increase in cationic selectivity and a decrease in membrane "leakage".

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RAMÓN LATORRE
M. CECILIA HIDALGO

Laboratorio de Fisiología Celular,
Facultad de Ciencias and
Facultad de Química and Farmacia,
Universidad de Chile,
Santiago, Chile.

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Vision Substitution by Tactile Image Projection

WE describe here a vision substitution system which is being developed as a practical aid for the blind and as a means of studying the processing of afferent information in the central nervous system. The theoretical neurophysiological basis[1] and the physical concept of the instrumentation[2] have been discussed previously, and results obtained with preliminary models have been briefly reported[3]. A detailed description of the apparatus will appear elsewhere (manuscript in preparation).

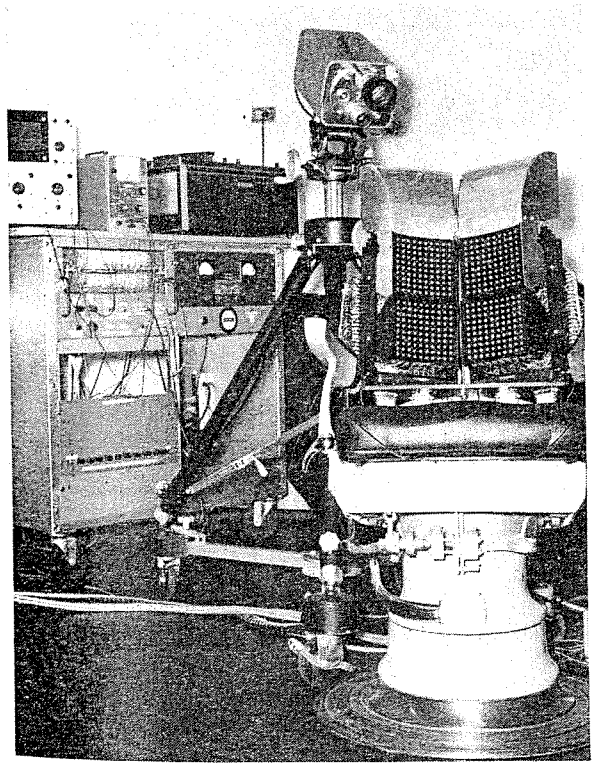

Fig. 1. Tactile television hardware comprising the vision substitution system. The digitally sampled television camera with zoom lens is seen high in the centre; the electronic commutator and control electronics with monitor oscilloscope and videotape recorder are on the left. On the right, the 400 point two-dimensional tactile stimulator matrix array is shown mounted in the back of a dental chair for projecting mechanical television images on to the skin of the back of blind subjects. In the position shown, the camera permits subjects to examine hand held objects from a visual angle approximating that of the eyes. When placed in front of the subject the camera can be manipulated to examine various parts of an object.

Fig. 2. Appearance of a 400 point representation of a woman's face as seen on the monitor oscilloscope. Subjects can correctly identify vibrotactile stimulus patterns of this level of complexity. Blurring and consequent half-tone appearance in the image occurs visually (and tactually) due to noise modulation and temporal integration of the 60 Hz field rate. (Visual perception of this type of digital display is sometimes enhanced by squinting or otherwise further blurring the image.)

Four hundred solenoid stimulators are arranged in a twenty × twenty array built into a dental chair. The stimulators, spaced 12 mm apart, have 1 mm diameter 'Teflon' tips which vibrate against the skin of the back (Fig. 1). Their on–off activity can be monitored visually on an oscilloscope as a two-dimensional pictorial display (Fig. 2). The subject manipulates a television camera mounted on a tripod, which scans objects placed on a table in front of him. Stimuli can also be presented on a back-lit screen by slide or motion picture projection. The subject can aim the camera, equipped with a zoom lens, at different parts of the room, locating and identifying objects or persons.

Six blind subjects have undergone extensive training and testing with this apparatus. The first of these subjects —a psychologist who has been blind since the age of 4— has had over 150 h of experience in the chair. At present he is training other subjects and is co-author of this report. The remaining five subjects are college undergraduates who have been selected for their verbal abilities, motivation and general adjustment, and who have been blind since birth (retrolental fibroplasia). Their experience ranges from 20 to 40 h of training.

After being introduced to the mechanics of operating the apparatus, subjects are trained to discriminate vertical, horizontal, diagonal and curved lines. They then learn to recognize combinations of lines (circles, squares and triangles) and solid geometric forms. After approximately 1 h of such training, they are introduced to a "vocabulary" of twenty-five common objects: a telephone, chair, cup, toy horse and others. With repeated presentations, the latency or time-to-recognition of these objects falls markedly; in the process, the students discover visual concepts such as perspective, shadows, shape distortion as a function of viewpoint, and apparent change in size as a function of distance. When more than one subject is presented at a time, the subjects learn to discriminate overlapping objects, and to describe the positional relationship of three and four objects in one field. The visual analysis technique and concepts thus

developed are then used in letter recognition, in the perception of moving stimuli and in the exploration of other persons standing before the camera. Our subjects learn to discriminate between individuals, to decide where they are in the room, to describe their posture, movements, and individual characteristics such as height, hair length, presence or absence of glasses and so on.

Although many of our data are anecdotal, we are attempting to test and quantify the perceptual acuity of our six experienced blind subjects as training progresses, and to compare their ultimate efficiency with that of six sighted subjects viewing the oscilloscope monitor. With this in view: (1) Grilles of parallel black and white lines were prepared at five levels of difficulty, containing four, six, eight, ten and twelve pairs of lines. These stimuli were presented vertically or horizontally in a random sequence by photographic slide. The subject was asked to detect the orientation, and his response latency was recorded. (2) A portion of a large checkerboard was photographed at an angle of 70° from the perpendicular, so that a slide was filled with slanting, converging black and white squares. The ratio of convergence was 2 : 1, with a total of sixty white squares. By rotation of the slide in the projector, the direction of convergence could be presented to the top, bottom, left or right. A random series of twenty presentations per testing period was given, with the trainer recording the latency and accuracy of the response.

Table 1. RESPONSE ACCURACY AND LATENCY FOR BLIND AND SIGHTED SUBJECTS ON JUDGMENTS OF LINE ORIENTATION AND CHECKERBOARD TILT

	Accuracy	
	Line orientation	Checkerboard tilt
Blind $N=6$	99·6%	82·9% $\sigma=10·4$
Sighted $N=6$	100%	97·5% $\sigma=1·5$
Significance	Non-sig.	$P<0·01$
	Latency in seconds	
	Line orientation	Checkerboard tilt
Blind $N=6$	1·2	8·4 $\sigma=2·9$
Sighted $N=6$	1·1	2·8 $\sigma=0·7$
Significance	Non-sig.	$P<0·001$

Table 1 shows that the two groups did not differ significantly in detecting the orientation of the parallel lines. On the checkerboard slant task, the sighted group was more accurate (97·5 per cent to 82·9 per cent, $P<0·01$), and latencies of the sighted group were significantly shorter (2·8 s to 8·4 s, $P<0·001$) than those of the blind group.

The blind subjects, restricted to manual manipulation of the camera, were somewhat slower in exploring the image than were the sighted subjects who visually scanned the monitor, thus perhaps explaining the difference in latency. In subsequent testing and training, three of the blind subjects have attained a criterion of 100 per cent accurate discrimination. (3) Block capital letters were presented individually by photographic slides in a random sequence. The subject scanned the letter and responded verbally. The trainer told the subject whether his judgment was correct or incorrect; in the latter case the subject responded again. The latency to correct response was recorded and averaged over twenty-six letters. For six subjects, the initial mean latency to correct response was 52 s; this latency fell to 17, 14 and 10 s on the three successive testing periods, respectively. (4) In introducing the "vocabulary" of twenty-five common objects, the trainer first directed the subject's analysis of each one, pointing out the parts, their relationships, and the object as a whole. He subsequently presented one of the objects and asked the subject to identify it, recording the time to correct response and giving such feedback as he thought appropriate. Recognition times were at first between 5 and 8 min per object for the first few presentations. As the subject became more familiar with each object and with its different possible orientations, and as his visual analysis techniques developed, the recognition time fell to 5–20 s after 10 h or more of training.

As the blind subjects become more familiar with objects, they learn to recognize them from minimal or partial cues. This skill permits them to describe with accuracy the layout of objects on a table, in depth and in correct relationship, even though the objects may be overlapping and only partially visible. For example, a telephone can be located although only its cord is showing.

Our subjects spontaneously report the external localization of stimuli, in that sensory information seems to come from in front of the camera, rather than from the vibrotactors on their back. Thus, after sufficient experience, the use of the vision substitution system seems to become an extension of the sensory apparatus.

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PAUL BACH-Y-RITA
CARTER C. COLLINS
FRANK A. SAUNDERS
BENJAMIN WHITE
LAWRENCE SCADDEN

Smith-Kettlewell Institute of Visual Sciences,
Pacific Medical Center,
San Francisco, California 94115.

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Control of DNA Synthesis in *Amoeba proteus*

IT is important for our understanding of DNA replication to determine the part played by the cytoplasm in the initiation and maintenance of DNA synthesis in the cell. That cytoplasm can "switch on" DNA synthesis in cells which are in G_0 or G_1 has been clearly shown in studies of hybrid cells[1,2], in transfer experiments using *Xenopus* egg cytoplasm[3,4], and in nuclear transfer experiments using G_1 and S phases of the protozoan *Stentor*[5]. Whether the G_2 nucleus can be "switched on" without first undergoing mitosis is not certain—available evidence is conflicting[6–8]. The following investigation was carried out on *Amoeba proteus* to determine (i) if S cytoplasm can initiate synthesis of DNA in the G_2 nucleus; (ii) if S cytoplasm can maintain synthesis of DNA indefinitely in "switched on" nuclei; and (iii) if G_2 cytoplasm can inhibit DNA synthesis in S nuclei.

Nuclear DNA synthesis in *A. proteus* follows the separation of the division sphere into two daughter cells, G_1 being negligible. In the two strains of amoeba used in this work, $P_{Da}X65$ and a related strain $P_{Da}X67$, 90 per cent of this synthesis occurs during the first quarter of the 40–48 h cell cycles[11], 1–5 h (referred to as peak S) being the time of greatest synthesis.

Fig. 1 shows the four types of transfer used to establish whether G_2 nuclei synthesize DNA if transferred to S cytoplasm. The G_2 period represents 30–36 h, during which it is unlikely that the nucleus remains in the same state, and so nuclei from all parts of the cycle were used for transfer. Autoradiographs obtained after pulse labelling with ^{3}HTdr showed that no matter from which