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DEVELOPMENT OF AN ELECTROTACTILE GLOVE FOR DISPLAY OF GRAPHICS FOR THE BLIND: PRELIMINARY RESULTS.

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Abstract: **We present preliminary results from a pattern perception experiment using a finger-mounted, optical-to-tactile image conversion system. The system converts light patterns from a linear camera to a corresponding column of electrotactile (electrocutaneous) stimulation on the palmer surface of the finger. Random presentations of four simple geometric patterns selected were correctly identified 63.5% of the time, demonstrating initial feasibility of the system.**

INTRODUCTION

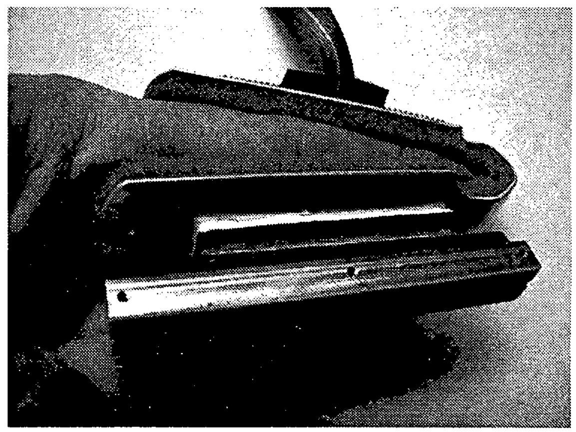
We are developing a tactile vision substitution (TVS) system to deliver graphical information to the brain via arrays of electrodes in contact with the skin of one hand. Such a system would be of enormous benefit to the approximately 200,000 people who have little or no useful vision [1], who cannot otherwise access the wealth of information contained in graphical formats (e.g. charts, graphs, & pictures).

In the present prototype, optical image information picked up by a linear video camera is converted to pulsed trains of stimulation delivered to discrete electrodes on a single finger. Conversion of this electrotactile [2] stimulus to coded neural pulses is then mediated by the skin receptors. Concurrently, kinesthesis provides information about the location, motion, and orientation of the sensing site. This dynamic sensory-motor process constitutes what is generally regarded as haptic perception [3]. The main advantages of the present prototype over other approaches are (1) there are no moving parts in the tactile display, and (2) the tactile display units themselves are small because they need only cover the fingertips or other parts of the hand, and not the entire image to be displayed.

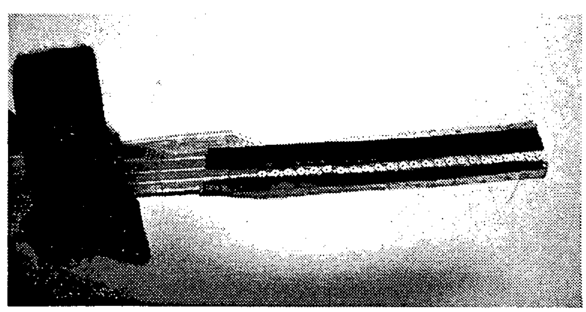
Prior studies with TVS systems have been extensively described (e.g., [4, 5, 6, 7]).

METHODS

Technical development: The present prototype employed a 1 x 512 pixel CCD array camera [Texas Advanced Optoelectronic Solutions (TAOS) Model TSL-208, 65.02 mm imaging area 3.9 lines/mm] with a SELFOC-Lens-Array (Model SLA-20D, focal length: 9.1 mm) from Nippon Sheet Glass (NSG).



As shown above, the camera was mounted on a foam padded finger splint, within which the 1 x 24 array of gold-plated electrodes (1.50 mm diameter, on 2.32 mm centers) was mounted (see electrode detail below), contacting the palmer side of the middle finger on the participants' non-dominant hand. A Teflon collar (0.38 mm thick) around the objective face of the custom lens mount was used to minimize both friction and entry of ambient light at the lens-display interface. Blocks of active pixels were mapped to each electrode at a ratio of 18:1, and each block was separated by 3 inactive pixels. This spatial pattern of pixels was selected to match the geometry of the linear electrode array.

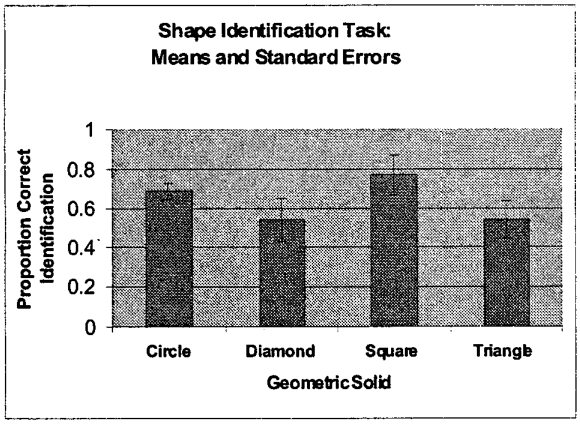


Geometric Pattern Perception

Six participants attempted to identify 1 of 4 simple patterns (circle, diamond, square, triangle) on the TVS. Participants were blindfolded for all tests. Each participant was given a practice trial on each pattern with feedback and then 32 shape trials without feedback. Across the 32 trials, each shape was presented 8 times in a random order without replacement. The shapes were displayed on an LCD computer monitor (1024 x 768 resolution) as solid white (or lighted) regions on a black background. Each shape was approximately 3.5cm high x 3.5 cm wide, except for the diamond (5.2 cm high x 2.6 cm wide).

RESULTS

The figure below shows that the participants correctly identified shapes 63.5% of the time (chance performance would be 25%).



Shape Identification Confusion Matrix

		STIMULUS			
		Circle	Diamond	Square	Triangle
RESPONSE	Circle	**0.69**	0.23	0.10	0.19
	Diamond	0.08	**0.54**	0.13	0.25
	Square	0.17	0.00	**0.77**	0.02
	Triangle	0.06	0.23	0.00	**0.54**

In the Table above, values in bold display the proportion correct identification (e.g., p(respond "Circle" for "Circle" stimulus). In general, there were several confusions that occurred fairly frequently: (1) the "Circle" was identified as a "Square"; (2) the "Diamond" identified as a "Circle" or "Triangle"; or (3) the "Triangle" was identified as a circle. The differences between patterns, in terms of proportion correct identification, was not significant, [$F(3,15) = 1.85$, $p = 0.18$]. Even though the ANOVA was not significant, the proportion of variance in performance accounted for by the differences between the patterns was 0.20, a relatively strong effect size. The effect-size analysis suggests that the above means would likely exceed significance with more participants.

DISCUSSION

Analysis of results of the task offers insight into scanning strategies and uses of various features of the spatio-temporal stimulation pattern on their finger as discrimination cues for identification of the perceived geometric pattern. In particular, 'Circle' and 'Square' may have been confused because of the difficulty in detecting the presence of apexes (often presented by only a single electrode), which is consistent with previous work. However, this confusion may also possibly be due to the relatively rapid onset of stimulation across a number electrodes as the camera passes over the edge of the 'Circle' or 'Square' image. This type of error may be resolved by proper training in the use of scanning and pattern discrimination techniques. Similarly, 'Diamond' and 'Triangle' were apparently confused, although to a lesser extent. On a more promising note, 'Diamond' and 'Square' were seldom confused. Both are quadrangles, yet differing in orientation (Diamond' is rotated by $\pi/4$ rad., and has asymmetric diagonals. Evidently participants were able to detect differences in the location and timing of sensation onset and offset as the images were scanned, allowing superior identification performance This result again suggests that the scanning strategy is critically important and points to the necessity for proper training, particularly as the perception of more complex patterns is explored

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