The visual glove

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THE VISUAL GLOVE

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Introduction

The generalised development of operating systems based on graphical interfaces has reduced the possibility for blind people, to access to computers. Many attempts have been done using assistive technology to overcome this problem [1,2]. One of these attempts is the possible use of sensory substitution, following work done by P. Bach y Rita [3,4]. In the sixties, P. Bach y Rita has developed a device using sensory substitution which is called the Tactile Vision Substitution System (TVSS) [5]. This TVSS uses a camera to capture an image. The video signal is then processed to activate a stimulation matrix (20x20 dots), located anywhere on the subject's skin, giving a 'tactile image'. The TVSS has been proved to be efficient, after a training period, for the identification of objects and even of people. But its weigh and price, as well as the limited resolution due to technical problems, has prevented its wide acceptation by visually impaired people. The main idea of our team is to use a minimal haptic stimulation to represent graphic information. The resolution would be due to the scan of the image by the hand carrying the sensors, rather than by an increase in the number of sensors. This device called 'The Visual Glove' is devoted to two main applications: helping the visually impaired people to identify graphic information on a computer screen; being used as a support for cognitive research on perception and training [6].

Material and Methods

This project focuses on two main research directions: a theoretical one, related to the study of perception mechanism, requires the study of the minimum number of sensors and stimulators needed, as well as their organisation, to be able to identify graphical patterns; an applied one, related to the feasibility of recognition of a graphical pattern on a computer screen, by means of a minimal sensors-stimulator coupling.
We have therefore developed two devices. The first one, called the 'tactile pen', is focused on theoretical research on cognition. It consists on a graphical tablet and its pen, interfaced with a computer. When one of the receptive fields of the pen passes on a black pixel of the pattern, the related stimulator is activated, in an all or nothing way. We can chose the size and the organisation of the different receptive fields associated to different stimulators. Figure 1 represents the first tested organisation. It consists on one central field of exploration of 1 pixel, surrounded by 4 peripheral fields (3x3 pixels wide). This organisation mimics a simplified retina with a narrow central field (fovea) and four wider peripheral fields for 'peripheral vision'.

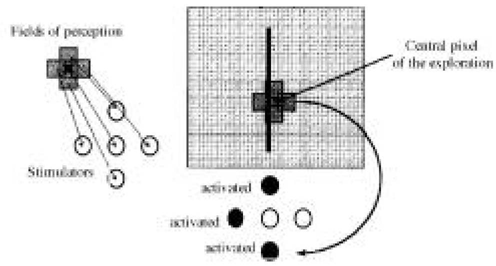

Figure 1*: Organisation of the links between five fields of perception and the five related stimulators. Each field is 3x3 pixels wide.*

The five stimulators are integrated in a 'tactile mouse' especially designed for this study (figure 2).

Figure 2*: The 'Tactile mouse' including an array of five stimulators*

Furthermore, this 'visual pen' allows the recording of the subject's movements during the pattern exploration [7]. These recordings permit us to analyse the different strategies used by the different subjects for the exploration.
The second device is made of a small video camera, as sensor, and uses the tactile mouse as the stimulator array. The organisation between the reception fields and the stimulators is similar to the one used with the visual pen. The adaptation of the device to the computer has required the choice of a flat screen, in order to avoid the problems of light inhomogeneity and of geometric distortion observed at the corner of a CRT screen.

The visual pen has been used for two different tasks: the first one, a discrimination task (recognition between the letter S and its symmetric) has been tested on 3 subjects; the second one is a recognition task: 9 tested subjects have had to identify one letter between the following ten: 'ITLPSVBORD'. The subject were not aware of this selected sequence. The test is stopped for each stimulation (presentation of one of the 10 letters) when the subject gives a response. No information is given back to him during the whole test (presentation of the 10 letters). The time needed to give the response as well as the recording of the exploration strategies are recorded for each stimulation.

The computer device has been tested on 19 subjects asked to identify a block letter displayed on the screen, with no time limit. We thus have measured the rate of success and the duration of the identification.
All subjects were sighted students with an eyemask and ear plugs.

Results

For the visual pen, used for the discrimination task, the rate of success is between 90% and 100% for the 3 subjects. The time needed to obtain the response is important during the first contact with the device, and decreases when the subject gets used to it. For the letter recognition task, the shape of the letter influences a lot the recognition efficiency (figure 3). The presence of curve on the letter decreases the rate of correct recognition. The main limit is related to the angle detection. The letter 'D' has never been correctly identified and has always been confused with the letter 'O'. The analysis of the pen trajectories permitted us to evidence that two main strategies of exploration are used: short scan

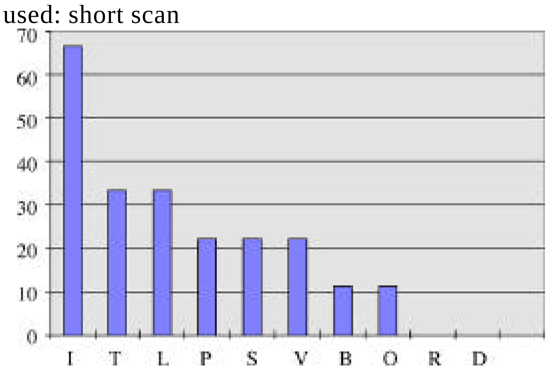

Figure 3: *Percentage of correct recognition for each letter. (A random response would give a rate of success of less than 4%)*

movements, to provide a contour tracking of the pattern edges, or larger scan movements, to identify the global structure of the whole pattern. Some subject used a combination of both strategies (figure 4).

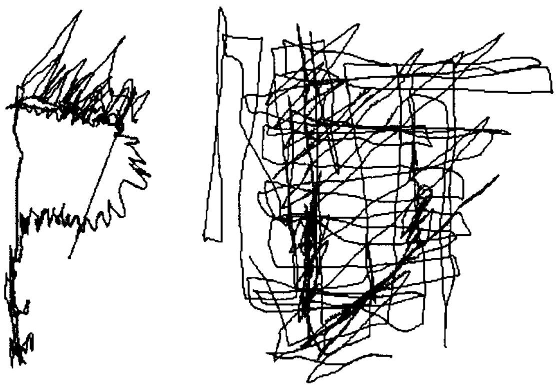

Figure 4: *The 2 strategies used for pattern exploration (a) Exploration of the letter 'P' by mean of short scan movements; (b) Exploration of the letter 'D' using first, large scan movements and then, short scan movements.*

For the computer device, the shape of the letter (figure 5), as well as the strategy of exploration (figure 6), seem to have also a great influence on the performance.

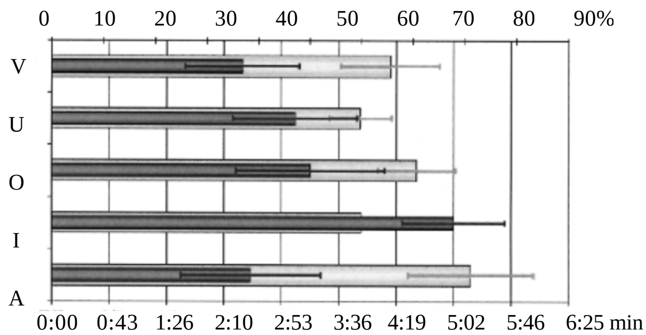

Figure 5: *Influence of the shape of the letter on the recognition performance. Dark grey: percentage of successful recognition; Light grey: mean exploration time (min).*

Discussion and Conclusion

These first experiments have demonstrated that it is possible to recognise simple black and white patterns, presented on a computer screen, by mean of these tactile sensory substitution devices. The original aspect of this work is that this pattern recognition is the result of combination of a partial perception of the pattern, by mean of the tactile information, and of the hand movement. Indeed these devices never allow the global perception of the whole pattern. The recognition is thus the result of a coupling between haptic actions and feeling.
The analysis of the influence of the exploration strategy permitted us to evidence the important role of learning in this substitution process. The combination of short and large scan movements seems to be more efficient for recognition. It allows a global mapping of the whole pattern, associated with a contour tracking, giving thus access to two kinds of information. This complementarity of information permits the subject to reconstruct

actively the shape of the pattern. The training period, essential to the use of such device would focus on this aspects.

The further step will be the analysis of the existing links between the detection fields and the stimulators: optimal number of stimulators, importance of the organisation of the links, and their influence on the performance.

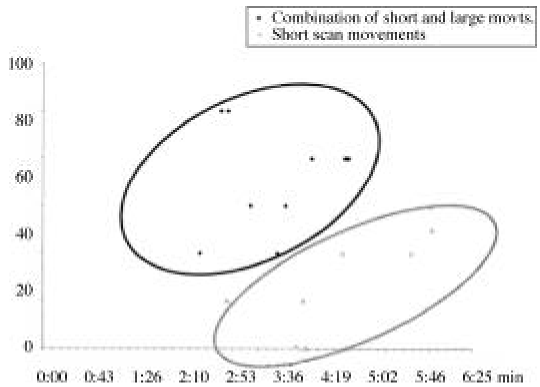

Figure 6: *Separation in term of recognition performance of two populations using different strategies.*

The 'visual glove' has now to be validated with blind people, by mean of a specific protocol which is now under study.

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