Perceptual Restoration of Missing Speech Sounds

Richard M. Warren

Science, New Series, Vol. 167, No. 3917 (Jan. 23, 1970), 392-393.

Stable URL:
http://links.jstor.org/sici?sici=0036-8075%2819700123%293%3A167%3A3917%3C392%3APROMSS%3E2.0.CO%3B2-J

Science is currently published by American Association for the Advancement of Science.

Your use of the JSTOR archive indicates your acceptance of JSTOR's Terms and Conditions of Use, available at http://www.jstor.org/about/terms.html. JSTOR's Terms and Conditions of Use provides, in part, that unless you have obtained prior permission, you may not download an entire issue of a journal or multiple copies of articles, and you may use content in the JSTOR archive only for your personal, non-commercial use.

Please contact the publisher regarding any further use of this work. Publisher contact information may be obtained at http://www.jstor.org/journals/aaas.html.

Each copy of any part of a JSTOR transmission must contain the same copyright notice that appears on the screen or printed page of such transmission.

JSTOR is an independent not-for-profit organization dedicated to creating and preserving a digital archive of scholarly journals. For more information regarding JSTOR, please contact jstor-info@jstor.org.

http://www.jstor.org/
Fri Apr 23 15:32:20 2004

appears that the prescribed feminine sex role is related to problems in population control. Our finding that women who reject in themselves the traits of the feminine stereotype implying low competence and immaturity have significantly fewer children than women who incorporate these undesirable feminine characteristics provides support for Davis's (2) and Blake's (2) thesis that the stereotypic feminine social role is a critical factor affecting family size in our society.

FRANK E. CLARKSON
SUSAN R. VOGEL, INGE K. BROVERMAN
DONALD M. BROVERMAN
Psychology Department,
Worcester State Hospital,
Worcester, Massachusetts 01604
PAUL S. ROSENKRANTZ
College of the Holy Cross,
Worcester, Massachusetts

References and Notes

1. J. Blake, *Population Studies* **20**, 27 (1966); R. Freedman and L. Coombs, *ibid.*, p. 197; P. K. Whelpton, A. A. Campbell, J. E. Patterson, *Fertility and Family Planning in the United States* (Princeton Univ. Press, Princeton, N.J., 1966).
2. J. Blake, *Science* **164**, 522 (1969); K. Davis, *ibid.* **158**, 730 (1967).
3. J. C. Ridley, *Milbank Mem. Fund Quart.* **37**, 227 (1959).
4. P. S. Rosenkrantz, S. R. Vogel, H. Bee, I. K. Broverman, D. M. Broverman, *J. Consult. Clin. Psychol.* **32**, 287 (1968).
5. For each subject a mean and standard deviation were computed across her 366 responses (masculinity, femininity, and self-responses to each of 122 items). Sigma scores were then computed by the formula $(\chi - \bar{\chi}/\sigma$.
6. B. J. Winer, *Statistical Principles in Experimental Design* (McGraw-Hill, New York, 1962), p. 374.
7. G. W. Allport, *Becoming* (Yale Univ. Press, New Haven, Conn., 1955); A. H. Maslow, *Motivation and Personality* (Harper, New York, 1954); C. R. Rogers, *Client-Centered Therapy; Its Current Practice, Implications and Theory* (Houghton, Boston, 1951).
8. I. K. Broverman, D. M. Broverman, F. E. Clarkson, P. S. Rosenkrantz, S. R. Vogel, *J. Consult. Clin. Psychol.*, in press.

3 November 1969

Perceptual Restoration of Missing Speech Sounds

Abstract. *When an extraneous sound (such as a cough or tone) completely replaces a speech sound in a recorded sentence, listeners believe they hear the missing sound. The extraneous sound seems to occur during another portion of the sentence without interfering with the intelligibility of any phoneme. If silence replaces a speech sound, the gap is correctly localized and the absence of the speech sound detected.*

We frequently listen to speech against a background of extraneous sounds. Individual phonemes may be masked, yet comprehension is possible. In a study of the effect of transient masking sounds, it was found that replacement of a phoneme in a recorded sentence by a cough resulted in illusory perception of the missing speech sound. Further, the cough did not seem to coincide with the restored sound.

In the first experiment exploring this phonemic restoration effect, 20 undergraduate psychology students were tested. The stimulus was a tape recording of the sentence, "The state governors met with their respective legislatures convening in the capital city," with a 120-msec section deleted and replaced with a recorded cough of the same duration. The speech sound removed (as determined by slow movement past the playback head and confirmed by a sound spectrograph) was the first "s" in the word "legislatures" together with portions of the adjacent phonemes which might provide transitional cues to the missing sound. The subjects were told that, after listening to a cough occurring somewhere in a sentence, they would be given a typewritten statement of the sentence so that they could circle the exact position at which the cough occurred. They were told also that they would be asked whether or not the cough replaced completely the circled sounds. The stimulus was heard binaurally through headphones in an audiometric room at 80 db (peak), and the cough was heard at 86 db (peak) above 0.0002 microbars.

Nineteen subjects reported that all speech sounds were present (the single subject reporting a missing phoneme selected the wrong one). The illusory perception of the absent phoneme was in keeping with the observations of others (graduate students and staff), who, despite knowledge of the actual stimulus, still perceived the missing phoneme as distinctly as the clearly pronounced sounds actually present.

No subject identified correctly the position of the cough, and half the subjects circled positions beyond the boundaries of the word "legislatures." The median distance separating responses from the true position was five phonemes. These errors were rather symmetrically distributed in time, with 11 subjects placing the cough early, and 9 late.

In order to determine whether phonemic restorations could be obtained with another extraneous sound, a second group of 20 subjects was tested under the same procedure except that the cough was replaced by a 1000-hz tone (intensity equal to the peak intensity of the cough). Results similar to those of the first experiment were obtained.

Every subject reported that all speech sounds were present, and no subject identified the position of the tone correctly. Eight subjects circled positions beyond the boundaries of the word "legislatures," the median distance separating responses from the true position was three phonemes, and most subjects (13) placed the tone earlier than its actual position, although this tendency to early placement was not statistically significant.

The inability to identify the position of extraneous sounds in sentences has been reported (*1*). In these studies very brief intrusive sounds (clicks and hisses) were used, and, as considerable care was taken to ensure that no phoneme was obliterated or masked, phonemic restorations were not observed. Inability to identify temporal order is more general than had been thought; it occurs with sequences consisting solely of nonspeech sounds such as hisses, tones, and buzzes. It was suggested that accurate perception of order may be restricted to items which may be linked temporally to form speech or music (*2*).

Phonemic restorations are linked to language skills, which enable the listener to replace the correct sound. The experiments involving the deletion of the first "s" in "legislatures" did not permit the listener familiar with English any choice (that is, no other sound could produce an English word). But, Sherman (*3*) found that when a short cough was followed immediately by the sounds corresponding to "ite," so that the word fragment could have been derived from several words, such as "kite" or "bite," the listener used other words in the sentence to determine the phonemic restoration; when the preceding and following context indicated that the incomplete word was a verb referring to the activity of snarling dogs, the ambiguous fragment was perceived quite clearly as either "bite" or "fight."

Phonemic restorations are not restricted to single phonemes, but may involve deleted clusters of two or three sounds. Also, extraneous sounds other than coughs and tones (for example, buzzes) may be used to produce the illusion. But, when a speech sound was deleted and not replaced with an extraneous sound, the gap was recognized in its proper location, and illusory perception of the missing sound did not occur. Of course, unlike extraneous sounds, a silence would not occur normally unless produced by the speaker. Also, silent intervals have functions akin to phonemes, requiring their accurate identification and localization for speech comprehension.

The ability to understand speech with masked phonemes is not surprising; the redundancy of language can account readily for this. However, our lack of awareness of restorative processes—our illusory perception of the speaker's utterance rather than the stimulus actually reaching our ears—reflects characteristics of speech perception which may help us understand the perceptual mechanisms underlying verbal organization.

RICHARD M. WARREN*
Department of Psychology,
University of Wisconsin-Milwaukee,
Milwaukee 53201

References and Notes

1. P. Ladefoged and D. E. Broadbent, *Quart. J. Exp. Psychol.* **12**, 162 (1960); T. G. Bever, J. R. Lackner, R. Kirk, *Percept. Psychophys.* **5**, 225 (1969).
2. R. M. Warren, C. J. Obusek, R. M. Farmer, R. P. Warren, *Science* **164**, 586 (1969).
3. G. Sherman, unpublished study.
4. Supported by PHS grant NB05998-03 and by the University of Wisconsin-Milwaukee Graduate School. I thank C. J. Obusek for assistance.
* Visiting Scientist until August 1970 at the Institute of Experimental Psychology, Oxford University, Oxford, England.

12 November 1969

Behavioral Measurement of Neural Poststimulation Excitability Cycle: Pain Cells in the Brain of the Rat

Abstract. *A new technique in which elicited behavior of the freely moving rat is used to measure the poststimulation excitability cycle of the central neurons mediating that behavior has been adapted from accepted methods of neurophysiology. A continuous train of pairs of brief pulses was delivered to pain systems in the midbrain. Rate of lever pressing to achieve 3-second rests from this stimulation was measured as a function of the interval separating the pulses within pairs. Evidence for latent addition, absolute refractory period, temporal summation, and adaptation was demonstrated. Obtained relationships suggested that three sets of fibers may carry the aversive signal and that synaptic integration of pain in the brain may be related to Stevens' power law functions.*

The differential responsiveness of an organism to the various temporal rates or patterns in which stimuli can occur is determined by the ability of the individual neurons and synapses in the pathways mediating the responses to accept and conduct stimuli at these rates and patterns. Thus, if one knew the excitability of the relevant neurons and synapses to various rates and patterns of stimulation, and if one could control or measure these rates and patterns, then the strength of the overt behavior might well be predicted. Furthermore, it is plausible to expect that the function expressing "response strength" in terms of "stimulus rate," which holds over a large range for overt behavior, should closely mimic in form the strength-rate function for the neurons subserving the behavior. This expectation is important to test because, if it proves in fact to be a general truth, one can then use the strength-rate function observed for any particular overt behavior to tell us much about the nature of the neurons and synapses mediating the connection between the stimulus input and the response output for that behavior.

In essence, this type of approach was employed early by Sherrington in his work on the neural organization of the spinal withdrawal reflex and has more recently been used, for example, by Barlow to study the phenomenon of temporal summation in the human retina (the Bunsen-Roscoe law). In these instances, rate or pattern of stimulation of receptors or peripheral nerves was varied, and a behavioral index such as a leg withdrawal or a verbal report was employed. However, to our knowledge no one has used electrodes to introduce the experimental manipulation of stimulus rate and pattern directly into the central nervous system in the context of this type of approach. We have done so with the idea that it may be possible thereby to analyze something of the nature of the neuronal and synaptic mechanisms underlying those complex behaviors which are organized in the brain.

The success of this approach depends upon first demonstrating that the strength-rate functions for electrically elicited overt behaviors are isomorphic with those obtaining for neurons. Fortunately, since the strength-rate functions for neurons have been generally identified, at least for the peripheral nervous system, it is possible to generate some predictions by which to test the validity of this approach. For example, the more rapidly a neuron is stimulated, the more likely it is that the postsynaptic neuron will fire because of the temporal summation of neurotransmitter in the synapse faster than it can be destroyed; thus, the strength of electrically elicited overt behavior should be greater as the interval between stimulus pulses is shortened. However, since neurons cannot fire to all the stimulus pulses if they follow each other too closely because neurons require a time to recover after each firing (the refractory period), the strength of the electrically elicited overt behavior should not continue to increase indefinitely as the interval between stimulus pulses is shortened, but should even decrease at those intervals falling within the refractory period. The details of our test of these and other predictions follow.

The techniques developed in our experiment were based upon those in which two 0.1-msec negative-going electrical pulses, one (the conditioning or C pulse) followed at a parametrically varied interval by another (the test or T pulse), were used as probes to explore the poststimulation excitability cycle of axons and synapses in the peripheral nervous system. Customarily the responses measured as a function of this interval separating the onsets of the C and T pulse (the C-T interval) were mainly action potentials, compound action potentials, and graded potential shifts recorded from short-term physiological preparations. The phenomena of latent addition, refractory period, super- and subnormality, temporal summation, and adaptation have been elucidated in this fashion, and an impressive correspondence between these phenomena and neuronal features such as size of axon diameter has been established. Our study was designed to show whether the same pattern of poststimulation excitability representative of the phenomena observed from peripheral nervous tissue can also be evidenced in the instru-