AN INVESTIGATION INTO SOME OF THE OBJECTIVE DATA ON THE INTERRELATIONSHIPS OF THE HUMAN SENSES AS THEY MAY BE RELATED TO SPEECH CORRECTION

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BIOGRAPHY

The author was born in Flint, Michigan, on September 12, 1923. He was graduated from the Michigan School for the Blind, Lansing, Michigan, in June, 1941. In the fall of the same year further studies were begun at Michigan State College.

In August of the summer following his freshman year he was seriously injured but reentered Michigan State College in the fall of 1943 and was graduated in 1947 with a B.A. degree in Speech with emphasis on Speech Correction.

After a semester of graduate studies at the University of Michigan he returned to Michigan State College to take advanced work in the department of Philosophy. In the spring of 1949 he transferred to the graduate school of Speech, Dramatics, and Radio Education, majoring in Speech Correction and minoring in Psychology. This thesis partially completes the requirements for the M.A. degree in Speech Correction.

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CHAPTER I

INTRODUCTION

It is known by correctionists that there are three sensory avenues of approach in speech rehabilitation. The avenues are audition, vision and kinesthesia. These senses cooperate in the learning and production of oral communication. However, the capacities and functionings of them are not fully known. It is hoped that this study, a major portion of which is a bibliographical collection, will help the speech correctionist to broaden his application of these avenues of therapeutic procedure.

It is necessary in the advancement of science for the experimenter to know what has been done in his specific field before he attempts an experiment. Speech therapists wishing to further their understandings of intersensory processes in like manner must inform themselves of important work done in this area. This is an exacting task for work shedding light on intersensory mechanisms is found in many different realms of study. Psychology, physiology, education, neurology, and anatomy are some of the divisions of knowledge which are partially devoted to sensory interrelationships. There are few books concerned wholly with this subject and a larger number which devote only a paragraph or two to intersensory processes. Many articles can be found, however, in numerous periodicals. A bibliography containing these scattered studies should prove very helpful for future investigations by speech correctionists.

Chapters II, III and IV consist of studies selected from the fields of psychology and physiology. They have been annotated. The studies are thus presented so as to inform the reader of the problem to be solved, the methods which the experimenter used, and his interpretation of the data obtained. The researches which will be described are not conclusive but will show some trends of research in this area of intersensory processes. The information in these chapters may be applicable to the understanding of some of the correctionist's problems. The annotations found in Chapter II are entitled "Vision Intersensorywise." The studies represented in this chapter are concerned first with heteromodal facilitation of vision. It next deals with non-visual brightness effects on vision and the body as a whole. And lastly, the question of synesthesia or tone-color is touched upon. Chapter III, "Hearing Interrelated with Other Senses," delves into the question, "Can non-auditory stimulation bring about a facilitation of hearing?" Auditory localization of sound is then given followed lastly with a study providing evidence that obstacle location by the blind is afforded by audition. Chapter IV is headed "Kinesthesia in Intersensory Processes." It reveals through studies concerned with motor consciousness the importance of kinesthesia in thinking. Chapter V, which is the major portion of this work, is the large bibliography collected so as to facilitate future studies in intersensory processes. Chapter VI, "Some Thoughts on Intersensory Relations," poses some possibilities which may be drawn from the annotations in Chapters II, III and IV.

In the past there have been surveys on intersensory relationships. One in particular, "Intersensory Facilitation and Inhibition," by G. M. Gilbert, which was published in 1941 in The Journal of General Psychology pertained only to the interfunctionings of senses and not to their social applications. Another study by J. D. Harris published in 1948 was limited to Some Relations Between Vision and Audition. Here again social application was not considered. Another such publication, Problems of Physiological Psychology, by J. R. Kantor, contains several chapters dealing with intersensory processes. In them he summarizes experiments and their interpretations. There are, as listed above, many publications by numerous scientists which contain bibliographies limited to the specific fields in which they work.

One great stride toward social application of facts found in experiments on intersensory functionings was made by Sara M. Stinchfield and Edna Hill Young. They devised a moto-kinesthetic approach in speech rehabilitation. Other workers in the field have developed numerous methods which involve intermodal functions. These methods have been evolved emperically and many have not been published. This paper may aid correctionists in developing new approaches, attitudes and methods in the cause of better speech correction.

Intersensory process is of broad aspect. Therefore, a limitation of scope will be necessary. Chapters II, III and IV will consider only the capacity of one or several senses to substitute for or facilitate the function of another.

The bibliographies, both the annotated and the source, consist of selections taken from the suggestions of men working in the various fields and the use of references found in researches and bibliographical surveys. Because of this it is difficult to catagorize the different areas in which there has been scientific research aimed at uncovering the interrelationships of the senses. Therefore, it shall not be attempted.

CHAPTER II

VISION INTERSENSORYWISE

The annotations found in this chapter are based on publications of various researches aimed at discovering the relationships of heteromodal stimulation on vision. The results of experiments, of which the following are a sample, tend to show that the data obtained from them do not always support any prejudged conclusion, and that the results of some researches tend to contradict each other.

The first three of the following studies by Kravkov, Serrat and Karwoski, and Allen and Schwartz investigate facilitational effects of one or several senses upon vision. On the other hand, the studies of Walter Börnstein which follow disclose the effects of heteromodal bright and dark stimuli upon the light adjustment of the eye and its general tonic influence throughout the body. The last annotation in this group on the work of T. H. Howells reveals some relationship between tone and color.

It should be concluded, however, that even though some contradictions may crop up, some of the results of several of the following researches may be interesting to the speech correctionist. He may ask himself, after reading an annotation, "How does this relate to speech correction problems?" The answer to this question may bring understanding or perhaps better insight into the correction problem at hand.

Kravkov, S. V., "Changes of Visual Acuity in One Eye Under the Influence of the Illumination of the Other or of Acoustic Stimuli," Journal of Experimental Psychology, XVII:805-812, 1934.

Kravkov is defending his experimental investigations which to him and his collaborator, Mrs. O. P. Holmskaya and two other investigators, Chikot Gotoh and Warren W. Wilcox, consider to be scientifically correct. He says that the border line between black and white is never sharply delineated upon the retina, owing to the imperfect accommodation of the eye and the phenomena of spheric and chromatic aberration; the region of maximum illumination is never directly contigeous with that of minimum illumination, but there is a gradual melting of one into the other. But acuity of vision can be increased by greater illumination when black squares are viewed upon a white background. The acuity decreases at a certain point with increasing illumination when white squares are viewed upon a black background. Also visual acuity will be heightened in the right eye when viewing black squares on a white background when the left eye is separately stimulated. The same effect can be observed when an auditory stimulus is given.

Kravkov states that the following is scientifically correct; visual acuity is heightened by central stimulus gained from extra excitation caused by hearing or the left eye when the right eye is viewing black squares on a white background. The opposite is true if the excitation of the left eye or of hearing accompanies the viewing of white squares on a black background when illumination of the viewed scene reaches a certain degree of intensity.

Kravkov and his associates have shown that a sound stimulus can, under a given situation, result in better visual acuity. The same effect takes place when the left eye is stimulated with light while the right eye is doing the task. But Serrat and Karwoski are not able to concur with Kravkov as can be observed in the next annotation.

Serrat, W. D. and T. Karwoski, "An Investigation of the Effect of Auditory Stimulation on Visual Sensitivity," Journal of Experimental Psychology, 19:604-611, 1936.

Two experiments on the measurement of the effect on visual sensitivity of simultaneous stimulation with a tone are presented.

Apparatus

The apparatus consisted of two units, (1) a spectral light source and (2) a source of sound. For the first, a Gaertner Rapid Setting Monochromater was used. An image of the exit slit was focused upon an artificial pupil. A chin rest and individual biting boards containing the subject's dental impression on beeswax were placed conveniently near the artificial pupil so that the observer could look through the pupil and maintain steady fixation. The field of observation was a patch of light defined by a diaphragm in front of a condensing lens. The diaphragm subtended a visual angle of 1°55'. In the center of the diaphragm was mounted a small nickel-plated ball. This served as a fixation-point when illuminated by a fine pencil of rays from a flashlight bulb whose intensity was regulated through a rheostat. The voltage of the spectral light source was kept constant; change in the intensity of the stimulus was accomplished by a wratten neutral tint wedge placed in front of the exit slit. The wedge was moved by a screw to which a crank was attached for the purpose of easy adjustment. An indicator moving upon a millimeter scale showed the position of the wedge. The wedge was 10 cm long with a transmission range from 1 to 1/1000.

Sound was obtained by means of an oscillating circuit containing an amplifying stage. The sound was transmitted to the subject's head by means of radio head-phones. A sound of 410 d.v. was used. The way of specifying the intensity available here was by means of a Dorsey pheneloscope. One of the head-phones was placed a quarter of an inch from the diaphragm of the instrument. With this arrangement the beam reflected from the instrument registered a deflection of 3.5 inches on a screen 63 inches distant.

Three subjects took part in the experiment. All subjects devoted at least one sitting to practice in determining thresholds.

In the study, procedure was as follows. The observer was dark adapted for about 15 minutes. Then he seated himself comfortably with his chin supported in such a way that his right eye was in position for the artificial pupil. A ready signal was given and shortly following it sound and light were presented simultaneously. The threshold was determined by a modified method of limits, the experimenter simply moving the wedge until the subject reported the threshold condition. The sound continued until the threshold was announced by the observer. Between trials the overhead lights, which were partially draped with a dark cloth, were put on for a few seconds. Then a pause of several seconds was made to allow for dilation of the pupil before resuming the observations. This procedure was followed because it promoted easy and constant fixation. Each subject made 50 ascending and 50 descending judgments for both the normal and sound series. The judgments were divided between the sound and the no-sound series in bunches of ten; after 10 judgments with sound, 10 without were taken, etc.

For this experiment a spectral light of 506 mu was used. The test field was observed through an artificial pupil 2.5 mm square.

No significant differences between normal and sound series were present.

The second experiment was to discover the effect of auditory stimulation of the specific threshold for color. For this purpose a spectral light of 710 mu was chosen because the total or nearly total lack of the photochromatic interval at the red end of the spectrum renders easier the judgment of presence or absence of hue. Furthermore, light from the extreme red end is not affected by dark adaptation as much as are other spectral lights so that the sensitivity for the parafoveal region, at least up to 10 degrees, is very close to that of the fovea. Slight shifts in fixation should therefore not affect the threshold. The artificial pupil was removed to add to the comfort of the observer, since it was believed to be unnecessary for work involving dim lights and especially with the large pupillary dilation under conditions of dark adaptation. A further simplification consisted of introducing a diffusing fine ground glass at the diaphragm in order to produce a surface of diffused light. Under these conditions the stimulus would not be easily obliterated if the eye was moved slightly as would happen if the beam were left focused on the lens of the retina. Constant stimuli was substituted for the modified method of limits in the former experiment.

The previous procedure of dark adaption was again followed. Two subjects were given 480 readings. After five readings per step were obtained, a rest period followed, and then repeated. Each rest period initiated a change from one experiment to the other with or without sound.

These results confirm those obtained in the previous experiment. Not only are the differences negative in character but in most cases they are only a fractional part of the probable error values.

The experiments here presented indicate that visual sensitivity as measured in terms of the threshold for light and color is not enhanced with simultaneous stimulation with an auxiliary sound stimulus.

These results are discussed with reference to the reported observations that visual acuity is increased in the presence of a simultaneously acting auxiliary stimulus. Since the threshold for light is a direct measure of the sensitivity of the retina, the negative results obtained between sound indicate either (1) that the alleged cortical diffusion is obtainable under particular conditions, not covered by these experiments, or (2) that the mechanism of diffusion is of such a nature that sensitivity for light is not primarily affected.

Although the above experiment could not provide facilitation of vision, it should not be inferred that such a facilitation cannot take place. In the following research Allen and Schwartz agree with Kravkov. They find that heteromodal stimulation does bring about visual facilitation.

Allen, F., and M. Schwartz, "The Effect of Stimulation of the Senses of Vision, Hearing, Taste, and Smell upon the Sensibility of the Organs of Vision," Journal of General Physiology, 24:105-121, 1940.

The purposes of the experiments are to discover the effect of stimulation of the senses of taste, smell and hearing upon the perception of colors, and also the effects of the stimulation of vision, hearing, taste and smell upon the oscillation of sensitivity of vision.

For convenience of investigation the critical frequency of flicker of the colors of the spectrum was observed before and after the stimulation of the other senses. By comparing the measurements obtained under both conditions, the influence of the other senses upon vision was determined.

The method of experimentation was as follows: A spectrum was obtained from an incandescent lamp of seventy-five watts which was kept at a steady brightness by a fine rheostat with a voltmeter placed across the terminals of the lamp to insure a constant potential difference. A Hilger spectrometer with the equivalent of three sixty degree prisms gave a spectrum of wide dispersion, a small portion of which of any desired wave-length was isolated in the eyepiece by adjustable shutters. Between the lamp and the slit a sectored disc was rotated by an electric motor whose speed was controlled by a leather brake resting upon the axle. To the rear end of the axle was attached a speed-counter which made electric contact every fiftieth rotation of the armature and disc, and the moment of contact was recorded on a strip of paper on a chronograph simultaneously with time indications from a clock beating half-seconds. By measuring these two records, the time of rotation of the disc, and hence the duration of a flash of color upon the retina at its critical frequency of flicker was accurately determined. In making a normal graph of the spectrum for purposes of comparison with those obtained after stimulation of the other sense organs, the eyes were kept adapted to ordinary daylight illumination of the room between the hours of 10:00 a.m. and 3:00 p.m. A selected patch of the spectrum whose wave-length was obtained from the calibration curve was viewed in the eyepiece, the disc was rapidly increased in rotation until the critical frequency of flicker was reached, and while this speed was maintained steady by the brake, the record was made upon the chronograph. The sense of hearing, taste or smell, or vision itself, was then adequately stimulated for two minutes and the measurements of the critical frequency were repeated immediately or after various intervals of time. This procedure was repeated for colors throughout the spectrum. The graphs for the normal and induced states of vision were then drawn together, and from their differences the effect of stimulation of any sense organ upon vision was determined. Since the physical brightness of the spectrum remained unchanged, the differences between the two graphs revealed the physiological changes in brightness, whether increased or diminished, and hence the alterations in responsiveness or sensitivity of the visual sensations, which stimulation of another sense had induced.

The experiment indicates that the stimulation of the three sense organs influences the responsiveness of vision. It is found that stimulation with red light, sound, quinine, and odors produces by its immediate action much the same effect upon vision, which is the depression of the red sensation and the enhancement of the green; the violet sensation for some reason being sometimes depressed and at other times enhanced in sensitivity. The magnitude of the visual effect seems in all cases to be about the same. Since stimulation of various senses demonstrably affects vision, stimulation of the eyes probably reciprocally affects those senses. It seems to be impossible to stimulate or influence in any manner a single color sensation alone.

It is shown also in the case of stimulation of the ear, that the intensity of the stimulus may be a determining factor in producing enhancement or depression of the sensitivity of the visual sensations. For it was found that loud and weak tones of the same low pitch evoked opposite conditions of responsiveness in the organ of vision. Also, it was shown that stimulation of the left ear evoked an enhanced visual response in the right eye.

In the above study heteromodal stimulation achieved facilitation in color brightness. At times, however, in the case of violet light a darkening occurred. The reason for this was not known. Would the cause be, as Walter Börnstein might tentatively suggest, that the effects of bright and dark stimulation of some of the various senses might cause this phenomenon? The passages below describe the results of Walter Börnstein's four series of experiments.

Börnstein, Walter, "On the Functional Relations of the Sense Organs to One Another and to the Organism as a Whole," Journal of General Psychology, 15:113-117, 1936.

Börnstein says it is to be expected that a brightness-excitation taking place on one field of sense will be regularly modified--strengthened or weakened--by a supervening stimulus from another field of sense. As a test organ for his experiments he has utilized the sense of sight, as changes in the phenomena of brightness are most easily observed in that field.

The degree of brightness in the optic and acoustic fields depends upon the amplitude and frequency of the light--or sound--vibrations: yellow (amplitudes being equal) is brighter than red; a high note is brighter than a deep one. In the same was, as vonHornbostel has shown, in other fields of sense the brightness of a perception-content is plainly determined by the nature of the stimulus. Sharp skin stimuli, for instance, have a bright effect, blunt ones a dark; cold has a bright effect, warmth a dark, urea and cane-sugar taste bright (cold), megnesium sulphate dark (warm); a sharp pain is bright, a dull pain dark.

For smells, vonHornbostel in 1933 drew up the following series of increasing brightness by way of example: sylenol 1,3,5; a cresol; benzol; a pine; citral; citronella; citronellold; citronellol 1.

According to vonHornbostel, the faculty of perceiving brightness and darkness is an intermodal primitive function of all sense organs.

First Series of Experiments

The Principle of the Additive Effect of Brightness Excitation

The mode of conducting the experiment is this: the subject sits in darkness, about two meters distant from a dull-surfaced disc of 35:25 cm lit evenly from above the threshold. As the disc is looked at, there occur, with differing strengths in different individuals, spontaneous variations in the subjective brightness of the disc, which are first of all observed as to their degrees. In ten to fifteen minutes from the start of the experiment, while the subject continues to contemplate the disc, there is brought into play non-optical bright or dark stimuli.

It is seen that when bright stimuli are brought to bear, for instance harmonium notes from the second to the fourth octave, or a bright smell, taste, or tactile stimulus, the disc often lights up subjectively far above the spontaneous variations, that its contours become more sharply defined, that it appears more solid; and that when dark stimuli are brought to bear-deeper notes, a dark smell or taste, then the disc darkens, its contours become blurred, and the surface takes on a looser appearance.

From this first series of experiments it can be seen that: Bright non-optical stimuli have upon an optical brightness-perception a brightening effect; and dark stimuli a darkening effect. Heteromodal supervening sense-stimulation affects the already active brightness-excitation on the optical sense; and that not by contrast-i.e., in a weakening manner-but in the direction of its own "brightness," thus giving the principle of the additive effect of brightness-excitations.

This result has been obtained in thirty-five out of every fifty cases.

Second Series of Experiments

The heightening of bodily tone by brightness-excitations; "phospenes" as an expression of heightened tone.

The hypothesis to be proved is: that the contractile substance of the retinal cones is functionally equivalent to the muscular system of the body, and forms a part of the tone-apparatus.

If this hypothesis be correct, then heightenings of the bodily tone-whatever may be the causes producing them, most always effect an increase in the contraction of the retinal cones, that is, "light-adjustment." In the expectation that light-adjustment would make itself subjectively noticeable by the occurrence of "phosphenes," that is to say, entoptical (colored or colorless) light-phenomena, the following experiments were carried out.

1. Heightening of bodily tone by active contractions of muscles of the body:

   The subject lies relaxed in darkness, until the eyes have completely adapted themselves to the darkness.

   If now a powerful contraction is effected at any part of the body, say for instance an arm is strongly flexed at the elbow or extended against passive resistance, then there become visible to the eyes--caused by the movement in question--luminous phenomena, which, moreover, are stronger on that side of the body upon which the contraction takes place.

2. Heightening the bodily tone by non-optical brightness-exciting stimuli:

   Again the subject lies completely at rest in darkness, until adaptation has taken place. Then bright and dark non-optical stimuli (sounds, smells, tastes, or tactile stimuli) are brought to bear upon the subject.

   These experiments were carried out upon seventy persons.

Here again, in about thirty per cent of the cases no influencing of the entoptical phenomena by heteromodal sense-stimuli was observed; and yet they were the same subjects who had shown themselves refractory to such induction in the first series of experiments.

3. <u>Appendix to the second series of experiments</u>

The objection, that the results observed in these experiments might be founded upon "associations," is automatically refuted by the fact that phosphenes are also induced by brightness-exciting stimuli which are imperceptible to the senses of the subject. Ultra-violet rays played on the bare back of a subject after adaptation to the darkness, and whose head has been completely insulated against rays of light, causes lightness-phosphenes to appear, after a time of one-half minute to one and one-half minutes. The subject at a distance was four feet from the ray-source. From twenty subjects positive results have always been obtained. Visible light rays at the upper end of the spectrum also produced positive results with diminishing returns as the lower end of the visible spectrum is reached. Heat rays, however, induce no phosphenic effect whatever.

Third Series of Experiments

The problem of this series is: does the Purkinje phenomenon hold when the persons are subjected to non-visual light and dark stimulation.

The experiment is carried out as follows: two revolving colored discs are placed side by side, one of which always bears the same shade of red, and the other a blue color that can be rendered darker to lighter by a measurable admixture of black. To begin with, in the twilight, both colored discs are adjusted to equal brightness. Then non-optical brightness-and-darkness-exciting stimuli are brought to bear, and a new brightness-equation established, in order to ascertain whether, and if so in what direction, a modification of the Purkinje phenomenon has taken place. This method of carrying out the experiment has the advantage that it can be executed without the subject's seeing through it, and also that the results obtained can be determined quantitatively.

These experiments have so far been carried out only upon nine persons. Moreover, those subjects who had been refractory in the first series of experiments proved refractory here also. Those subjects who had proved positive in the first series of experiments, except one case, reacted positively here also. This series of experiments, however, is not yet sufficient to allow binding conclusions.

Fourth Series of Experiments

In the case of the frog it has been proven experimentally that hormonal modification is a consequence of simple exposure to light; blood from a "dark" frog (i.e., one that has been kept in darkness for twelve to twenty-four hours) injected into the enucleated eye of another dark frog induces no change. The blood of a frog that has been exposed to light induces lightness-adjustment in the retina of the eye of a dark frog.

Further Information on Börnstein's
Studies on Hormonal Modification
by Light can be Found In:

Börnstein, Walter, (Contribution to the Problem of the Physiological Foundations of Perception. II. On the Influence of "Light" and "Dark" Stimuli on the Condition of the Melenophores of the Amphibian Skin). Achives Internationales de Pharmacodynamie (et de Thérapie) Bruxelles-Paris. 61:387-417, 1939. Biol. Abstr. XLII: 13051. Location: Library of the University of Michigan, Ann Arbor, Michigan.

The reader has observed from the first series of experiments that bright non-optical stimuli have a brightening effect upon an optical brightness-perception and a darkening stimuli a darkening effect. The second series shows that the contractile substance of the retinal cones is functionally equivalent to the muscular system of the body, and forms a part of the tone apparatus as is defined in this group of experiments according to the appendix of series two, the results found in the serious should not be attributed to learned associations in the last series it appears that the Purkinje phenomenon does not hold when non-optical brightness and darkness-exciting stimuli are brought to bear, for a new brightness-equation is established.

The fourth series of Walter Börnstein's studies proves experimentally that hormonal modification is a consequence of simple exposure to light.

The question may be asked, "Does the phosphenic phenomenon discussed in the appendix of series two occur because of the hormonal modification of simple exposure of light discussed in series four?"

The last annotation of this chapter investigates synesthesia through learned associations.

Howells, T. H., "Experimental Development of Color-Tone Synesthesia," Psychological Bulletin, abstract, 34:714, 1937.

Reports of synesthesia cases bring forth the question of whether coupled senses are native or acquired. Also the problem arises as to whether or not sensory qualities are a discrete product, limited to a specific sensory mechanism, or whether they are the joint production of a plurality of various mechanisms, or perhaps of the whole organism. Sense theories may be influenced by the resolution of the issue. There is also a need to supplement the available subjective reports with objective data regarding synesthesia.

The particular experimental problem was influencing apparent color by accompanying tones which were previously associated with various color stimuli.

The method of this experiment was presenting for one second two identical patches of either green or red light in random order. Red was usually associated with the low tone (low c). Green was associated with the higher tone (middle c), however, the opposite associations were occasionally introduced. The task for theobserver was naming the color correctly every instance. After 5,000 trials intensity of the hue diminished at a steady rate until the colors became a pale but a recognizable standard.

Eight subjects completed 20,000 plus trials. The ratio of errors significantly increased for seven subjects, ranging from 24 per cent to sixty-six per cent. These subjects made a significant increase of errors over and above the control series without tones. Three conditioned subjects were given a test series which used only white stimuli. Color reports corresponded with tones although one subject began to suspect the patches were white. Subjects reported that the hues corresponded with associated tones but apparently shifted to the other color as the tone ceased.

This study would indicate that synesthesia is a learned phenomenon. Although the results of the foregoing researches are not definitely correlated, they present some pertinent experiments dealing with the relationships of heteromodal stimulation on vision.

Though Serrat and Karwoski could not find heteromodal stimulization causing visual facilitation, Kravkov and Allen and Schwartz found that sound, smell and taste did create facilitational effects. In a different phase of intersensory processes Börnstein showed that bright and dark stimuli on various senses produce a contractile effect upon the cones of the eye. He also demonstrates a physiological or hormonal effect caused by light radiated on non-visual areas. Howells' study investigates the basis of synesthesia.

CHAPTER III

HEARING INTERRELATED WITH OTHER SENSES

The annotations to follow are derived from published experiments dealing with hearing from several aspects. The first two studies by Hartmann, and Child and Wendt, consider auditory facilitation brought about by visual stimulation. A brief account is given, in the third study, of Freund and Hoffmann's results of light radiation upon the deafer side of a subject's head who is suffering from afflictions of the inner ear.

The last two articles in this chapter afford the reader an opportunity to gain some information on how hearing can, in a limited degree, substitute for vision. The first of these two articles refers to the work of Stevens and Newman which demonstrates the effectiveness of the ear in locating the source of sound. The last one by Worchel and Dallenbach gives evidence to show that hearing is the sense used by the blind in obstacle perception. The reader will find in the source bibliography articles dealing with the blind and their orientation by means of sensory substitution. It also contains publications concerning the deaf.

The following study investigates the influence of light upon pitch discrimination in opposition to pitch discrimination in the dark.

Hartmann, George W., "The Facilitating Effect of Strong General Illumination Upon the Discrimination of Pitch and Intensity Differences," Journal of Experimental Psychology, XVII:812-822, 1934.

Is auditory acuity facilitated when the visual sense is stimulated?

The subjects used in the experiments were twenty undergraduate students and twenty graduate students at The Pennsylvania State College.

The Seashore musical records for pitch and intensity were used. The experiments took place in a small laboratory research room with light tan walls. Illumination was gained by two 100-watt, two 75-watt, two 50-watt, and one 40-watt bulbs. A white oilcloth cover upon the table was used. A 10-watt flashlight was also used.

The order of test administration was as follows: The pitch and intensity records were first played in the darkened room and then repeated in the lightened one. The pitch record was the starter on the first night followed by the intensity record; on the second night, the order was reversed with the light condition preceding the dark and the intensity score obtained before the pitch data. Twenty undergraduates served as subjects in this series.

In the second procedure the intensity record was used alone. Without altering the total wattage the brightness was increased by placing a 100-watt bulb about thirty inches before the subject's eyes. For one-half of the group, the order of presentation was 'dark-light-light-dark'; for the other half, 'light-dark-dark-light'.

In the last procedure the 10-watt recording light used for the subject to write his answer was eliminated, because it seemed to prevent the attainment of the sharpest opposition between light and dark conditions. The subject was now in as complete darkness as possible and his reports were vocal. Twenty graduate students participated, ten in the dark-light-light-dark sequence, and ten in the light-dark-dark-light sequence. The pitch and intensity records were both played again this time.

The statistical treatment here followed shows that the mean auditory efficiency as measured by procedures one and two is definitely better by about three per cent in the light than in the dark. In procedure three the effort is almost as sharply reversed in the opposite direction in favor of the dark. The high positive correlations secured between the scores under the two circumstances imply that the improvement under the light condition was fairly uniform for the group studied. The best one can say is that most adult subjects are capable of somewhat finer tonal discrimination under bright light than under dim or dark conditions.

The data observed in the preceding study reveal that light has a slight facilitational effect on perceiving intensity and tonal discrimination by hearing while light was a constant visual stimulus. The supervening work presents several momentary light stimuli in different temporal positions analogous to the sound stimuli.

Child, Irwin, and G. R. Wendt, "The Temporal Course of the Influence of Visual Stimulation Upon the Auditory Threshold," Journal of Experimental Psychology, 23 (No. 2):109-127, August, 1938.

This study is concerned with the influence of a flash of light upon the audibility thresholds for an accompanying tone.

Eleven subjects, nine graduate students and two instructors in psychology took part in the experiment.

The tone was produced in a magnetic-diaphragm-type telephone receiver (Brandes Matched Tone, + Superior). The receiver was attached over the right ear, held by a sponge rubber cap fitting around the concha so that its mouth was about three-fourths inches from the meatus. The tone was not accompanied by any audible click.

For visual stimulation a two-degree circular patch was employed. Between stimulations it was kept at a low brightness level to serve as a fixation field. The stimulus consisted of a period of one-tenth second. The sound stimulus was a one thousand d.v. tone produced in an ear-phone. Its duration was one hundred and sixty-five milliseconds. The tone intensity in any trial was one of five intensities separated by two-decibel steps, and so chosen that approximately half of the tones were below threshold.

This study concerned the influence of a flash of light upon the audibility threshold for an accompanying tone. When the light and tone were simultaneous, or when the light preceded the tone by half a second or one second, there was a highly reliable increase observed in all subjects, in the frequency with which near-threshold tones were reported as heard; the maximum effect was found when the light preceded by half a second. When the light followed the tone by half a second, the facilitating effect was absent for the average of the eleven subjects' results in the first two experimental days but reliably present in the last two days. When the light preceded the tone by two seconds there was no consistent facilitating effect. In all experimental conditions, the maximum facilitating effect was of small magnitude.

The experimental findings of Child and Wendt coincide with Hartmann in that they present facilitation of hearing by light as a heteromodal stimuli. However, the following data described by Freund and Hoffmann found in Hartmann's article gives a different mode of attack on auditory facilitation as can be discovered in the following brief account.

Hartmann, George W., "The Facilitating Effect of Strong General Illumination Upon the Discrimination of Pitch and Intensity Differences," Journal of Experimental Psychology, XVII:814-816, 1934.

The specific influence of light stimulation has been studied by two Viennese physicians, Freund, an actinologist, and Hoffmann, an otologist. They radiated for five minutes with a thousand-watt lamp the deafer side of the heads of patients suffering from high-grade afflictions of the inner ear, and using the whisper test they found that fifty per cent of their clinical cases had an average improvement equal to double the customary acuity. With long wave-lengths of light, the gain set in immediately upon illumination, remained at a fixed level for a time, and they rapidly declined; with short wave-lengths, however, little alteration would be detected during the radiation, the improvement occurring only after a latent time when the reddening of the skin set in. In general, the greater the intensity of the lamp, the better the results.

For additional background compare with: Licht and Hören, Medizinische Klinik, 1929, 1-5, and Ueber den Einfluss des Lichtes auf die Funktionen des Gehör-und Geruchsorgans, Strahlentherapie, 1929, 34, 100-116.

This can be found in the library of the University of Michigan.

A marked facilitation of hearing was achieved by Freund and Hoffmann who radiated light upon the non-visual area proximate to the ear of patients afflicted with disturbances of the inner portion of the organ of hearing. Whether these findings anticipate the disclosures of Walter Börnstein's research or if they are moot to the problem has yet to be considered.

The next two works treat the analogousity of intersensory substitution. The first research deals with the actual location of sound sources by the ear.

Stevens, S. S., and E. B. Newman, "The Localization of Actual Sources of Sound," The American Journal of Psychology, XLVIII:297-306, 1936.

Quantitative information relative to the ability of an S to localize actual sources of sound in free space is prerequisite to the formulation of an adequate theory of localization. The experiment aimed at solving this problem was conducted in the open air.

Apparatus

In order to avoid possible reflecting surfaces a tall swivel chair was erected on top of a ventilator which rises nine feet above the roof of a several storied building. S was thus placed in a position where there were no vertical reflecting surfaces on any side of him to interfere with free passage of sound. The source of the sound was mounted on the end of a twelve foot arm attached to the pedestal of the chair. When properly counterbalanced, it could be moved noiselessly in a complete circle in a horizontal plane on the level of S's ears.

For the larger portion of the experiments a small four-inch magnetic speaker, mounted in a twelve-inch baffle, served to generate the tones. Only in the case of the lowest frequency (60 cycles) was it necessary to use a large cone speaker in order to obtain sufficient power. This speaker was mounted on the same arm at a distance at six feet from S.

A beat-frequency oscillator, which could be adjusted to the desired frequency, supplied ample power to the loud speaker. The voltage was adjusted by means of a 7000-ohm potentiometer, while a further shunting resistance was used to turn the tone on and off without producing clicks. The tones were made reasonably pure by the use of suitable filters.

Comparative results for two noises were obtained by the use of a click and a hiss. The click was produced by applying forty-five volts from a battery to the loud speaker for a brief instant. It was heard by S as a single sharp click which possessed the high frequency characteristic of the speaker. The hiss was produced by blowing air through a small brass tube, the end of which had been cut and pinched. The brass tube was attached to the end of the swinging arm and was blown through a long rubber tube by E. The sound produced contained a perceptible high-pitched whistle with a frequency of about 7000 cycles. The remaining energy was probably distributed over a wide band of frequencies.

Procedure

The tones were presented at thirteen different positions and were spaced fifteen degrees apart beginning at 0 degrees immediately in front progressing to one hundred and eighty degrees immediately in back. The S's task was to name the position of the source of sound in this plane.

Conclusions

(1) The ability to localize tones varies markedly with frequency. It is approximately constant below 1000 cycles, drops rapidly to a minimum between 2000 and 4000 cycles, and rises again to its former level at higher frequencies.

(2) The error of localization is smallest for tones located near the median plane and increases as the tone is moved toward the side of the S. The relation between the azimuth of the tone and the error of localization is approximately the same for both high and low frequencies.

(3) The confusion of positions lying in the quadrant in front of the S with those in the quadrant behind him is very frequent. Below 3000 cycles the frequency of such reversals was about that which should be given by chance. Above 3000 cycles it was only about one-third of the chance value.

(4) Noises (a click and a hiss) were located more readily than any of the tones. Differences of quality and intensity were discernible between different positions of the noises.

(5) All of the above facts are consistent with the hypothesis that the localization of low tones is made on the basis of phase-differences at the two ears, and that the localization of high tones is made on the basis of intensitive differences. There is a band of intermediate frequencies near 3000 cycles in which neither phase nor intensity is very effective and in which localization is poorest.

The capacity of the ear for localizing the exact source of a sound is critically described above. The blind who use this organ as a substitute for vision abide by its excitation in perceiving obstacles in their path.

Worchel, Philip, and Karl M. Dallenbach, "Facial Vision: Perception of Obstacles by the Deaf-Blind," The American Journal of Psychology, 60:506-553, 1947.

The problem of the study is to determine whether the aural mechanisms shown in obstacle sense are auditory or cutaneous or whether both are involved.

The subjects used in this experiment are five deaf-blind who seemingly demonstrate a degree of obstacle perception.

The tests took place in a room sixty feet long and twenty feet wide. Two long strips of carpeting and several portable wall-like structures were used.

The long strips of carpeting were placed parallel to each other at approximately thirty inches apart. The strips were in the center of the room running lengthwise. The carpeting delimited the pathway which the deaf-blind followed. The directions which the blind were to follow were written in braille. Each was told to walk toward the wall and when he first sensed the obstacle, he was to raise his hand and stop. He was then to continue forward and stop when he was as close to the wall as he could get without touching it.

Another trial was run for cancelling out secondary floor cues. This was done by placing portable wall-like sections in the pathway as substitutes for the wall itself.

The conclusions are that the deaf-blind subjects who were selected upon the basis of their ability to get about alone, do not possess the "obstacle sense" and they are incapable of learning it. The cutaneous surface of the external ears (meatuses and tympanums) are not sufficient to the perception of obstacles.

The pressure theory of the "obstacle sense" is untenable. Auditory stimulation is both necessary and a sufficient condition for

> the perception of obstacles by the blind. The problem of this study is answered; the aural mechanisms involved in the perception of obstacles by the blind is audition. The auditory theory, sustained by the results of this study should no longer be regarded as theory but as established fact.

Worchel and Dallenbach state that their experimental findings are that the ear is the organ which is used by the blind in detection of obstacles in their path.

At the beginning of this chapter Hartmann in the first article and Child and Wendt in the second state that hearing becomes more efficient when a visual stimulus is given but they say this increase is not great. However, Freund and Hoffmann claim that better results seem to be obtained when light is radiated on the deafer side of the heads of persons suffering from types of inner ear complications.

In the area of sensory substitution, the reader may have found of some interest the results of the work of Stevens and Newman on auditory sound localization and the brief description of the results concerning obstacle perception of the blind by Worchel and Dallenbach.

CHAPTER IV

KINESTHESIA IN INTERSENSORY PROCESSES

The results of research by Jacobson and Max are presented in this chapter showing kinesthesia with some of its various mechanisms and functions within the body. Though the annotations deal specifically with the motor theory of consciousness, they also show subjective awareness of muscular tensions (kinesthesia) and the objective means of gaining knowledge of such tensions without the use of trained introspectionists. The reader will remember that kinesthesia is used in speech correction by Edna Hill Young in her Motokinesthetic method.

Jacobson, Edmund, "Electrophysiology of Mental Activities," The American Journal of Psychology, 44:677-695, 1932.

General Methods

It has been necessary to develop extremely sensitive apparatus in order to detect and measure the slight changes in potential in the nervous or muscular system during mental activities. Thermionic amplification has been used with the string galvanometer. In the most recent studies, measurements are possible of potential differences as small as one millionth of a volt, and such small changes are recorded with negligible lag in time on photographic film moving about 1 in. per sec. Electrodes are devised to connect the tissues with wires leading to the amplifier.

For the most part, Ss are employed who previously have been trained to relax. This is generally necessary because restless movements occurring in untrained Ss occasion action-potentials which obscure the readings concerning phenomena of mental activity. Relaxation, then, is requisite to furnish control tests and, in a sense, to isolate the mental activity investigated.

The S lies relaxed upon a couch in a darkened, quiet, partially sound-proof room. His eyes are closed. Distraction by E is carefully avoided. It is agreed between E and S that the clicks of a telegraph key are to be signals: the first, to engage in a particular mental activity; the second, occurring soon afterwards, to relax any muscle tensions present. By means of a signal magnet, the instant of occurrence of each click is recorded on the photograph.

Imagination of Movement

To secure data for statistical consideration, one instruction is used many times with one S and with others.

During a period of general relaxation, when the galvanometer string with one lead attached to the right biceps is recording an approximately straight line, the signal is given for the subject to imagine what would in actual performance involve contractions in the above mentioned muscle; for instance, to imagine that he is steadily flexing the right forearm. Generally within a fraction of a second, the string ceases its steady course and engages continually or intermittently in relatively large swings which cease soon after the signal is given to relax any muscular tensions present. This test has been made on 20 Ss.

But under the above conditions, if it has been agreed upon that the first signal is to mean, "Imagine bending the left foot," the string shows no such onset of large swings, generally continuing unaltered in its course. This type of control test is "Control I." Similarly the string continues in a steady course even after signals have been given. "Imagine bending the left arm." (Control 2, "Actually bend the left foot one inch" (Control 3), "Actually bend the left arm one inch" (Control 4), "Imagine the right arm perfectly relaxed," or "Imagine the right arm paralyzed" (Control 5), "Imagine extending the right arm" (Control 6), and "When the signal comes, do not bother to imagine" (Control 7).

The negative results noted in the control tests rule out two possibilities: (1) that the string deflections observed during imagination

are due to effects of the sound of the S; (2) that the act of imagination involves "action-currents all over the body."

It is necessary to test for the presence of action-potentials when instructions are given which can be carried out by the S in terms of responses of one or another muscular group not always determinable in advance. Ideally, for these tests we should need a separate string and a set of electrodes for each important neuromuscular group, as well as a galvanometer circuit considerably freer from electromagnetic and electrostatic disturbances than was the circuit first employed; for there is always the possibility that results may be called negative through masking of very slight action-potentials by extraneous electrical disturbances.

In half of these preliminary tests (14 out of 28) the string excursions were markedly increased during imagination as contrasted with relaxation; but in the other half the contrast was not marked. The Ss sometimes stated that following the instruction to imagine, they carried out the imagined act with some muscle-group other than the flexors of the forearm. In other instances they stated that they visualized themselves performing the act, but failed to have arm-muscle sensations.

The Differences Between the Galvanic Reflex and the Action-Potentials

(1) The galvanic reflex has many times the voltage of action-potentials.

(2) Reaction-time is 1-4 seconds for the galvanic reflex but only a fraction of a second for the action-potentials. Evidence is presented that the later phenomena are simultaneous with imagination.

(3) Frequency per second: galvanic reflex commonly lasts considerably more than one second, while action-potential occurs frequently per second.

(4) Wave form: galvanic reflex is a rise or fall of curve, while action-potential at usual film rates is a series of connecting almost vertical lines.

(5) Direction of potential: galvanic reflex often is chiefly unidirectional with respect to the line of zero potential. But in all instances either electrode used in recording action-potential is alternately positive and negative occurring many times per second.

(6) Tissue of origin: galvanic reflex arises from changes within the skin-sweat gland secretion, vascular changes, or altered permeability of cells; while action-potential can be recorded directly from muscular tissue when the skin has been excluded.

(7) Stimulus: galvanic reflex is involuntary, whereas action-potential is voluntary.

(8) Contraction: contraction takes place during action-potential whereas galvanic reflex is, due to, general conceded, to electrical effects depending upon elements in the skin.

An Objective Measurement of Introspection

The coincidence of the occurrence of imagination and of lengthened string vibrations is clearly brought out in certain additional tests. A signal magnet is arranged to record on the photographic record a line which can be broken when S presses the button on a switch with his left index finger. He is instructed to press the button during the period when imagination is taking place, releasing it at other times. In order to gain some idea of the reaction-time of these 3 Ss, as they lay upon a couch with their eyes closed, they were requested to press the button during periods when a buzzer sounded. For all 3 the average value was 0.24 sec., according to the signal line thus made by the Ss in these tests, the period during which imagination takes place, coincides with the period during which the string shows lengthened vibrations, except for fractions of a second at the beginning or end. As anticipated the reaction-time of S in pressing the button needs to be taken into account. Fifty figures were secured for the three Ss in total, representing the discrepancies in onset or conclusion between the period of lengthened vibrations and the period of imagining indicated by the S. The average for these figures was found to be practically identical with their average reaction-time, 0.23 sec. The extremely close correspondence of the latter figure to the value 0.24 previously mentioned is probably in part accidental; but making due allowance for this, the result indicates that the period of imagining coincides with the period of lengthened vibrations, subject to the slight discrepancies introduced by S's reaction-time. The procedure just described is of interest in that, viewed from a certain angle, it is an objective test of S's introspective observation.

The Amputated Limb

What occurs in individuals with amputated limbs who assert that they can do everything in imagination with the lost part that they can do with the intact part?

In brief, the results with this S show that when he imagines bending the missing left hand, there generally occur action-potentials from the stump-biceps muscle as well as action-potentials from the muscles that flex the right hand. In other words, when this S engages in mental activity concerning his left hand, certain muscles contract; but these, for example in imagined flexion, instead of being merely the muscles that flex the left hand, as in intact S, are in the stump of the upper arm, or in the intact arm, or in both places. It was therefore of striking interest, when, after he had evidently engaged in subjective observation during a number of tests, he suddenly volunteered to correct his original statement. He now stated that when he does something with his right hand and the left seems in imagination to duplicate the performance, going through the same experience. But he never has experiences of his left hand's performing any act independently of the right. No independent imagination, such as exists for intact Ss, exists for this S's left hand.

Visual Imagination and Recollection

Visual imagination and recollection are tested with electrodes placed near the eyeballs. The circuit used yields a pattern on the photographic record distinctive for looking in each particular direction. During a period of general relaxation, when the galvanometer string is vibrating slightly and uniformly, recording a fairly horizontal band on the photographic paper, the signal is given which will incite the subject to visual imagination. Generally within a fraction of a second, the string shoots forth and back or alternately for fractions of a second or more, producing deviations from the horizontal on the photographs. These deviations cease soon after the signal is given to relax any muscular tensions present.

The photographic records for visual imagination show patterns resembling those above-described for eye-movements. For instance, the pattern for imagining Eiffel Tower is practically identical with the pattern of the same S for looking upward. Evidently in imagining the tower, the S's eyeballs move upward, somewhat as they would upon actually seeing a tower. Correspondingly he reports that in imagining he looks from the base to the top of the tower.

In general, during visual imagination and recollection, we find that electrical records are secured from the ocular muscles, producing photographic patterns like those following instructions to look in one direction or another. As shown by these records, eye-movements (or convergence) characteristically occur during visual imagination and recollection.

Variation of Specific Muscles Contracting During Imagination

On introspective grounds, it has long been assumed that the same act or object can be imagined by S at different moments through different types of imagery. The physiologist needs to develop objective tests to avoid such assumptions. These are made in the present instance by attaching a set of electrodes in the ocular region of the subject, while the lever is used simultaneously to record flexion of the right arm.

When the trained S is instructed "to visualize bending the right arm," voltage changes in the ocular region, as from the eyeball movement, are recorded in almost all instances, but under the same conditions, action-potentials are absent from the arm-muscles in almost all instances. This indicates that the matter of bending the right arm may be imagined in at least two physiological manners.

In different S's, the same muscles do not always contract during the recollection of imagination of a particular act or object. But the results indicate that during imagination or recollection, muscular contraction, if absent from one region, will be found in another.

The Speech Musculature

A test for determining action-potentials in verbal thought is made with electrodes in the muscles of the tongue or underlip. Instructions are chosen to include not only imagination and recollection, but also other types of mental activity.

When the electrodes are connected in the speech musculature of the trained S, the string shadow is practically quiet during relaxation. But promptly after the signal is sounded to engage in mental activity involving words or numbers, marked vibrations appear, indicating action-potentials. Soon after S hears the signal to relax any muscular tensions present, the vibrations cease, and the string returns to rest. The series of vibrations occur in patterns evidently corresponding with those present during actual speech. For if the amplifier rheostat is set for a relatively low sensitivity and the first signal is to count aloud but as faintly as possible (1-2-3), three series of vertical lines are generally found on the photograph separated by a horizontal interval. If the amplifier rheostat is changed to a sufficiently higher sensitivity and the instruction is to imagine or to recall counting but not actually to count, a quite similar photograph is secured.

Conclusions

(1) When the S, lying relaxed with eyelids closed, engages in mental activity such as imagination or recollection, contraction (commonly slight and fleeting) occurs in specific muscles. Evidence is thus afforded that the physiology of mental activity is not confined to closed circuits within the brain but that muscular regions participate.

(2) During visual imagination or recollection, the muscles that move the eyes contract, as if S were looking at the imagined object.

(3) During what psychologists term "inner speech," muscles in the tongue and lips contract as if to say the words in swift and abbreviated manner.

(4) During imagination or recollection of muscular acts or of matters that involve such an act on the part of the S, contraction occurs in some of the muscle-fibers which would engage in the actual performance of the act. Exceptions are noted when visualization occurs alone which is characteristic of some Ss.

(5) During a particular mental activity, the muscles of a quietly lying S, trained to relax, remain as a rule inactive, excepting those specifically engaged as above stated.

(6) Electrical records along with subjective reports indicate that during general progressive muscular relaxation, imagery and thinking processes dwindle and disappear.

(7) Relaxation of the specific muscular contractions present during a particular mental activity brings about the disappearance of the activity.

(8) The Action-potentials measured in the present investigations are proved to be very different from the galvanic reflex.

The above study reveals data which tends to confirm the motor consciousness theory. It also shows the importance of kinesthesia. The subjects tested in this experiment possessed all their sensory faculties. However, in the following research by Max, the subjects were bereft of hearing.

Max, Louis William, "Experimental Study of the Motor Theory of Consciousness," The Journal of Comparative Psychology, 24:301-334, 1937. Edited by: Knight Dunlap and Robert M. Yerkes.

This investigation studied action-current responses from the flexores digitorium of deaf subjects during the drowsy state following sleep, and during the solution of simple and complex thought problems. As a control, similar records were taken simultaneously from the leg muscles of the deaf, and also from the arm muscles of hearing subjects and from the tongue.

The recording system consisted of two microvolt-sensitive amplifiers activating two Hindle string galvanometers. The use of two set-ups made possible a more complete picture of the physiological processes by permitting simultaneous recording from two sets of muscles. The response came unpredictably, at times from the right arm, and at times from the left, and if only one galvanometer had been used a negative result might conceivably have been recorded. Plate electrodes of the Ag-AgCl or Pb-NaCl type were employed, a pair of leads being taken from the flexores digitorium of each arm. After the electrodes were applied, the subject lay down on a wide bed, the room was darkened and he was instructed to shut his eyes and make himself as comfortable as possible. Direct training in arm and hand relaxation or reference to the arm muscles was deliberately avoided, so that the subject's attention would not be attracted to those muscles. An advantage of the present approach was the possibility of registering action-currents from the forearms without making the subject aware that his finger muscles were the object of study.

Each problem was typed on a separate three by five inch card and was usually answerable by either yes or no, or by a number. As the subject lay on the bed with eyes shut, a card was placed quietly on a stand in front of him. A sample of the foreperiod was photographed, and with the film still in motion the problem-card was illuminated, whereupon the subject opened his eyes, read, and performed the task assigned. The reading light was so arranged as to illumine also the subject's fingers, so that any visible movement could be observed. When he had the answer, the deaf subject indicated this fact by shutting his eyes, or by vocalizing it orally if he could speak, whereupon the light was extinguished and he relaxed again. Thus, the subject had no awareness of the problem during the control or foreperiod.

Conclusions

(1) Since various motor theories stress the importance of linguistic mechanisms as the seat of motor activity during consciousness, and since the arms and fingers of the deaf are the locus of their oral, written and gestural speech, the present investigation studied action-current responses from the flexores digitorium of the deaf during awakening and during the solution of simple and complex thought problems. By taking the leads of the string galvanometer from the forearm at some distance from the fingers, both the inhibitive effect of encumbering apparatus and the facilitative suggestion-error were reduced. As a

control, similar records were taken from the leg muscles of the deaf, from the tongue and from the arm muscles of hearing subjects.

(2) As the deafer subjects awakened, there was a gradual increase in action-current amplitude reaching a maximum immediately after awakening but subsiding again to a lower level as the subject relaxed. An average of 0.76 microvolt was recorded for the preceding sleep period compared with 1.35 microvolt for the first relaxation period after awakening.

(3) The peripheral currents involved in waking thought are ordinarily so small as to be submerged by the electromyographic aspect of muscular tensions normally present. To isolate peripheral thought responses it is necessary to reduce such tensions to a minimum by shaping experimental conditions to encourage maximum relaxation. Such relaxation, however, may in itself be a source of error in that it may train away motor responses normally present during thinking. Accordingly, direct training in arm relaxation was avoided and an attempt was made to choose subjects who could relax readily.

(4) The subjective experience of a kinaesthetic image was accompanied by peripheral action-current responses in 73 per cent of the cases with hearing subjects and in 88 per cent of the deaf cases. The kinaesthetic sense was found to be a less sensitive indicator of existing muscular contraction than the electromyogram, a fact which helps to explain "imageless thought."

(5) Abstract thought problems elicited manual action-current in 84 per cent of the cases in 18 deaf subjects as compared with 31 per cent of the cases in 16 hearing subjects. The average amplitude of response was 3.41+ microvolts for the deaf and 0.8 microvolt for the hearing. In simultaneous electromyograms from the arm and leg of the deaf, the frequency of positive responses during thought was 73 per cent in the arm and 19 per cent in the leg. Whereas during kinaesthetic tasks involving arm muscles, the percentage of positive arm responses from hearing and deaf subjects was substantially the same, during thought problems the arms on the deaf yielded larger and more frequent responses than those of normal.

(6) Simple reading and mental repetition of verbal material gave smaller and less frequent action-current responses from the deaf than reading with intent to remember,

memorization and other more complex thought problems. Similarly, problems in mental arithmetic of an automatized nature yielded less electromyographic response than non-automatized ones.

(7) Vocalized speech, nodding of the head and non-manual language substitutes were frequently accompanied in the deaf, and only occasionally in hearing subjects, by simultaneous action-currents in the hand and arm muscles.

(8) In general, the more intelligent and more educated deaf subjects tended to give less electromyographic response to problem situations; previous vocational experience, fear of the laboratory situation and other emotional states were found to influence the nature of the response. After preliminary practice sessions, individual subjects showed characteristic response levels which remained fairly constant even after 15 months in the laboratory.

(9) Certain thought problems of predetermined configurations elicited roughly corresponding action-current patterns from the arms of the deaf in 41 per cent of the positive records and in 29 per cent of all the records of these problems, but no such patterns from the legs or from hearing subjects.

(10) In view of the instances of lower microvoltage during waking relaxation than during sleep and the instances of zero microvoltage during the actual thinking process, we do not feel justified in further urging the progressive parallelism between conscious and motor responses tentatively suggested in a previous paper. However, in view of our findings that sensory stimulation and dreams tend to evoke electromyographic responses in the arms of sleeping deaf subjects, that abstract thought problems elicited action-current responses more frequently and to a greater extent in the arms than in the legs of the deaf or in the arms of hearing subjects, that vocalized speech was accompanied by manual currents more frequently in the deaf than in hearing subjects and that the electromyographic response patterns from the arms of the deaf often varied differentially in rough temporal correspondence to the conditions imposed by the problems themselves, it is our tentative conclusion that these manual responses in the deaf are more than adventitious effects of irradiated tensions (though the existence of the tension factor is not

gainsaid), and that such responses have some specific connection with the thinking process itself. Since the arm muscles are a focal mechanism for speech in the deaf, our results thus lend some support to the behavioristic form of the motor theory of consciousness. The further question as to whether the motor responses are essential to consciousness remains to be determined. Our negative results in some cases during waking relaxation and even during thought problems must not be overlooked. While it is possible that these negative findings are more apparent than real and are due to shifting to other muscle groups not connected into the galvanometer circuits, another alternative is the operation of a short circuiting mechanism in some higher brain center.

A string galvanometer objectively tested the accuracy of the subject's kinaesthetic awareness. This awareness was unreliable when compared with action-potentials detected by the string galvanometer.

In addition to the consideration of the motor theory of consciousness these annotations show subjective awareness of kinaesthesia. It was found that when imagination, abstract thinking or visualization took place that muscular contractions, as detected by introspection or action potentials, also occurred.

CHAPTER V

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CHAPTER VI

SOME THOUGHTS ON INTERSENSORY RELATIONS IN SPEECH CORRECTION

In Chapters II, III and IV which are concerned with vision, hearing and kinesthesia respectively some thoughts on intersensory relations in speech correction may arise in the mind of the reader. This chapter will be devoted to some of the thoughts. The manner of procedure will be to consider the chapters and their contents as they appear in this paper. It has been seen, however, that the experiments contained in the preceding chapters are not totally confined to one or two senses and that in some cases the researches are arbitrarily placed under the heading which is deemed most appropriate. This fact plus the inter-chapter correlations which will be drawn, will cause a deviation at times from the afore mentioned procedure.

It has been observed that the first two annotations found in Chapter II "Vision Intersensorywise" describe studies conducted by Kravkov and Serrat and Karwoski. The purposes of the experiments were to discover if non-optical stimulation causes an increase in visual acuity. Kravkov found that there was a small amount of facilitation. Serrat and Karwoski were not able to substantiate Kravkov's findings from the data found in their experiment. They stated, however, that

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their research may not have been measuring the same phenomenon as other experimental tests dealing with visual facilitation had done. This doubt on the part of Serrat and Karwoski is probably agreed with by G. M. Gilbert when he says:

> The consensus of opinion is that an excitation originating in any of the receptors does not remain strictly localized but irradiates to some extent throughout the entire nervous system, thus affecting the excitatory states of all other conductor mechanisms and consequently the sensory responses for which such excitatory states are important predisposing factors.[1]

The third study in Chapter II by Allen and Schwartz provides evidence which is in agreement with Kravkov and G. M. Gilbert. They found that heteromodal stimuli enhanced or inhibited the subjective brightness of color when tested by their critical frequency method. It was also thought that the intensity of stimulus had a marked effect upon optical sensations for it was demonstrated with sounds of different volumes.

The fourth annotation discusses four different series of experiments which were conducted by Walter Börnstein. These researches were made to reveal whether visual brightness and darkness was paralleled by the auditory, gustatory, or olfactory senses. This was found to be true in the experiments. But more interesting to the speech correctionist, Walter Börnstein found that

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[1]G. M. Gilbert, "Intersensory Facilitation and Inhibition," Journal of General Psychology, vol. 24, 401 pp., 1941.

light adjustment of the eye, adaptations to brightness, was in effect contraction of the retinal rods and cones and that dark heteromodal stimulus brought about depression of light adjustment.

The light adjustment of contraction of rods and cones is a tonic reaction. It is thought that dark stimulation may depress this tonic reaction. G. M. Gilbert declares that such adjustments radiate to other sense modalities. Börnstein also found that muscular contractions in the legs and arms brought about phosphenic (light adjustment) reactions in the eye. He would probably agree that tension would radiate its tonus throughout the body also.

According to Mabel Farrington Gifford, tension is antagonistic for the stammerer in developing clear speech.

Most speech correctionists are aware of her relaxation technique. She says:

> Tension is the opposite of relaxation. The best way to realize how it feels to relax, however, is first to tense separately and deliberately the various parts of your body and then withdraw the force you exert. When you thus tense your muscles before relaxing them, you are throwing tension voluntarily into your body, with your mind in control of the situation. The tension you feel while talking is ordinarily not voluntary. It is an almost automatic accompaniment to the fears and other emotional patterns you have built up in connection with the blockade which inhibits your speech. Your muscles cannot respond properly when you are tense. Most stammerers say that the effort to speak creates at times an intense bodily contraction,

> particularly noticeable in the abdomen and shoulders.[2]

The question now arises, can Börnstein's dark stimulus through hearing or olfaction bring about the lessening of tension in normal speech clinic procedure or can the same result be obtained by the lack of non-visual bright stimuli? If this can be done through non-visual sense modalities a new technique in clinical practice may develop.

It must be remembered, however, that thirty per cent of the cases with which Börnstein worked did not react intermodily as did the others. In reference to this Börnstein says:

> Jaensch distinguishes between two types of psychic constitution: the "integrated" and the "disintegrated" type. By the integrated type, Jaensch understands, in contradistinction to the disintegrated type, persons in whom there exists an especially intimate functional connection between all sensual performance on the one hand, and the motorium on the other.
>
> Now, in the ambulatorium for constitutional medicine (Director: Private-Dozent Dr. Walter Jaensch) I have investigated with Mandowsky so far nineteen cases in such a manner that each of us has applied his own methods independently of the other. At the conclusion of our experiments we compared results, and found, in fifteen out of nineteen cases, complete agreement in regard to the designation of the subjects as "positive" (Börnstein) or "integrated" (Jaensch-Mandowsky) and "Negative" or "disintegrated"

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[2]Mabel Farrington Gifford, "How to Overcome Stammering," Chief, Bureau for the Correction of Speech Defects and Disorders, Department of Education, California, New York, 7-9 pp., 1940.

> cases. These figures are not, it is true, sufficient to base a theory upon. They do, however, indicate that further investigation will be fruitful of results.[3]

It can be implied here that if dark adjustment is experimentally tested in speech clinics, all subjects may not react favorably. A great deal of research will have to be made to discover the worth of these avenues of approach to relaxation.

The last annotation in this chapter gives brief reference to one of T. H. Howells' studies on audio-visual synesthesia. The reader has found a large number of articles in the preceding bibliography in Chapter V concerned with the subject of Howells' research.

The first two annotations found in Chapter III, "Hearing Interrelated with Other Senses," consider auditory enhancement by heteromodal stimulation. These studies, by G. W. Hartmann and Child and Wendt, provide data supporting this fact. However, the facilitation is small.

In the next study by Freund and Hoffman quoted from G. W. Hartmann there is provided a possible aid in speech correction. As is remembered some of their patients with high grade inner-ear afflictions could hear much better after having been radiated with the

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[3]Walter Börnstein, "On the Functional Relations of the Sense Organs to One Another and to the Organism as a Whole," Journal of General Psychology, vol. 15, 117-31 pp., 1936.

light from a thousand watt bulb. The interrogation now posed is, can the auditory facilitation brought about by the light radiation method be used in the speech training of some of the hard of hearing? It would be agreed that proper hearing for speech training, if it could be obtained for a long enough time without the use of various types of amplifiers, would be the better method. It might be suggested here that Börnstein's fourth series of experiments may shed some light upon the auditory facilitation obtained by Freund and Hoffmann. Their work brought about the immediate enhancement of hearing by a light of long wave lengths and a delayed facilitation with a light of short wave lengths. G. W. Hartmann states, however, that

> While Freund and Hofmann are plainly aware that these intersensory phenomena must have a 'central' neurological explanation, they do not distinguish sufficiently between the direct local effects of the light rays upon the skin and auditory tract, and the indirect, remote influences traceable to optical stimulation.[4]

These ramifications probably play a part in the apparent discongruity with Walter Börnstein who found that infra-red light played upon the backs of his subjects brought about no phosphenic reaction whereas the ultraviolet light did. The "Hell" hormone named by Börnstein may be associated with sensory stimulation. This is

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[4]George W. Hartmann, "The Facilitating Effect of Strong General Illumination Upon the Discrimination of Pitch and Intensity Differences," Journal of Experimental Psychology, vol. XVII, 814-6 pp., 1934.

verified according to G. M. Gilbert when he states, "Other bodily mechanisms, such as tonic and hormonal adjustments, are also affected by prolonged sensory stimulation."[5]

It has been observed that the above research by Freund and Hoffman may have combined several mechanisms, and the complexities probably do not stop there. This should not trouble the speech correctionist. If he is able to obtain auditory facilitation by the Freund and Hoffman method, it seems that the lack of scientific controls would be far overshadowed by the benefits obtained in his work.

The last two experiments in Chapter III consider hearing as it relates to the blind. Audition is in this case a substitution for vision. The first of the two annotations which is by Stevens and Newman provides data concerning the accuracy of the ear in locating the exact sources of pure and impure tones. This may aid the reader in better understanding the second study which deals with obstacle location by the blind, which was conducted by Worchel and Dallenbach. In this research, not only may an understanding of the capacities of the blind be obtained but some observations dealing with the use of senses other than hearing in substitution for vision is found.

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[5]G. M. Gilbert, "Inter-Sensory Facilitation and Inhibition," Journal of General Psychology, vol. 24, 401 pp., 1941.

"Kinesthesia in Intersensory Processes" is the subject of Chapter IV. The two annotations in this chapter consider the series of studies by E. Jacobson and L. W. Max. The purpose of these studies was to test the hypotheses held by the proponents of the motor consciousness theory. In reading the article on L. W. Max it was found that the string galvanometer could register action potentials more reliably than could the kinesthetic sense. It was also found that action potentials tended to occur in the flexors digitorium which are used in symbolism by the deaf. Jacobson claims that thinking is difficult, if not impossible, when the subject is relaxed and the action potentials are very slight. It is stated by Gray and Wise

> Thinking is implicit speaking, a neuromuscular process with the muscular component reduced to slight, perhaps invisible and inaudible, sometimes entirely imperceptible, contractions. It is an all-over-the body process, not limited to Broca's or any other brain area.
>
> The ability to speak, then, is based upon the possession of innumerable neurograms, which have resulted from conditioning the musculature of the speech organs to respond to substitute stimuli. These muscles act in response to innervation by neurons of the C.N.S. The reflex arcs which the motor neurons complete may originate in afferent neurons receiving stimuli from any of the extero-, entero-, or proprioceptors.[6]

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[6]Giles W. Gray and Claude M. Wise, The Bases of Speech, 333-5 pp., 1946.

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A profitable use of the facts set forth by Gray and Wise is represented by the moto-kinesthetic method devised by Sara M. Stinchfield and Edna Hill Young, briefly they state it to be

> There is a surer and better plan than the one of letting the young child find his way into speech by a "trial and error" method. By this better plan the adult directs the muscles in a definite way whenever the child is unable to find the correct procedure by himself. The adult sets the patterns for correct movements for the child to follow. Through the center of the brain which is capable of setting and retaining impressions from movements performed, the child again senses the movements used to produce correct forms for words and sentences and through use builds up automatic responses. A most interesting piece of work may be accomplished for the very young child, as we teach him through the muscular or kinesthetic sense to associate movement with the correct auditory sound-pattern used to express a definite idea.
>
> The child from twelve months to two and one-half years responds more readily to moto-kinesthetic help than he does to the auditory or to the visual in speech.[7]

This moto-kinesthetic method provides a good example of the use of a broad background in the field of intersensory relationships. This paper provides a collection of publications in this area so as to help facilitate the further development of researches which the author hopes will add to the methods and techniques used in the field of speech correction.

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[7] Sara M. Stinchfield and Edna Hill Young, "Children with Delayed or Defective Speech, 99-100 pp., 1938.