Perceptive Supplementation for an Access to Graphical Interfaces

Mounia Ziat, Charles Lenay, Olivier Gapenne, John Stewart, Amal Ali Ammar, and Dominique Aubert

Costech, University of Technology of Compiegne,
60203 Compiegne France
{mounia.ziat,charles.lenay,olivier.gapenne,john.stewart,
amal.aliammar,dominique.aubert}@utc.fr

Abstract. Studies using the sensory substitution devices reveal that perceptive activity itself is embodied in a living body capable of movement and possessing its own spatial dimensions. To study the conditions of a prosthetic perception, we developed a minimal device, Tactos, which carries out a coupling between the pen of a graphics tablet and tactile sensory stimulators. This system allows subjects to explore virtual tactile pictures and is intended to give to blind people an access to computer graphics. We will present here experimental results regarding the different aspects of perception using this device.

Keywords: Sensory substitution, haptic and tactile perception, Perception/action coupling.

1 Introduction

Sensory substitution systems offer to blind people (and blindfolded subjects) a new kind of perception, a new sensorial modality which can compensate a lost sense and/ or be added to the other modalities in order to perceive the world. One of these devices is TVSS (Tactile Visual Substitution System) [3] which converts an image acquired by a camera into a ''tactile picture''. This tactile image is produced by a matrix of vibrotactile stimulators (400 stimulators) placed on a subject's abdomen, back or forehead. Bach-y-Rita's work with TVSS showed that perception is active, and not simply a passive reception of information. To perceive the information appropriately it is necessary to interact with one's environment, in order to understand the laws which control one's actions and sensations [8] and which enable one to perceive things. With TVSS, the human subjects (sighted and blind) displayed a real recognition of shapes, but only if they were in full control of the camera. If the camera is fixed, the subject feels a prickling sensation on the skin but cannot describe the object depicted. On the other hand, when handling the camera oneself one comes to understand that a particular action corresponds to a particular sensation and vice versa, thus activating a circular process between actions and sensations, giving rise to perception via the device. An absolutely essential observation is that this shape recognition capacity is accompanied by perceptual externalization. Whilst moving, the user is able to recognize objects, forgetting the prickling sensation and perceiving objects in space.

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From this observation the idea was born within our research team of creating an ultra-simplified device (1 sensor and 1 stimulator) to explain and understand how a human subject learns to perceive and recognize objects via sensory substitution devices [7]. Starting from a very basic prototype, we would then improve the interface, either by increasing the number of stimulations (points of sensation) or by enriching the points of action. This prototype named Tactos [5] is a platform which allows the exploration of digital 2D shapes on a computer screen using tactile stimulations of the index finger. It includes three parts: a computer, a graphics tablet with stylus, and tactile stimulators (see Fig. 1). The stimulators are two electronic Braille cells, each including eight tactile pins. They are connected virtually to a sensor able to distinguish figures on the screen from the background. In other words, when the sensor is on the outline of the figure a signal is transmitted to the stimulators and the corresponding pin is raised. The idea is to move the stylus on the graphical tablet so that a figure on the computer screen can be explored and recognized even though the user is blindfolded. The whole allows the recognition in blind mode of writing and/or drawing on the computer screen. Subjects used the stylus to sweep over the tablet while keeping the index finger of the left/right hand (according to the dominant hand) on the 16 tactile pins (two Braille cells of 16.7 mm x 6.4 mm). Each shape or drawing displayed on the screen is haptically perceived according to the movements of the stylus on the tablet. The subject feels the stimulators being activated under the index finger each time the cursor (which corresponds to sensors) comes into contact with the outline of the shape on the screen.

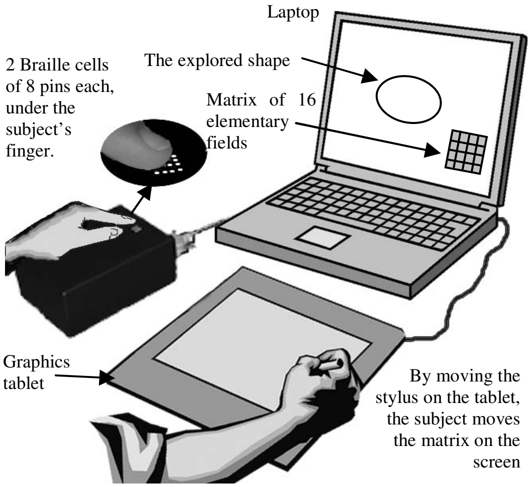

Fig. 1. Tactos

Virtual sensors can have different shapes (circular, square, and rectangular), different sizes (the smallest sensor is a square of one pixel while the largest one can cover the total area of the screen), and can contain a variable number of elementary receptor fields (see Fig. 2).

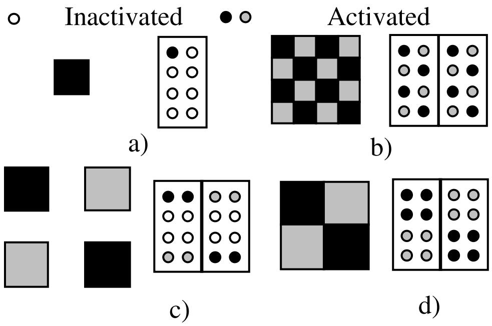

Fig. 2. Examples of pin activation using different matrices: a) mono-field matrix activating one pin, b) 16-field matrix activating 16 pins (black and grey are only used to make the schema clearer), c) 4-field matrix activating 8 pins, d) 4-field matrix activating 16 pins

1.1 Working with Visually Impaired Partners

Tactos initially designed in its minimal shape is the current subject of an ergonomic process of conception and evaluation. Tactos offers a non-visual access to 2D numerical forms and is designed to be used in learning mathematics. The formalization of its efficient appropriation is at stake. The methodology is based on a longitudinal study which was managed in two stages. The first stage was conducted in collaboration with two blind adults. The second one is being achieved with four blind schoolchildren and pursues the work with the two adults. The experiments showed the heuristical advantage of the strategies analysis whose comprehension allows us to propose new specifications.

For the blind, one of the major limits of digital technologies is the accessibility and interaction with graphic objects. Tactos offers haptic access to digitized graphical documents. The objective of this work is twofold [1]: to define the conditions under which the device is appropriated by blind secondary school pupils and to propose specifications for the design of future versions of Tactos. Our analysis focuses particularly on exploratory strategies which allow an efficient perceptive activity. The methodology employed follows a constructivist tradition and implements a minimalist approach: initially, the device is restricted, in order to characterize better the strategies employed, which in their turn are used to improve the design of the device. A longitudinal study carried out with six blind subjects (two adults and four teenagers), allowed us to systematize the analysis of their perceptive capacities. We preferred working in individual sessions in order to be able to characterize the subjects' strategies in their variability and in their potential convergence.

The tasks proposed to the subjects got gradually more complex, from the exploration of simple mathematical forms to the use of Tactos with mathematical software during an individual course of geometry. These studies show that the recognition of geometrical forms was feasible and improved substantially across the different studies. Four types of exploratory gestures were identified (see Fig. 3):

1. the continuous follow-up : the subject tries to maintain a constant contact with the form
2. the micro-sweeping : the subject voluntarily leaves the form while oscillating along the line
3. the macro-sweeping : the subject crosses the line right through
4. the lateral tap : the subject rebounds on the line without crossing it.

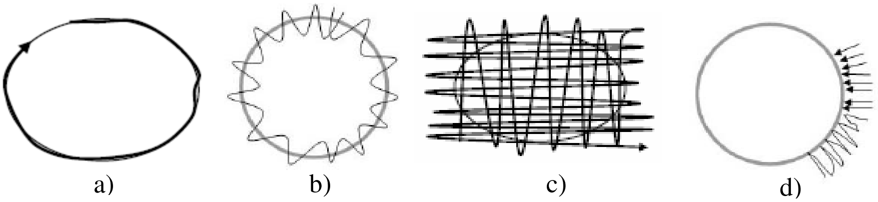

Fig. 3. a) Continuous follow-up, b) micro-sweeping, c) macro-sweeping, d) lateral tap

The personal profile of how these four gestures are used defines an exploratory style [12]. The results highlight the essential character of the exploratory technique: the continuous follow-up proves to be a superior strategy for correct recognition of mathematical forms. The mastering of this latter strategy made it possible for the blind pupils to interact with a complex geometrical digitized figure in a mathematical exercise. Using Tactos, Geoplan[1] and Jaws[2], the pupils were able to create a figure, recognize it, move it and modify its dimensions. These graphical transformations helped them to take note of what remains invariant through all these transformations and deduce the mathematical property of the figure. This encouraging study justifies a continuation of this work to find the optimal specification of the interface. The design issues considered so far associate simultaneously:

1. How to assist and guide the perceptual activity (for instance bi-modality to enhance some elements of the figure) and use the zoom (see sections below).
2. How to teach specific strategies.

2 Experiments and Results

2.1 Shape Recognition

Several results [2, 10, 13] clearly demonstrate that shape recognition is possible with even minimal forms of sensori-motor coupling. A point of interest in this approach is that the perception of shapes takes time, and requires the external deployment of exploratory activity. Precisely for this reason, traces of the patterns of exploration can be easily stored for subsequent analysis. Analysis of these dynamic patterns shows that experienced subjects deploy identifiable strategies, which can and must be

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[1] Geoplan is a software of edition of dynamic and interactive mathematical figures into two and three dimensions, available at: http://www.geoplan.com

[2] A screen reader, http://www.freedomscientific.com/fs_products/software_jaws.asp

learned for rapid and reliable perception to occur successfully. The essential role of action in the progressive emergence of structured percepts strongly suggests that what is perceived, or recognized, does not derive from invariants in the sensory information, but rather from invariants in the sensori-motor cycles which are inseparable from the activity of the subject. This action allows the subject to seek and construct "rules" of constant relations between actions and subsequent sensations. Spatial localization, as well as form recognition, correspond to a temporal synthesis of successive sensations in accordance with a law linking action to sensation.

2.2 Parallelism

The tactile stimulators are two Braille cells and are activated when the cursor crosses the shape. The cursor is a virtual sensor called matrix of elementary fields and can have various shapes and contain various fields and that we called parallelism of elementary fields. In general, application of the parallelism concept enables information to be accessed more precisely and easily when the number of sensors is high. Results show that by applying the parallelism concept to the detection field, people with visual impairment can increase the speed of exploration of geometric forms without decreasing the level of accuracy: thus avoiding a speed-accuracy trade-off [10, 11].

2.3 Bimodality

The perception of mathematical forms by two blind subjects, by means of the Tactos device, is substantially improved when an additional sensory modality (the audition associated to the tactile sense) is introduced to emphasize salient points of the geometrical figure (the summits of the polygons make a sound), or in order to facilitate the differentiation between a curve and the axes of the Cartesian coordinates. This is an interesting innovation in the design of an interface making it possible for non-sighted subjects to read, to draw and generally to appropriate mathematical concepts in an operational fashion [1].

Indeed, in mathematics a coding is used to indicate a conceptual difference between the elements of a figure. This traditional coding improves both perceptive discrimination and conceptual distinction. For instance, the gradations will not have the same size whether they correspond to a whole number or a decimal number and a right angle is symbolized by a small square. Relief figures - that are commonly used by the blind - need to compromise between the simplification of the figure (in order to facilitate tactile recognition) and the presence of distinctive features adapted to tactile perception. With Tactos we propose to the subjects bimodal signs to facilitate the reading (the axes) and the organization of their perceptive activity (the possibility to create a reference point thanks to an audio marking). In addition, in the context of mathematical learning, the use of sound seems to benefit the reading of alpha-numerical characters.

2.4 Haptic Zoom

In general, a zoom corresponds to a change in the resolution of an object. This can be represented as a window of constant size moving on a vertical axis of scales [4]. If the object becomes small relative to the window, this corresponds to moving away; if the object becomes large relative to the window, this corresponds to a movement towards the object. It is the relation between the size of the image and the size of the window which defines the level of zoom ; this can be expressed by the formula z = I/F, where z is the level of zoom, I the size of the object, and F the size of the window (see Fig. 4).

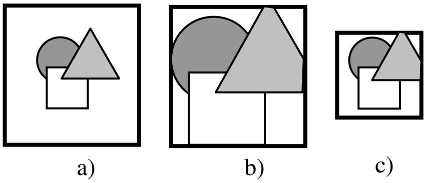

Fig. 4. a) original image b) zoom on the image with a fixed window c) zoom on the window with a fixed image

On the basis of this formula, we can examine the situation when the size of the image remains constant and it is the size of the window which changes. In this case, when the size of the window F increases, the level of zoom decreases; when the size of the window decreases, the level of zoom increases. Technically, this situation is functionally equivalent to the classical situation. Concretely, using the sensory substitution device Tactos, the "window" corresponds to the size of the matrix of receptor fields. The Tactos device makes it possible to explore 2D graphical objects by moving a stylus on a graphic tablet. These displacements of the stylus command the displacement of a matrix (the virtual window) on the computer screen, and which give rise to a tactile stimulus if the receptor field encounters a (virtual) object on the screen. This "window" which moves on the screen can be compared to a virtual screen which moves over fixed numerical objects. By changing the size of this window, we can obtain the resolution and precision required. Thus, the smaller the size of the window/receptor field, the higher the resolution; the larger the size of the window, the lower the resolution and the (virtual) zoom. Technically, this corresponds to a change of scale. To obtain full functional equivalence with the classical form of zoom where it is the size of the object which changes, the movements of the stylus (and hence the movements of the virtual cursor on the computer screen) must be scaled down in strict proportion to the size of the window [14, 15].

2.5 The Eye-Hand System

The eye-hand system [9] proposes a solution to the problem of missing points of reference. This system exploits two types of receptive fields: « The hand » is based on the same principles of haptic compensation and exploration that we used in our other studies previously described. « The eye » is connected to two additional Braille cells (i.e., the system needs four cells altogether). Its receptive field consists of 16 elementary receptive fields and covers the entire monitor. It indicates the absolute position of the cursor by activating one of the 16 pins. Figure 8, illustrates the set up of the eye-hand system.

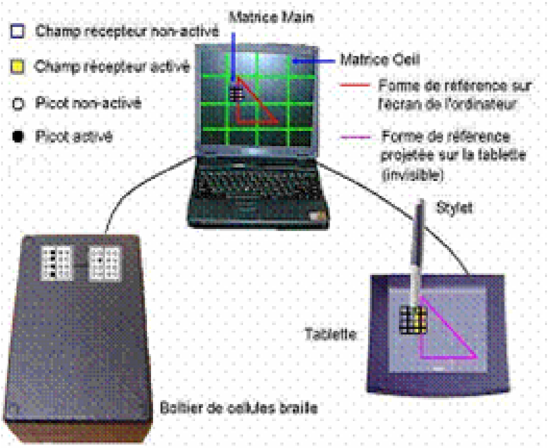

Fig. 5. Eye-hand system

3 Perspectives

In addition to shape recognition and parallelism, others possibilities of the Tactos device were experimented such as the "Tactos network", the "Basic Tactos Task", the Tactos Mobile, etc.

3.1 Tactos Network

If several Tactos devices are networked, a same digital image can be explored by several users situated in different places. A tactile interaction space is therefore created: when, by means of his receptive field, a user meets the receptive field of another user, he receives a signal at the same time as his partner. This can be called a "distal caress" since each person moving his receptive field on the partner's one is touched and touching at the same time. It was demonstrated that the tactile interaction dynamics that arise allow each user to discriminate between the perception of objects and the perception of the other subjects perceiving him simultaneously.

3.2 The Basic Tactos Task

Unlike other tactile and haptic displays, which function in closed virtual world, Tactos allows the exploration of the graphical user interface. The blind users are invited to explore the bi-dimensional space in which the sighted are used to interact. Therefore, Tactos has a twofold advantage over the other haptic devices:

1. It is integrated into a familiar technological context (Braille cells, graphical interfaces and screen readers).
2. It provides access to the graphical objects of the interface.

Further studies will be necessary to establish to which extent the direct manipulation of these objects is useful and efficient for blind users.

3.3 The Tactile Stylus

A first version of the tactile stylus combines the stylus and the Braille box on the same effector (Figure 5). Actually, the fact to dispose of a free hand could allow the subject to receive additional spatial cues. The effector is mounted on a rectangular basis that can be used to trace lines. Comments by the blind subjects and preliminary results [11] led us to conclude that this type of effector is problematic. The stability of this effector helps following lines and gives the subject a good perception of his own movements. However, this effector makes it impossible to rotate the wrist on the horizontal plane and, therefore, restricts the subject in the exploration of curves. We are considering the possibility to integrate the Braille cells directly in a stylus small enough to be used by young blind subjects. Nevertheless, before opting for this effector we need to carry out further experiments with both blind and blindfolded subjects.

Fig. 6. Tactile stylus

3.4 MobiTact: A Mobile Version of Tactos

In order to compensate for the small size of the screen of PDAs, we introduced an additional haptic modality in a mobile haptic prototype, called MobiTact. Our aim is

Fig. 7. TactiPen

to investigate how a user interacts with a mobile haptic interface. MobiTact is a mobile version of Tactos equipped with a “haptic zoom”. It consists of an IPAQ PDA running under Linux and using TactiPen [6], a tactile stylus. As shown in Fig. 6, Tactipen has been built using the body of an electronic marker, big enough to contain a single Braille cell (8 points). The electronic marker was emptied of its contents; the PDA stylus, the Braille cell, a micro-controller interfacing the Braille cell and a serial port, were then inserted.

5 Conclusion

As long as one holds fast to a classical conception of perception in terms of the acquisition of information, one will be stuck with the principle that it is always better to have access to more information. In this framework, persons with sensory handicaps will inevitably be considered as defective. We have proposed an alternative conception, in which "sensory substitution systems" are rather thought of as supplementation devices which bring about new modes of coupling with the environment. They do not make a difference disappear; rather, they create new differences – and they have applications which are not exclusively reserved for handicapped persons (for example, artistic applications, games, augmented reality, the development of portable and intuitive systems for the detection of heat, radioactivity....). In spite of appearances, it is the classical perception which carries the germ of exclusion since it considers that the problem of handicapped persons lies in a quantitative difference. By contrast, true respect for the world of handicapped persons lies with better knowledge and understanding of the qualitative difference of possible perceptual modes.

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