TACTILE COMMUNICATION

62-11

FEDERAL AVIATION AGENCY
Aviation Medical Service
Research Division
Civil Aeromedical Research Institute
Psychology Branch
Oklahoma City, Oklahoma

MAY, 1962

TACTILE COMMUNICATION

GLENN R. HAWKES, Ph. D.
Sensory Psychology Section
Psychology Branch

62-11

FEDERAL AVIATION AGENCY
Aviation Medical Service
Research Division
Civil Aeromedical Research Institute
Psychology Branch
Oklahoma City, Oklahoma

MAY 1962

TACTILE COMMUNICATION

GLENN R. HAWKES, PH. D.

ABSTRACT

Tactile communication represents a relatively unexploited channel of information transmission in the field of aviation. Visual and auditory input channels frequently reach an information saturation point during various flight operations. A cutaneous communication system can bring to the pilot and crew, additional information for suitable disposition, and can be used for such purposes as guiding an aircraft to a landing, or keeping an aircraft on course during cross-country flying. This system can also be used to transmit emergency warning signals.

In 1957, Frank A. Geldard gave, as a presidential address to the Experimental Division of the American Psychological Association, a talk entitled *Adventures in Tactile Literacy*.[1] It was pointed out in his talk, and backed up with experimental data, that although the human skin is seldom used for communication purposes, it can be – and usefully so. Subjects trained for a relatively short period of time (about 12 hours) could successfully associate meaning (letters of the alphabet) with stimulation by one of five mechanical vibrators resting on the chest. Use of 3 intensities and 3 durations for each of the vibrators gave a total of 45 different stimulus-combinations available in this system, as shown in Fig. 1. It should be noted in Fig. 1 that only one vowel was assigned to a particular locus, that frequently used letters were assigned to brief durations to increase speed of transmission, and that some stimulus-combinations were assigned no meaning in order to increase the system's adaptability for special uses. Even with this somewhat less than ideal system, one subject could receive messages at a rate of 38 words per minute, considerably faster than is usual with Morse Code.

The question may legitamately be asked, why didn't communications engineers and others concerned with special problems – such as how to communicate efficiently with personnel in high noise areas adjacent to jet aircraft – immediately begin to utilize the additional sensory input channel? The writer believes that the answer lies in the complexity of the system: the equipment and training problems seemed formidable. Further, the gain in speed of reception of messages over Morse Code was not enough to be spectacular, and the maximum speed of the system (calculated on the basis of the amount of time needed to transmit individual letters of common five-letter words) was only some 67 words per minute. As of this writing, no further investigation has been made of training problems utilizing such a system*

The equipment problems of a cutaneous communication system could be simplified if

* There have been many attempts to train subjects to identify mechanical cutaneous vibrations produced by speech (see Gault[3]), but with a notable lack of success. The writer knows of only one person who has been consistently able to identify such vibrations: Helen Keller.

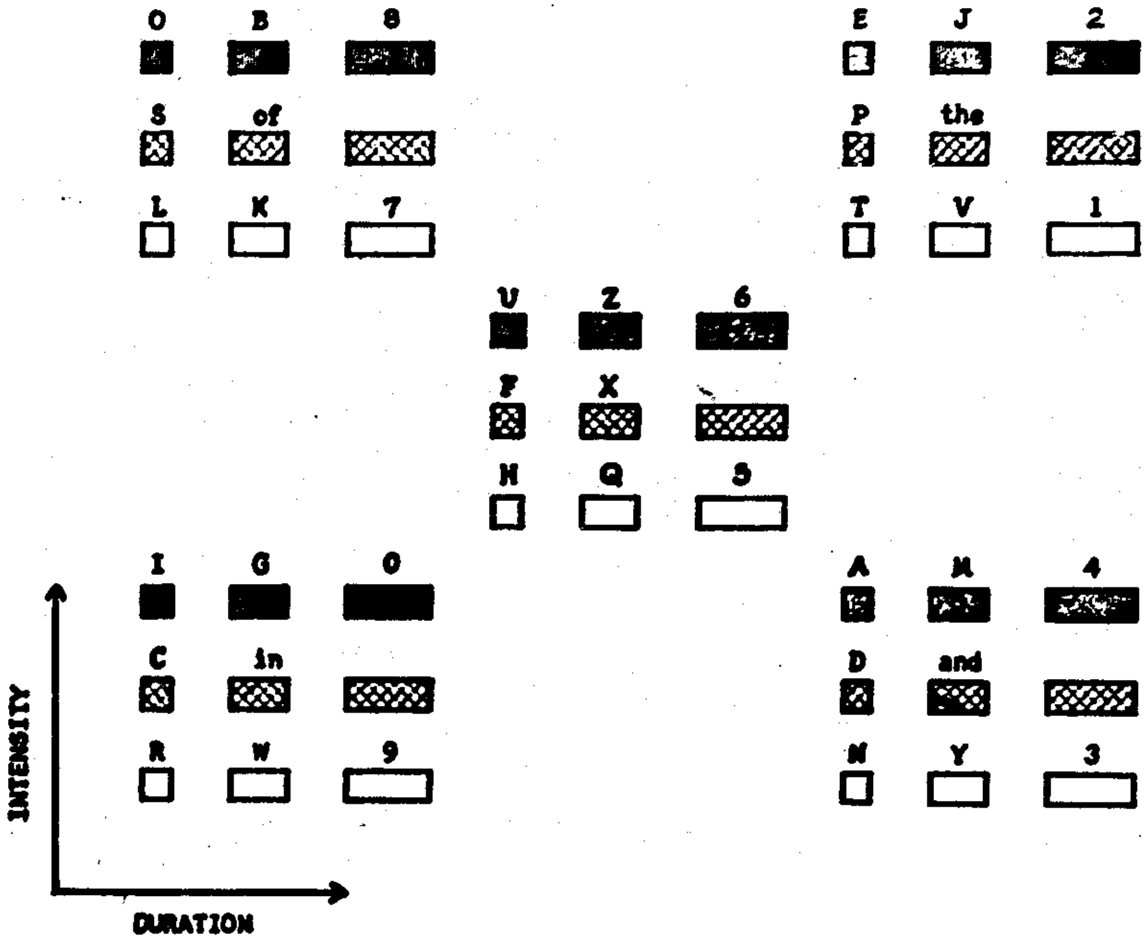

FIGURE 1. Mechanical Vibratory Cutaneous Code described by Geldard.[8] The Groupings represent Signals applied to each of 5 Vibrators, with 3 Intensity-Levels and 3 Durations giving 45 different Stimulus-Combinations (data from Howell[14], by permission of the author).

one avoided the use of mechanical vibrators, which are bulky and require considerable power, and instead used electrical current as the source of stimulation. It has been suggested by the writer[8] and by Gilmer[4] that either direct or alternating current would be suitable for communication purposes. Electrodes are easily mounted on the body surface, and have less bulk and a lower power requirement than mechanical vibrators. Sensitivity for mechanical vibration is dependent upon skin temperature, whereas the amount of electrical current required to reach absolute threshold apparently is independent of surface temperature.[8] Further, mechanical vibratory sensitivity falls off rapidly as locus is changed from bony to fatty areas of the body[10]; sensitivity for electrical current is dependent mostly upon the nerve supply rather than the thickness of the epidermis.

The communication system described by Geldard utilized several intensities, durations, and loci, based on studies of the number of variations along these dimensions which people could readily identify. Electrical current applied to the skin may elicit sensations of pressure, pain, warmth or cold, under suitable conditions. Alternating current at weak intensity levels, however, usually produces a "tingling" sensation which typically is indistinguishable from mechanical cutaneous vibration.[11] An increase in the amount of current will elicit mild pain analogous to that felt when a needle just penetrates the skin; mild pain of this nature is tolerated by human subjects without emotional or other disturbances.[13] The ability to tolerate mild pain with equanimity may be very useful for communication purposes.

If a subject is asked to identify a number of electrical cutaneous intensity-levels within a range producing tingling (or vibratory) sensations but not pain, then two levels can be identified without error. Maximum transmission of information is possible when using three intensity-levels.[6] Extension of the stimulus range to include intensity-levels producing mild pain permits efficient identification of four levels,[15] as shown in Fig. 2. The addition of knowledge of results did not produce a statistically significant gain in information transmitted over that with the extended range alone. Performance when identifying intensity levels of alternating current applied to the skin, therefore, is about the same as with mechanical cutaneous vibration: at least three intensities can be identified efficiently.

Similar results are found when identifying a number of stimulus-durations. About three durations of electrical cutaneous stimulation can be identified efficiently[7], again comparable to the three stimulus durations used in the mechanical vibratory communication system of Geldard.[3] As was the situation when identifying electrical intensity-levels, the data shown in Fig. 3 indicate that extension of the physical range of durations permits efficient identification of more than three stimulus-durations.[8] An additional complication, however, is apparent from the results shown in Fig. 3: efficiency of identification depends at least partly upon the stimulus intensity-level used. Further, the dependence of performance efficiency on stimulus intensity is particularly important if the subject is inexperienced in the task. A similar consideration, the interaction (or confusion) of frequency and intensity of stimulation, precluded the use of stimulus frequency as a cue in the mechanical vibratory system described

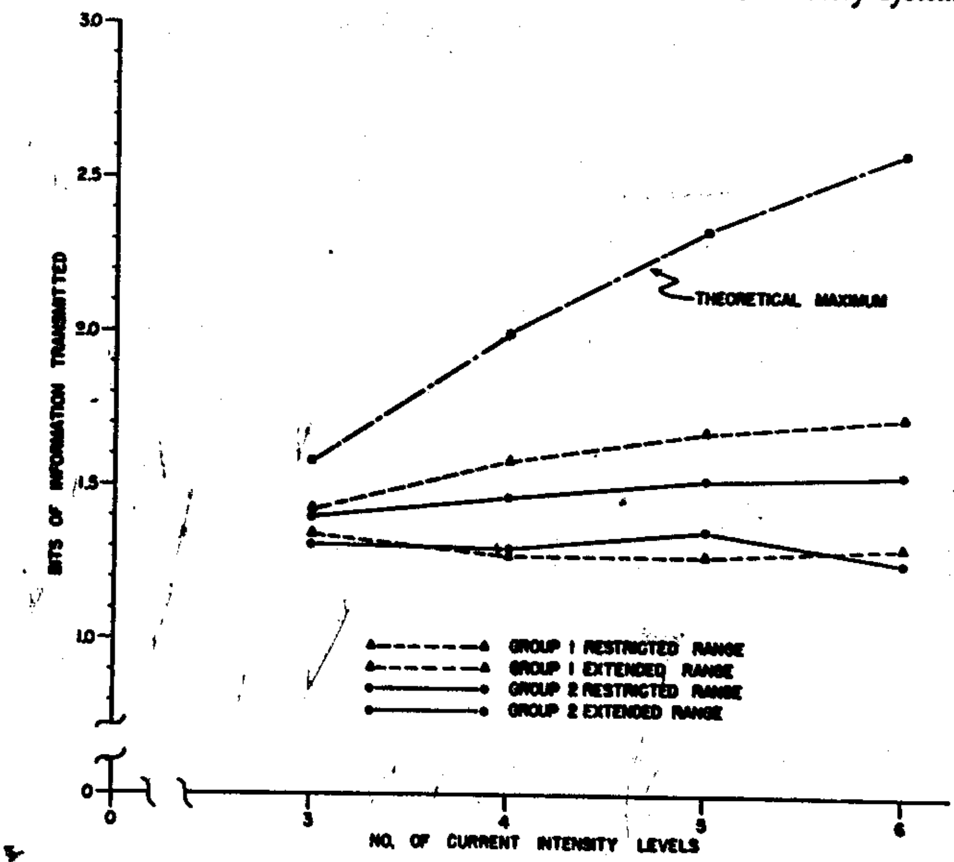

FIGURE 2. Amount of Information Transmitted via Absolute Identification of Electrical Cutaneous Intensity-Level. The Restricted Intensity Range avoided Pain (data from Hawkes[6]); the Extended Range included intensities eliciting Mild Pain (data from Hawkes and Warm[15]). With the Extended Range, Group 1 received Knowledge of Results.

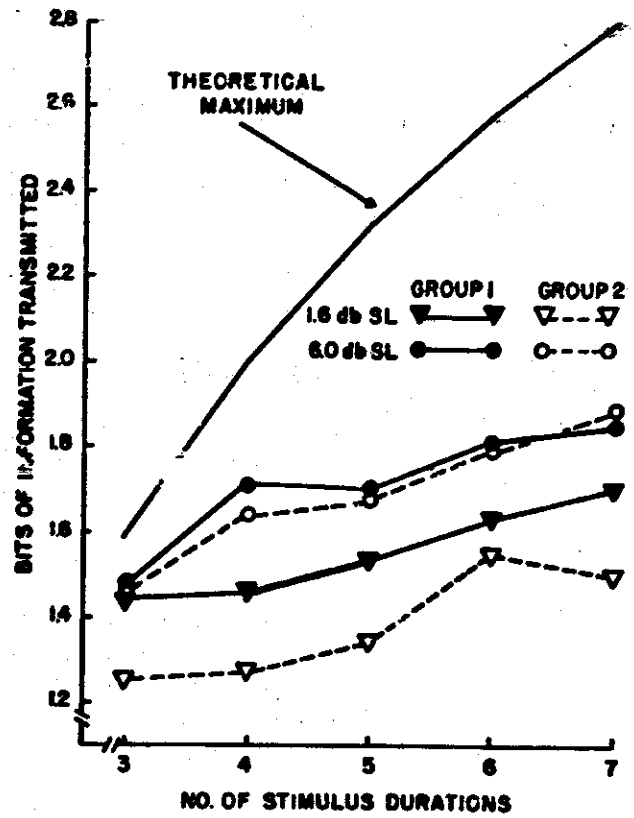

FIGURE 3. Information Transmitted via Absolute Identification of Electrical Cutaneous Stimulus-Duration with stimuli presented at 2 Intensity-Levels. Group 1 was Experienced; Group 2 was Naive (data from Hawkes[8]).

by Geldard.[8] Much additional work remains to be done on selection of the most efficient stimulus parameters for cutaneous communication, on the problems of training with an electrical cutaneous system, and on comparisons of electrical to mechanical vibratory cutaneous communications.

Cutaneous signaling efficiency in vigilance tasks has been compared to performance with auditory stimuli. In situations where subjects responded to the presence of infrequently presented electrical cutaneous, mechanical vibratory, or auditory signals of a weak intensity-level, response latency and signal detection were poorer for the cutaneous stimuli.[10, 18] Efficiency of cutaneous signal detection relative to that with auditory stimuli was well-maintained, however, in another study where a moderate (rather than weak) stimulus intensity level was used.[11] In the latter study, efficiency of responding to the presence of the signals remain high even when the intersignal interval was as long as 600 seconds.

Nevertheless, performance deteriorates with time-on-task for moderate intensity cutaneous stimuli if the subjects are required to discriminate among stimuli as opposed to responding to its mere presence. When cutaneous or auditory stimuli are presented under alerted conditions, judgments of stimulus-duration for these two kinds of stimuli are not significantly different[14]. Subjects have no difficulty in distinguishing between 0.5 and 1.0 second durations with either kind of stimulation. However, if the subject is required to respond to infrequent 1.0 second stimuli but *not* to regularly (every 2.0 seconds) presented stimuli of 0.5 second duration, then performance deteriorates with time-on-task for cutaneous signals but not for auditory ones.[17] If the cutaneous and auditory signals are intermixed in the same session (but not presented simultaneously), then detection probability deteriorates for cutaneous but not for auditory signals. When the two kinds of signals are presented simultaneously, detection probability is about the same as that for auditory signals alone.

Cutaneous vs. auditory signaling at present may be evaluated on these criteria: (1) training time required, (2) speed of reception, and

(3) vigilance performance. On the basis of Geldard's report[9], cutaneous communication apparently compares favorably to Morse Code on (1) and (2), but reception speed probably is severely limited when compared to that for speech. It may be seen from the above that vigilance for cutaneous stimuli also is considerably poorer than performance with auditory signals.

It seems worthwhile at this point to consider a matter of relevance to cutaneous systems and also to all other forms of communication: what meaning should be assigned to the stimuli employed? In Morse Code, two signal durations (plus pauses) are used to form groupings which stand for letters of the alphabet. It is generally recognized, however, that Morse Code is grossly inefficient when compared to the rate of information reception from speech (up to about 250 words per minute) or from reading (500 or more WPM). Quite a large number of symbols would have to be available if each symbol were to refer to different word. Coded symbol sets, such as used in the Gregg shorthand system, could greatly reduce the number of signals required for rapid communication; at least some 31 to 50 signals would still have to be available.[9] Alluisi[1] has offered yet another suggestion: signals could be used to stand for the sounds or "phonemes" of speech. Japanese schoolboys are now trained with a system (termed *Kana*) of 51 characters, each representing a speech sound, so that there is direct correspondence between what is read and what is heard. Perhaps it is possible without too much training to have, for example, the three "dots" signal-group of Morse Code, or a locus-intensity-duration combination in Geldard's cutaneous communication system, stand for a speech sound or shorthand symbol rather than a letter of the alphabet. If so, message reception rate on coded communication systems might be greatly accelerated.

Although a number of uses for cutaneous communications may be envisioned, such as in high-noise areas or for the blind and deaf-blind, it may be seen from the above that much additional work is necessary before a cutaneous communication system such as that described by Geldard is readily available for use. Nevertheless, there is a vast array of situations in which cutaneous signaling can be utilized immediately. Possible immediate uses of stimuli applied to the skin are for (1) emergency warning or alerting purposes, and (2) providing limited information such as is needed for guidance or direction-giving purposes.

DISCUSSION

Cutaneous stimuli could be used to give any kind of warning or alerting signal. The following examples were chosen in an attempt to illustrate the sorts of advantages possible with use of signals applied to the skin rather than, or in addition to, the eyes or the ears. In aircraft operation, pilots or other control personnel are now warned in emergency situations by an intermittent light or loud sound. These signals often are ineffective because the visual and auditory input channels are receiving a continuous stream of information from instruments and earphones, a condition termed "channel overload". A somewhat similar situation, in that the eyes and ears for practical purposes are not available, may occur when the pilot is threatened by anoxia. Mild anoxia may interfere with detection and response to auditory and visual signals. An electrical or mechanical tactile signal could alert the pilot to the lack of oxygen, particularly if the signals were intense enough to evoke some pain; it was mentioned earlier that subjects tolerate mild cutaneous pain without emotional or other disturbances.[10]

Another possible application of cutaneous signaling is in the earlier mentioned high-noise area. Near jet aircraft and in many industrial areas of operation, noise levels are such that communication by loudspeakers, bells, sirens, etc., is difficult if not impossible. In most of these situations, a person is occupied visually by the normal requirements of his task. Rapid alerting of personnel in the advent of danger could be accomplished by triggering an electrical or mechanical signal to the skin of personnel in the area.

Additional ways in which cutaneous signaling can offer advantages may be illustrated in an example in the area of Civil Defense. The principles, however, apply equally well to many situations. Personnel responsible for alerting and controlling people within a particular area need to be informed with minimal delay of the imminence of enemy attack or other impending disaster without necessary dependence upon normal telephone, radio, or television communication. The Civil Defense Headquarters could simultaneously alert all of its key personnel within the area of responsibility by transmitting a radio signal to activate devices worn by the personnel, receipt of a cutaneous signal permitting these personnel rapidly to execute plans of action. Large numbers of key personnel could be alerted simultaneously, whether or not they happened to be watching television or listening to the radio at any given moment.

Auditory or visual signals must compete with many other signals of similar nature. Very little information, however, is derived from the skin, thus offering the possibility of ease of interpretation of cutaneous warning signals. It is neither being suggested nor implied that cutaneous signaling should replace more traditional forms of communication. The addition of another sensory input channel to the auditory and visual should increase the probability of detection and response to signals in many situations. Further, where for some reason the eye and the ear are not available the skin may represent the only opportunity for effective communication. The following is offered as an illustration of other situations requiring transmission of limited information where cutaneous signals could prove to be a valuable supplement to lights and sounds.

Information necessary for guiding an aircraft on an appropriate path for landing is now furnished by both light and sound. Addition of another sensory channel, the cutaneous, should be relatively easy and would increase the likelihood of efficient communication. Further, Howell[8], among others, has shown that tracking performance with only cutaneous signals is possible, thus demonstrating the possibility of receiving such information when other sensory channels are not available. It is relatively easy to conceive of other uses for cutaneous communication systems offering choices among limited signal possibilities. For example, it might be desirable to have several different kinds of emergency warning signals available in a single system. The equipment and training problems of a cutaneous communication system designed for limited information transmission should be only slightly more difficult than that necessary for cutaneous warning or alerting purposes.

CONCLUSIONS

It may be concluded that cutaneous signaling could be useful for any form of communication. Transmission of complete messages with such a system, however, will require considerable additional investigation even though feasibility has been demonstrated by Geldard. The best immediate applications of cutaneous signaling are in the areas of warning or alerting, and for direction-giving among sets of limited possibilities as in guidance systems. Cutaneous communications will not replace the eye or the ear, but in many situations, "tickle talk" can be useful.

REFERENCES

1. Alluisi, E. A., "On Optimizing Cutaneous Communication: A Respectful Supplement to some Adventures in Tactile Literacy," In Hawkes, G. R. (Ed.): Symposium on cutaneous sensitivity. *US Army Med. Res. Lab. Rep.* No. 424, Ft. Knox, Ky., 1960, pp. 114-130.

2. Gault, R. H., "Hearing Through Sense Organs of Touch and Vibration," *J. Franklin Inst.*, 204: 329-358, 1927.

3. Geldard, F. A., "Adventures in Tactile Literacy," *Am. Psychologist*, 12: 115-124, 1957.

4. Gilmer, B. v. H., "Possibilities of Cutaneous Electropulse Communication," In Hawkes, G. R. (Ed.): Symposium on Cutaneous Sensitivity. *US Army Med. Res. Lab. Rep.* No. 424, Ft. Knox, Ky., 1960, pp. 76-84.

5. Gregg, J. R., *Gregg Shorthand*. New York: Gregg, 1929.

6. Hawkes, G. R., "Cutaneous Communication: Absolute Identification of Electrical Intensity Level," *J. Psychol.*, 49: 203-212, 1960.

7. Hawkes, G. R., "Information Transmitted via Electrical Cutaneous Stimulus Duration," *J. Psychol.*, 51: 293-298, 1961.

8. Hawkes, G. R., "Absolute Identification of Duration," *Percept. mot. Skills*, 13: 203-209, 1961.

9. Hawkes, G. R., "Effect of Skin Temperature on the Absolute Threshold for Electrical Current," *J Appl. Physiol.* 17: 110-112, 1962.

10. Hawkes, G. R. and Loeb, M., "Vigilance for Cutanous and Auditory Signals." *J. Auditory Res.*, 1: 272-284, 1961.

11. Hawkes, G. R. and Loeb, M., "Vigilance for Cutaneous and Auditory Stimuli as a Function of Intersignal Interval and Signal Strength." *J. Psychol.*, 53: 211-218, 1962.

12. Hawkes, G. R. and Warm, J. S., "Maximum I_t for Absolute Identification of Cutaneous Electrical Intensity Level. *J. Psychol.*, 49: 279-288, 1960.

13. Hawkes, G. R. and Warm, J. S., "The Sensory Range for Electrical Stimulation of the Skin." *Am. J. Psychol.*, 73: 485-487, 1960.

14. Hawkes, G. R., Bailey, R. W. and Warm, J. S. "Method and Modality in Judgments of Brief Stimulus Duration." *J. Auditory Res.*, 1: 133-144, 1961.

15. Howell, W. C., "Training on a Vibratory Communication System." Unpublished master's thesis, Univ. Virginia, 1956.

16. Howell, W. C., "On the Potential of Tactual Displays: an Interpretation of Recent Findings." In Hawkes, G. R. (Ed.): Symposium on cutaneous sensitivity. *US Army Med. Res Lab. Rep.* No. 424, Ft Knox, Ky., 1960, pp. 103-113.

17. Loeb, M. and Hawkes, G. R., "Detection of Differences in Duration of Acoustic and Electrical Cutaneous Stimuli in a Vigilance Task," *US Army Med Res. Lab. Rep.*, No. 522, Ft. Knox, Ky., 1961.

18. Loeb, M. and Hawkes, G. R., "The Effect of Rise and Decay Time on Vigilance for Weak Auditory and Cutaneous Stimuli." *Percept. mot. Skills*, 13: 235-242, 1961.

19. Vernon, J. A., "Cutaneous Interaction Resulting from Simultaneous Electrical and Mechanical Vibratory Stimulation," *J. exp. Psychol.*, 45: 283-287, 1953.

20. von Skramlik, E. "Psychophysiologie der Tastsinne," *Arch. ges Psychol*, Ergaenzungsbd. 4, 1937.

FAA AC 63-3326