frequency of correct responses for human/human trials does not seem to be influenced by the complexity of the robots (Fig. 5).

2 Bayesian procedures make it possible to estimate a posteriori the size of the effect or the true difference (δ) with a guarantee of .90. We have retained as criterion that Pr[δ/σ] < .33 = .90 can be considered as negligible. Furthermore, we consider that Pr[δ/σ] > .66 = .90 can be taken as noteworthy, i.e. that one can consider with a guarantee of .90 that the true calibrated effect (δ/σ) is greater than a value of 0.66.
Overall, the learning effect is significant for the trials where the subjects interact with robots ($t_{(15)} = 3.0531 ; p = 0.0036$) and for the trials where the subjects interact with other humans ($t_{(15)} = 4.1693 ; p = 0.0001$). However, neither of these effects can be considered noteworthy (respectively $Pr |\bar{\delta}/\sigma| > .66 = .04$ and $Pr |\bar{\delta}/\sigma| > .66 = .25$). However, a more specific analysis shows that the learning effect for trials where the subjects interact with robots is only significant for the group 1, who interacts with the simple robots ($t_{(17)} = 4.3236 ; p = 0.0005$). However, this effect cannot be considered noteworthy ($Pr |\bar{\delta}/\sigma| > .66 = .88$). Concerning the trials where the subjects interact with other humans, the learning effect is significant for the group 1 ($t_{(17)} = 3.1224 ; p = 0.0062$) and for the group 2 ($t_{(17)} = 2.5325 ; p = 0.0215$), even if neither of these effects can be considered noteworthy (respectively $Pr |\bar{\delta}/\sigma| > .66 = .59$ and $Pr |\bar{\delta}/\sigma| > .66 = .38$). Furthermore, even if the learning effect is not significant for the group 3, it cannot be considered negligible ($Pr |\bar{\delta}/\sigma| < .33 = .35$).

In order to help understand these results, a final analysis concerns more specifically the trials where the subjects interact with other human subjects. We are interested here in the frequency of mutual recognition (both subjects identify each other mutually as humans), compared to the frequency of unilateral recognition (only one of the subjects identifies the other as human), and compared also to the frequency of non-recognition (neither of the subjects identifies the other as human) (Fig 6).

Globally, we observe that the frequency of mutual recognition is higher than the frequency of unilateral recognition (respectively $45.83\%$ and $35.65\%$). Furthermore, this latter is higher than the frequency of non-recognition ($18.52\%$). This tendency is observed within all the groups, except for the group 2, where the frequency of mutual recognition and the frequency of unilateral recognition are quite equivalent (respectively $44.44\%$ and $45.83\%$) (Fig 6). From a statistical point of view, the effect of the complexity of the robots is significant for any of the terms of recognition, either for mutual recognition ($F_{(2,15)} = 0.4503 ; p = 0.6458$), for unilateral recognition ($F_{(2,15)} = 1.9526 ; p = 0.1763$), or for non-recognition ($F_{(2,15)} = 1.6855 ; p = 0.2186$).

Next, we compare the terms of recognition, so whether the terms are significantly more frequent than others. It appears that mutual recognition is not statistically different from the unilateral recognition ($t_{(15)} = 1.3370 ; p = 0.2011$), although this difference cannot be considered negligible ($Pr |\bar{\delta}/\sigma| < .33 = .52$). However, mutual recognition is significantly more frequent than the non-recognition ($t_{(15)} = 4.1167 ; p = 0.0009$), but this effect cannot be considered noteworthy ($Pr |\bar{\delta}/\sigma| > .66 = .84$). Similarly, the unilateral recognition is statistically more frequent than the non-recognition ($t_{(15)} = 2.8131 ; p = 0.0131$), but this effect cannot be considered noteworthy ($Pr |\bar{\delta}/\sigma| > .66 = .48$).

But the most interesting result seems to lie in the differences between the two blocks of trials (trials 1 to 8 on one hand and trials 9 to 16 on the other hand) for each term of recognition (Fig 7 and 8).

We observe that the frequency of mutual recognition is higher in the last 8 trials ($58.39\%$) than in the first 8 trials ($29.81\%$). This difference is statistically significant ($t_{(15)} = 4.7730 ; p = 0.0002$), and can be considered noteworthy ($Pr |\bar{\delta}/\sigma| > .66 = .92$). On the other hand, the frequency of unilateral recognition is lower in the last 8 trials ($26.67\%$) than in the first 8 trials ($46.30\%$). This difference is statistically significant ($t_{(15)} = 2.7020 ; p = 0.0164$), but cannot be considered noteworthy ($Pr |\bar{\delta}/\sigma| > .66 = .44$). Finally, the frequency of non-recognition is lower in the last 8 trials ($14.02\%$) than in the first 8 trials ($23.89\%$). This difference is not statistically significant ($t_{(15)} = 1.7438 ; p = 0.0101$), but cannot be considered negligible ($Pr |\bar{\delta}/\sigma| < .33 = .39$). Moreover, these tendencies are observed whatever the group. In order to clarify the relationship between the terms of recognition (excluding non-recognition) and the learning, we find a significant interaction effect ($t_{(15)} = 4.0371 ; p = 0.0011$), even if this latter cannot be considered noteworthy ($Pr |\bar{\delta}/\sigma| > .66 = .82$).

Finally, it is important to note that the observed results about mutual recognition cannot be explained simply by a propensity of
the subjects to reply “human” whatever the type of interacting agent. Thus, for all trials together, the frequency of mutual recognition is 45,83%, whereas the probability that the two subjects that the two subjects reply mutually “human” is 25,34%. As regards the last trials, the frequency of mutual recognition is 58,38%, whereas the probability that the two subjects reply mutually “human” is 28,59%.

4.2 Discussion

The overall results tend to show that the implementation of human-like behaviors in the movements of the robot is sufficient to mislead the subject. Thus, the greater the complexity of the robot, the more the frequency of correct responses decreases. If we seek to explain the effect of the complexity of the robots, we realize that this effect cannot be imputed just to the fact of interacting: indeed, the interactive programmes are actually better identified as robots than the closed programmes. It seems therefore that the quality of the interaction is of over-riding importance. Because of this, the complex behaviors instantiated in the robots (variability of behaviors and the probability of stopping) can be considered as reflecting only a part of the human characteristics. Indeed, the humans are more often identified as humans than robots as robots, whatever the complexity of the latter. Consequently, we form the hypothesis that the interaction between subjects is qualitatively different, and leads to a better identification.

In addition, the results show that the subjects improve their performance over the two blocks of trials: they seem to learn to recognize humans and robots over the course of the trials. But in accordance with the previous results this learning seems to be more stable for the Human/Human trials. Because of this, the interactions between human subjects seem to present a constancy which is better and better identified, even if the more complex robots can on occasion induce errors. This is to be put in relation with the fact that during the last Human/Human trials, the subjects recognize each other better in mutual fashion than unilaterally and this over and above the propensity of the subjects to reply “human” whatever the interacting agent. Indeed, the most fruitful result is the fact that we can conclude to a differentiated evolution of the terms of recognition during the task. Thus, learning is reflected in an increase of mutual recognition and in a decrease in unilateral recognition between both blocks trials. In other words, subjects jointly identified themselves more and more frequently. The mutual dynamics of interaction progressively stabilizes and is recognized as such by the subjects in interaction. The strong hypothesis of this work is that this mutual dynamics provides a support for the constitution of a common world of meanings.

In conformity with the previous studies, this result suggests that it is the mutual dynamics of the interaction which is recognized, more than the individual intentionality of the subjects in interaction [13]. It therefore seems crucial to place the interactions themselves at the center of the study of intersubjectivity, so as to involve the very act of interacting in the understanding of social understanding [15]. This enactive approach [16-17] to interaction suggests that perceptual crossing between two subjects, even reduced to its simplest expression, consists in the meeting of two perceptual activities which construct meaning, including the interpersonal recognition. This joint perceptual activity seems to lead to the emergence of a singular dynamic, which becomes the basis for a mutual construction of meaning.

5 Conclusion and perspectives

The research presented here has two complementary facets: a fundamental theoretical facet and an applied facet. Thus, what is at stake is to link the question of the accessibility of digital information to the question of the sharing of this experience by users at a distance. A reflection on the design of shared tactile spaces is thus decisive for the elaboration of a technical and social device relevant for the world of visual impairment. However, this research reaches beyond the framework of handicap alone, by posing the question of the interaction and the processes involved, that we have tried to characterize. The main result indicates that the mutual dynamic of interaction is more important than individual recognition. This seems to be a relevant track when we speak about assistive devices, especially those designed for interaction. The co-construction of meaning is therefore an opportunity for people with visual disabilities, by tracing a path to the collective appropriation of assistive devices, which had been previously so little used when designed in a strict individual fashion [18]. The possibility to interact is the possibility to produce shared meaning, and thus, the possibility to constitute a usage community.

In order to substantiate these results, further analyses are being carried out. In particular, we analyze in detail the actual perceptual trajectories produced by each subject. This operation makes it possible to achieve a more qualitative analysis of the data, centered on the strategies deployed by the subjects, in order to better understand their constitution. The objective is to identify patterns of interaction, in order to try to isolate the objective signatures of the intersubjective recognition of the subjects.

Finally, other studies are planned in order to understand how the dynamics of interaction could lead to the constitution of a shared world of meaning. For instance, we designed an experiment where the subjects have to identify a common object, which can be perceived by both users in interaction, from private ones, which can be perceived only respectively by one or the other. In this way, we try to show that in virtue of the emergence of a specific dynamics of interaction, users can take a deictic stance, perceiving both the other and the common object, and establishing a reciprocal perceptual crossing which determines what is shared in a world of meaning.

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