Recovery functions of human cortical potentials evoked by tones, shocks, vibration, and flashes^{1, 2}

DENNIS B. GJERDINGEN and RICHARD TOMSIC,³ Central Institute for the Deaf, St. Louis, Mo. 63110

Averaged evoked "V potentials" were obtained from four Ss at five interstimulus intervals from 0.5 to 10.0 sec. Amplitude-recovery functions for vibrotactile, electric shock, auditory, and visual stimulation were quite similar in form but differed in slope. In the range from 1.0 to 5.0 sec, the percentage increase in amplitude for doubling of the interstimulus interval was: for vibration, 48; for shocks, 41; for tones, 35; and for flashes, 16.

The averaged evoked V potential (Davis et al, 1966) is a transient response, conventionally recorded with an "active" electrode at the vertex and the referent at the ear. A similar late (100- to 250-msec) response appears to acoustic transients, vibrotactile stimulation, electric shocks, and flashes of light (Fig. 1) It has been established that the amplitude (N_1 to P_2) of the auditory V potentials increases as the interval between stimuli is increased up to about 10 sec (Davis et al, 1966; Nelson & Lassman, 1968). The relation between amplitude and interstimulus interval (ISI) has been referred to by Davis et al (1966) as the "recovery function."

Some recent results (Rothman, Davis, & Hay, in preparation⁴) suggest a more rapid recovery following electric shocks to the median nerve than for filtered clicks. We undertook the broader task of comparing systematically the recovery functions of the slow potentials evoked by four types of regularly recurring stimuli: tones, vibration of a finger, flashes of light, and electric shocks to a nerve.

METHOD AND APPARATUS

One of our four Ss was a paid volunteer, a 14-year-old female. The other three, members of the staff, were a 47-year-old female and two males, 29 and 31 years old.

The "active" electrode (Beckman miniature silver-silver chloride) was placed about 3 cm laterally from the vertex, aiming to place it over or near the somatosensory projection area contralateral to the stimulated hand (to enhance the vibrotactile response, which is usually weak in adults). The reference electrode was on the right postauricular

area and a ground electrode was on the forehead.

The pass-band of the recording amplifier was 1.0 Hz to 30.0 Hz. An evoked response audiometer (Princeton Applied Research, Model 140) summed and recorded the V potentials, 40 responses for each record. An upward deflection indicated relative negativity at the "active" electrode. The waveforms of the responses are shown in Fig. 1, with the negative and positive peaks at about 100 to 150 and about 200 msec, respectively. This peak-to-peak voltage is our measure of amplitude.

All four types of stimuli were used with each S in each session. The interstimulus intervals (ISI) were 0.5, 1.0, 2.0, 5.0, or 10.0 sec. Stimuli of one type were presented at all five intervals before going to the next type. After the trials for two types had been completed (about 40 min), the S was given a 10- to 15-min rest. Since the serial order of the various interstimulus intervals may have some effect on the amplitude (Rothman, Davis, & Hay⁴), intervals were presented in a random order across three sessions. The two male Ss sat later for two more sessions, and for them

Fig. 1. Evoked potential records obtained from the same S at an ISI of 5.0 sec for four modalities of stimulation. Upward deflection means vertex more negative. Electrodes: parietal and high postauricular. The latencies include conduction time in the tactile and shock modalities and photochemical processes in the eye in the visual modality. The longer latency of response to shock and flash compared to tactile is due chiefly to the delay introduced by a relay in the control circuit.

each interval occurred at least once in each serial position (1st, 2nd, . . . 5th) for each type of stimulus. This we call the "balanced condition."

The stimuli were as follows: (1) Auditory—Tone bursts at 1,000 Hz, 65-dB hearing level (ISO), 100-msec duration, 20-msec rise-decay time, presented binaurally through Sharpe HA-10 earphones. (2) Tactile—Vibratory bursts at 125 Hz, 100-msec duration, delivered to the distal phalanx of the middle finger. The finger pad rested on the rod of a vertically mounted Goodman V47 vibrator. The hand and the vibrator were placed in an acoustically sealed box (Hay, 1970), to attenuate the sound of the vibrator. The Sharpe circumaural earphones were worn and the combination rendered the stimuli inaudible. The amplitude of vibration was just below the discomfort level. (3) Visual—The S looked directly at a Grass photostimulator PS2 at 1-m distance. The intensity setting was "2." (4) Shock—dc pulses, 3 msec in duration, from a Grass S4 stimulator and SIU 478 isolation unit were delivered to an electrode attached to the wrist over the median nerve and another on the upper forearm. The wrist electrode was cathodal. The pulses were 1 V below the threshold for a twitch of a muscle of the thumb.

RESULTS

(A) Balanced Trials:

Two Ss, Five Sessions Each

The peak-to-peak amplitudes of response were measured and the median values found across sessions for each S, each interstimulus interval, and each type of stimulus. For both Ss and all four types of stimuli, the median amplitude showed a monotonic increase with increase in the interstimulus interval from 0.5 up to 5.0 sec. One S showed a further increase with shocks for interstimulus intervals of 10.0. The other S showed a similar increase for vibration and for flashes. Neither S showed this last increase for tones.

(B) Unbalanced Trials:

Two Ss, Three Sessions Each

These trials were too few to be fully counterbalanced for serial-order effects. Nevertheless, each S showed, for each type of stimulus, a monotonic increase in amplitude of response with increasing intervals from 0.5 sec to 2.0 sec. For one S, the increase continued to the 5.0-sec intervals for vibration and to 10.0 sec for the tones and flashes. For the other S, the increase was continuous to 10.0 sec for tones, shocks, and vibration, but for flashes the 2.0-sec interval yielded the greatest amplitude.

(C) Combined Data:

Four Ss, 16 Sessions in All

The data for each S were normalized,

Fig. 2. Recovery functions for four types of stimulation: average of medians for four Ss. The medians for each S were first normalized, with the amplitude (for the appropriate stimulus) at 2.0-sec ISI taken as 100%. The normalized medians were then averaged across Ss. A straight line for each type of stimulus was fitted by eye to the points for the 1-, 2-, and 5-sec interstimulus intervals. The interquartile range of the normalized amplitudes at 2-sec ISI ($N = 16$) is shown by the vertical bar above the cluster of points. The data are too scanty for meaningful measures of dispersion at the other points, but the range of amplitudes is particularly large for the responses to shock and to vibration at 10-sec ISI.

taking as 100% his median response for each stimulus at the 2.0-sec interstimulus interval. The median values were then averaged across Ss. Figure 2 displays these average amplitudes for each type of stimulus. Straight lines were fitted by eye to the points at 1.0-, 2.0-, and 5.0-sec ISI for each type of stimulus. Note that the points for the 10.0-sec ISI fall on the appropriate straight lines for flashes and for shocks but below the lines for tones and vibrations. The responses at 0.5-sec ISI were small for all types of stimuli and were frequently distorted or completely obscured by the background noise.

The slopes of the recovery functions plotted in Fig. 2 are conveniently expressed as the percentage increase in amplitude of N_1 - P_2 produced by doubling the interstimulus interval within the range from 1 to 5 sec. The increases are, for vibration, 48%; for shocks, 41%; for tones, 35%; for flashes, 16%. The recovery function for flashes has much the flattest slope of the four.

CONCLUSIONS AND DISCUSSION

The amplitudes of the responses to all four types of stimuli conform to a linear function fitted to the three middle interstimulus intervals (1.0, 2.0, and

5.0 sec) when amplitude is plotted against the logarithm of the ISI. The recovery functions level off between 5.0 and 10.0 sec for tones and vibration. Nelson & Lassman's data (1968) indicated such a leveling off for tones. Our points at the 10.0-sec ISI still fall on the straight line for both flashes and shocks. Actually the 10.0-sec ISI point for shock is relatively high in the averaged data because of one S who had an extremely high-amplitude response at that interval. The data from the other three Ss showed a leveling off at 5.0-sec ISI for shocks. Thus the shock, vibrotactile, and auditory modalities have recovery functions that are similar in slope and also in the ISI at which they "level off," while the visual recovery function is clearly different.

No single S's data could be fitted satisfactorily with a straight line for each modality. One S's recovery function for vision and another's for shock leveled off as early as 2.0 sec. These deviations seem to be random and may or may not be characteristic of the individual. The suggestion of Rothman, Davis, & Hay⁴ that a more rapid recovery may follow shocks than tones was confirmed for only one of the four Ss. We interpret their results as

due to variability or individual differences, or both.

REFERENCES

- DAVIS, H., MAST, T., YOSHIE, N., & ZERLIN, S. The slow response of the human cortex to auditory stimuli: Recovery process. *Electroencephalography & Clinical Neurophysiology*, 1966, 21, 105-133.
- HAY, I. S. The slow cortical evoked potential: Cross-modality interaction of auditory, vibro-tactile and shock stimuli. Unpublished MA thesis, Washington University, January 1970.
- NELSON, D. A., & LASSMAN, F. M. Effects of intersignal interval on the human auditory evoked potential. *Journal of the Acoustical Society of America*, 1968, 44, 1529-1532.
- ROTHMAN, H. H., & DAVIS, H. The amplitude of slow evoked cortical responses in relation to temporal features of stimulation. *Electroencephalography & Clinical Neurophysiology*, 1969, 27, 699-700.

NOTES

1. This investigation was supported by Public Health Service Grant NB-03856 from the National Institute of Neurological Diseases and Stroke.
2. The authors thank Dr. Hallowell Davis for the suggestion of the problem and for his guidance in the conduct of the experiments and in preparation of the manuscript.
3. Present address: Department of Psychology, Florida State University, Tallahassee, Fla. 32306.
4. Rothman, H. H., Davis, H., & Hay, I. S. Slow evoked cortical potentials: Interactions of electrical and auditory stimuli. In preparation.

The effects of delayed judgmental similarity on evaluative attraction

GUILLERMO F. MASCARO, *University of Florida, Gainesville, Fla. 32601*, and JOSE A. LOPEZ, *Embry-Riddle Aeronautical Institute, Municipal Airport, Daytona Beach, Fla. 32015*

The effects of three levels of judgmental similarity on evaluation and attraction were investigated under noninteraction delayed-feedback conditions. Significant

effects of similarity on attraction and on evaluations of intelligence and knowledge were found. However, the effects of judgmental similarity on evaluations of morality and adjustment were not significant. The results were discussed by contrasting the effects of judgmental similarity (i.e., conceptualized as cognitive attitudinal component) on evaluative attraction with the effects of similarity in the evaluative attitude dimension.