Vibrotactile colour rendering for the visually impaired within the VIDET project

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ABSTRACT

The VIDET project aims to the design of a tactile vision substitution system for the visually impaired. An important enhancement would be colour rendering. Here we face the possibility of conveying colour information to the fingers by means of vibrations. Experiments on seeing and blind subjects confirm the validity of the idea.

Keywords: RGB, Sensory substitution, Blindness, Colour vision

1. INTRODUCTION

VIDET (VIsual DEcoder by Touch) will be a portable device by which a visually impaired person will explore a virtual bas–relief of the environment.[1] This will be performed by a camera pair, a portable computer and a robotic apparatus (WireMan, a thread device[2,3]). The project is presently under development at DEIS (Electronics, Informatics and Systems Department), at DIEM (Department of Mechanical Engineering) and at our Department at the University of Bologna, under the direction of Prof. Claudio Bonivento (DEIS).

The idea is to bring far objects within reach of the user. So, blind persons will use the sense of touch for understanding shapes – what they already do quite well for close objects. This was quite impossible before the recent big advances in virtual reality; in particular, this possibility was suggested by the existence of very sophisticated force–feedback systems.[4] We hope that VIDET will require less training than the two–dimensional displays already in use for tactile vision substitution, since it is more directly related to everyday's experience of the blind; moreover it should overcome the obstacle of discriminating figure from background, as they will be felt at two different depths.

It was a non-seeing person, Vittorio Bacchetti of APH (Handicap Project Association), who suggested to add colour rendering to VIDET. At first, we thought that a colour transducer might be of interest only for people who, as Vittorio, had been once normally seeing and remember colours. On the contrary, the most enthusiastic reaction came from one of the subjects (and collaborators) of our experiments, Claudia Piccioni – blind since her birth – who was very excited at the idea of having a concrete feeling (literally) of "colours", which were part of her conceptual environment, but were totally abstract up to now.

Although an acoustic transduction seemed attractive, we decided for a tactile rendering, so that the user can psychologically build all of his/her reconstruction at hand level. Much experience on tactile displays for sensory substitution is available in the literature,[5–7] but we do not know of any already existing device for colour rendering. We would like to stress that this research has nothing to do with direct colour perception by touch, as studied by some scientists in the 1960's.

2. SIGHT VS. TOUCH

It is well known that colour vision in Humans is due to the presence of three families of receptors ("cones") in the retina; each is most sensible to a specific wavelength. This is also basically why colour TV (through RGB) works.

So, a tactile transducer of colours should somehow convey a mixture of three signals. The main problem, to be treated in the next section, is that tactile receptors do not have a similar subdivision. Actually, there are different receptors in the derma, but they are sensible to quite different stimuli, not to different occurrences of the same stimulus, as with coni in the eye.

There are different kinds of tactile receptors: Meissner corpuscles, Merkel disks, Ruffini corpuscles, Krause terminal bulbs, Pacini corpuscules, free nervous terminations. Of them, the Pacini corpuscles seem to be the most

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apt to receive colour information: they are located deep in the derma, and have 1 to 4 mm length and 0.5 to 1 mm calibre; they are stimulated only by very rapid movements of the tissue and respond in few hundredths of a second. Therefore they mainly detect vibrations in the tissue.[8]

Of course, we don't drop the idea of using other means than vibrations, to convey information. So, other types of receptors might become relevant to future investigations. In particular, we plan to repeat the experiments with electrotactile stimulation, as suggested, e.g., by,[9,10] but we prefer not to adopt invasive solutions.[11,12]

3. HARDWARE SETTING

A firstly devised solution consisted in the most similar setting to the one of colour: the superposition of three signals (vibrations) at different frequencies. They had to be presented to the tip of a forefinger by means of a stimulator (actually a tiny headset loudspeaker). All initial experiments (with seeing subjects) were highly deceptive: Single frequencies – well in the 50 to 300 Hz range of skin sensibility – were not distinguished. It turned out that amplitude could be much better discriminated than frequency.

The second solution – of which four versions were elaborated – consists in presenting three vibrations by means of three stimulators; all have the same frequency, but each can independently be modulated in amplitude. Just three levels of amplitude are admitted at the present stage of the research: Low, Medium and High, corresponding to signals of 0 v, 0 mA, of 0.7 v, 30 mA and of 1.4 v, 60 mA respectively, all at 75 Hz. The simple signal emitting device is connected to the parallel port of an i486 based PC.

The images to be presented to subjects, are loaded as bitmaps, then they are processed and they are explored with a mouse, within a specially designed program. It should be noted that spatial resolution is not the main issue (at least at the present stage): We do not present fine details to be distinguished at fingertip level; we just need the different types of vibration to be recognized, together with their intensities.

4. THE SOFTWARE

The program designed for the experiments, consists essentially of three parts: Loading and displaying an image, approximating colours, and sending colour signals to the parallel port, in correspondence of cursor position. It has been written in Turbo Pascal, and runs under Windows 3.1 or later versions.

Of the 27 possible combinations of signals only 13 were chosen for the experiments (some actually used only 8). The corresponding colours are shown in Table 1. The choice was made in order to have a palette of well–distinguishable colours, with definite names. Of course, we aim to make a much braoder palette available, so that nuances may be appreciated (although possibly not named) by the user.

Colour	Red	Green	Blue
Black	L	L	L
Dark red	M	L	L
Red	H	L	L
Orange	H	M	L
Yellow	H	H	L
Dark green	L	M	L
Green	L	H	L
Sky–blue	L	H	H
Blue	L	L	H
Dark blue	L	L	M
Violet	H	L	H
Grey	M	M	M
White	H	H	H

Table 1. Colours and codes (L= Low, M=Medium, H=High)

5. EXPERIMENTAL RESULTS

All experiments were in two parts: Recognition of a colour, and exploration of a simple coloured image. The first part was performed passively by the subject, while the operator selected different colours on the screen. In the second part, the subject used the pen of a graphic tablet to explore and recognize the image; this consisted in a geometric figure (equilateral triangle, circle, rectangle) on a differently coloured background; the figure was homogeneously coloured, with no marked contours.

Training was performed in the same session, and consisted in sending the vibrations, corresponding to the colours, to the subject while saying the colour name; this was done in two identical sequences, and it took a time varying from two to five minutes.

In the first part (colour recognition), for each colour to recognize the subject was given up to twenty seconds, with the vibration going on. So long a time was used very rarely: the subjects generally responded within five seconds. In the second part (image exploration) no time limit was given. In both parts, there were differences in the response time between subjects, but they seemed not to depend on the subject being sighted or blind.

Four different schemes were used: vibrations on different phalanxes of the same finger, vibrations on the distal phalanxes of three fingers; in both cases, the vibrations could be either simultaneous or with a 0.5 seconds delay in the activation of the vibrators.

In tables 2 to 8, we shall use the letters C and I for the Colour and the Image experiments, respectively, O and T for vibrations on One or on Three fingers, respectively, S and D for Simultaneous or Delayed vibrations. Of course, the I–type experiments were limited in number (2 to 7), as they were tiring and took some time. Between brackets are the numbers of tests in each experiment.

As can be seen, setting the vibrations on the phalanxes of the same finger did not yield good results. This is why we tried the three fingers solution; the idea of delaying actuation was given us by Subject 3.

Habituation was an important issue. After a first phase of increasing efficience, time delays in recognition became longer and longer. A residual feeling of vibration, after the removal of the apparatus was experienced by all subjects. We are thinking of differentiating the vibration frequencies at the three fingers; a different use of frequency differentiation might be an enhancement to amplitude modulation.

A very interesting issue is the fact that mistakes were meaningful; they were – so to say – *reasonable* for a seeing person, as mistaking an orange for a yellow or a red (two mistakes which occurred frequently). Much more so, when the error was in the I–type experiment, and the contrast between foreground and background confused the subject (e.g, sky–blue on blue perceived as green on blue). This was not the case of another frequent mistake — violet felt as white — probably imputable to numbness and residual vibration feeling.

It should be noted that the experiment of image recognition are interesting for the colour transducer *per se*, but not as much for the final use, i.e. within VIDET. In the complete project, image understanding will be mainly carried out by 3D exploration, colour being just a supplementary piece of information.

A rough version of the CTD experiment was used as a demo at a computer fair with tens of subjects. Most were exposed just to the seven easiest colours: black, red, green, blue, yellow, violet, white. The demo was performed with the subjects standing, in a very crowded and jumbled environment with great success. The best reacting subjects were then exposed to all 13 colours, again with success. They even answered correctly when exposed to the vibrations representing colour grey, which was not previously presented in the training procedure.

The experiments presented here are merely a hint that vibrotactile colour rendering can work. Actually, they give a dynamical idea of how the present setup developed. Carefully planned experiments will be necessary for choosing the right stimulation system, the best use of frequencies and the effect of extensive training.

6. CONCLUSIONS

We have performed experiments on a simple transducer of colour by touch. Colour is encoded as a triple of vibrations. The experiments, performed on subjects with different sight histories, are nicely satisfying.

The next development will be the integration with VIDET. Further variations (e.g. the use of different frequencies for the three vibrators, or use of electrotactile stimulation) are possible.

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Experiment	COS(44)	IOS(2)
% of hits	61	100

Table 2. Subject 1; congenitally blind

Experiment	COS(46)	IOS(4)
% of hits	80	75

Table 3. Subject 2; blind since adult age

Experiment	CTS(66)	ITS(4)
% of hits	85	100

Table 4. Subject 3; blind since childhood

Experiment	COD(64)	IOD(3)	CTS(31)
% of hits	92	67	100

Table 5. Subject 4; congenitally blind

Experiment	COD(59)	IOS(7)
% of hits	100	100

Table 6. Subject 5; normally seeing

Experiment	COD(39)
% of hits	74

Table 7. Subject 6; normally seeing

Experiment	CTD(73)	CTS(54)	ITS(2)
% of hits	90	81	100

Table 8. Subject 7; blind since adult age