Localisation, form recognition and emergence of sensation in sensory substitution

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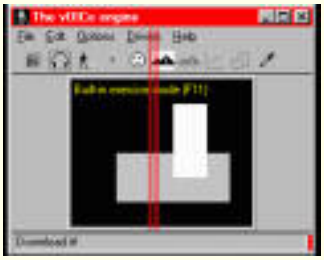
Introduction

Sensory substitution systems allow blind people to "see" via tactile or auditory stimulation. In these experiments, we attempt to determine the different stages involved in the mastery of a sensory substitution device. We have named these five stages: contact, exteriorisation, spatialisation, comprehension of the information, and immersion. We especially test the ability to localize objects and the ability to recognise forms.

Experimental Protocol

We use a visuo-auditory device: "The Voice", developed by Peter Meijer. Images provided by a portable webcam are converted into a greyscale image, scanned from left to right and translated into sounds as a function of the position and brightness of the pixels.

Subjects are in a white room. They are blindfolded and equipped with The Voice. They use a web cam in order to explore their environment and have headphones to hear the scene in front of them.



We gave them several tasks and a questionnaire to complete, in order to understand the development of their mastery of the device. The experiments were done with six sighted subjects that were blindfolded. On average the experiments took between ten and fifteen hours.

1- Contact stage.

The first stage: contact, consists in learning how to keep contact with the objet and how to find it when it is lost.

In a first experiment we check if subjects are able to find a target and to keep it in contact while they move.

Results : Making contact with objects by the use of the device is almost immediate. For all the subjects, the auditory signal is easily interpretable, moving the Web Cam is effortless, in consequence it is easy to manipulate and maintain control over the signal.

2- Exteriorization stage

The second stage, exteriorization, is the ability to distinguish two kinds of stimulation: the sensory stimulation and the information which is provided by it. Users have to understand that auditory information represents an object which is in front of them, and that it exists independently of the sensations in their ears. We understand this stage through the reports of subjects during the experiments, and with questions asked afterwards.

Results : A kind of exteriorization sets in very rapidly. This is essentially because there are movements. Subjects feel that if sounds (or things) change as a function of their movements, they are not just passively receiving a noise, but acting on physical space. The noise immediately has a meaning in terms of outside objects.

3- Spatialization stage

Spatialization is the constitution of the metric of the new perceptual space, that is, the constitution of the ability to act in the simulated environment.

To understand how users manage to master this new space, in the first part of the experiment, we ask them to walk across a room and grasp an object. We measure the time taken to move and to point, and the number of pointings done (18 tries).

Then we try to determine to what extent the metric of this new space is acquired by asking the observer to do a more precise pointing task. Subjects are seated in front of the table. We place the target in different places, and ask them to point at it (26 tries).

Results : Subjects manage rather easily to localize the target and to point at it. Performance significantly improves over time as shown by fig 1. We found that subjects had problems with their displacements. This is probably due to an inability to integrate movements of several body parts, and the consequence of this is that subjects had problems gaining access to depth information. The two experiments show that the further away the target is, the less accurate subjects are (see fig 1 & fig 2).

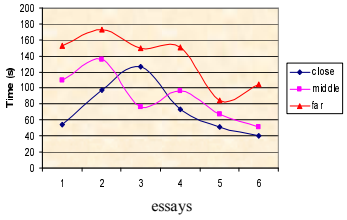


Fig 1. First pointing task. Mean over subjects of the time taken to point at the target for 3 positions of the target (close middle, far).
Performance significantly improves over time : $F(5, 102)=3.085$, $p<0.001$
Performance is significantly affected by the vertical emplacement of the target :$F(2, 81)=7.5625$, $p<.02$

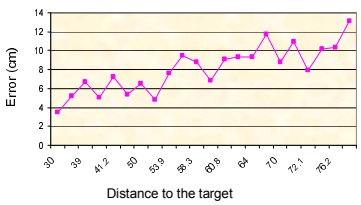


Fig 2. Second pointing task. Mean pointing error as a function of the distance between elbow and target. Performance is significantly affected by the distance to the target
: $F(21, 133)=1.7544$, $p=0.03$

4- Comprehension of information stage

The fourth stage, comprehension of information, corresponds to the comprehension of the objects which are represented by sounds. This implies recognizing objects and also categorizing them.

Experimental protocol : We place an object on a table in front of the subject, and ask him if he can recognize it. If he can't we ask him to explore it with his hand. Then we present him with another object. We use 10 objects to recognize, and do 50 trials.

Then, once the subject is able to recognize the different objects we check his ability to generalize what he had learnt. On the table in front of him we show him in random order the objects we showed him before, and some variants of these objects, that is objects varying in size or a little in form, but belonging to the same category. We use the 10 preceding objects and 9 additional objects which differ by their size or by form and do 50 trials.

We measure the time taken to recognize the objects, and the number of objects enumerated before the subject gives the correct response.

Results: the approximation of forms is rather intuitive. Subjects make several rough categories and associate rapidly an object to a category but they have difficulty refining their recognition.

For this reason, the categorization task was problematic : Subject often associated new objects to old objects of the same category because they didn't identify the small differences.

Mean over subjects and objects of the time taken to recognize the objects at each successive viewing.
Performance significantly improves over time : $F(4, 276)=3.085$, $p<0.005$

5-Immersion stage

Immersion corresponds to the moment when observers no longer have to think about how the information is transcribed. They don't have to interpret the auditory stimulation. They have direct access to perceived elements.

We understand this stage through the reports of subjects. We found that making contact with objects by the use of the device is very intuitive. But then each time subjects encounter a problem they go back to a deductive mode in order to elaborate strategies of movements and adaptation. But as subjects reach the mastery of the device, they have to think less about what their are doing.