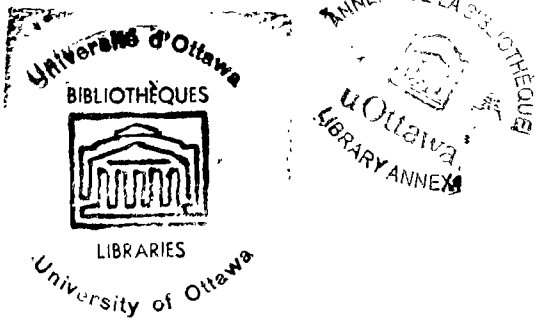
AN EXPLORATORY STUDY ON THE EFFECTIVENESS OF AUDIO-ANALGESIA

by Joseph G. Marone

Thesis presented to the School of Psychology and Education of the University of Ottawa as partial fulfillment of the requirements for the degree of Master of Arts



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ACKNOWLEDGMENTS

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CURRICULUM STUDIORUM

Joseph G. Marone was born October 28, 1938, in Jersey City, New Jersey. He received the Bachelor of Science degree in Social Studies from Villanova University, Villanova, Pennsylvania, in 1961.

ERRATA

Page	Line	
3	25	"substratum" overrides the one inch margin.
13	6	"implication" to implications.
17	4	"cuff-off" should read cut-off.
22		Title of Pain Apprartus should be placed on the bottom margin of the page.
32	9	"to you" should read "that to you"
39	2	should read "significance at the .05 level on the second trial.
44	16	should read "but was rejected at the .05 level.
47	11	should read "at the .05 level".
51	12	should read "but was rejected at the .05 level of probability in the Audio-Analgesic condition".
59	12	should read "statistically significant (.05) shift".

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INTRODUCTION

Pain affects us all -at our entry into life, and at intervals throughout life. Every individual knows from personal experiences just what pain is, yet no one has been able to accurately define it. However, it is not so much the definition of pain that has intrigued man as the means and methods of how to reduce or alleviate it.

At the turn of the century, opiates and ethers were the main anesthetics in use; however, not all patients were amenable to these techniques. Many suffered serious mental and physical side effects. Recently in the late 1950's, a new technique called Audio-Analgesia was introduced into the medical and dental sciences. The technique has been defined as the suppression of pain by sound.

Controlled experimentation with this technique has had some success in the field of dentistry, but little or no success in the area of psychophysiological research. The rationale is essentially neurophysiological in essence; however, the specificity of it has been recently modified by various psychological implications of suggestion and distraction. Because of the lack of psychophysiological research in this area, it is the main objective of this report to evaluate the effectiveness of Audio-Analgesia in the suppression of brachial pain. Secondary objectives are to investigate what effect white noise has on pain and what effect stereophonic music has on pain.

The following dissertation is divided into three chapters. Chapter one presents a brief summary of the underlying rationale of Audio-Analgesia, followed by a review of the literature concerning the effectiveness of the technique in the fields of dentistry and psychophysiological research, and is concluded with a summary and the basic hypotheses. Chapter two describes the experimental design which includes the sample population, the psychophysiological apparatus, and the statistical techniques used to analyze the data. Chapter three presents the results and a discussion of them, as well as some suggestions for further research.

CHAPTER I

REVIEW OF THE LITERATURE

The first section of this chapter presents the underlying theory of Audio-Analgesia. The second section presents a review of the literature covering the field of dentistry and psychophysiological experimentation on the effectiveness of Audio-Analgesia. The third section presents selected studies on pain where emphasis has been placed upon the psychological factors of attitude and suggestion, and their effects on the individual's reaction and perception to pain. The fourth section states the experimental and null hypotheses and describes the experimental conditions used to test the hypotheses.

1. Theory of Audio-Analgesia.

In 1959, Gardner and Licklider[1] described a new phenomenon, the suppression of pain by sound, which was called Audio-Analgesia.

Sound from an Audio-Analgesic apparatus was transmitted to the individual through a set of earphones. He received sounds of two types, stereophonic music and

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1 W.J. Gardner and J.C.R. Licklider, "Auditory Analgesia in Dental Operations", in the Journal of the American Dental Association, Vol. 59, December 1959, p. 1144.

white noise,[2] the ratio and intensity of which he himself controlled. The individual was instructed to increase the intensity of either the music or the white noise or both, when he felt pain.[3]

The neurophysiological theory of the phenomenon is based upon the interaction of sensory modalities. Gardner and Licklider[4] and Licklider[5] and Mittleman[6] have indicated that the sound spectrum produced by white noise saturates the auditory nerve with impulses, which in turn excite the medial geniculate body of the thalamus. When impulses that that originate from a painful stimulation register in the ventral nucleus of the thalamus (which nucleus is situated just above the medial geniculate body of the thalamus), this surrounding area "being confused by white noise"[7] interprets the pain impulses at a level of consciousness differentially

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2 White noise is a blend of the various sound wave frequencies, much as white light is a blend of the various lightwave (color) frequencies.

3 Council on Dental Therapeutics, "Audio-Analgesia", in the Journal of the American Dental Association, Vol. 63, October 1961, p. 517.

4 W.J. Gardner, J.C.R. Licklider and A.Z. Weisz, "Suppression of Pain by Sound", in Science, Vol. 132, 1960, p. 32-33.

5 J.C.R. Licklider, "On Psychophysiological Models", in Sensory Communications, 1962, p. 49-71.

6 Jerome S. Mittleman, "The Principles of Audio-Analgesia", in Dental Digest, March 1963, p. 68-71.

7 Ibid., p. 68.

from the normal impulse pain. Licklider[8] has commented on a paper written by Mountcastle as to the hypothetical functions of sensory interaction in the suppression of pain:

> 1. The organization of the nervous system is characterized by focalized excitation or facilitation and diffuse inhibition or suppression. (...) Where two or more sensory systems come into a common region but do not map themselves, point-for-point, into a common projection, therefore, we may expect the effects of one system on another to be inhibitory or suppressive rather than excitatory or facilitory.
>
> 2. It is necessary for the sake of stability that, on the average, inhibitory processes have higher gains than excitatory processes at high levels of activity, and that excitatory processes have higher gains than inhibitory processes at low-levels of activity. Otherwise, the brain would either 'run down' into quiescence or undergo a regenerative 'chain reaction' up to saturation.
>
> 3. The temporal parameters of excitatory processes are usually shorter than those of inhibitory processes. This fact may be related to the focalization of the former and the diffuseness of the latter.
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> 4. There is a measurable activity in the neural substratum (for example, 'spontaneous activity') even in the absence of contemporary stimulation... (...) It seems reasonable to postulate an underlying pain process that has continuous existence, though at low levels, during intervals in which there is ordinarily no report of pain.[9]

The specificity of this neurophysiological theory has been modified by the psychological factors of suggestion, distraction and a pre-occupation of the individual's attention with stereophonic music. Because of these factors, the psychological states of motivation and expectancy have

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8 Licklider, Op. Cit., p. 54-55.

9 Ibid., p. 54-55.

been highly emphasized. As it shall be noted in the section on Pain, the mental attitude of any individual towards the relief of pain is known to be an extremely important consideration in the successful placebo reaction. Much depended on what the individual was persuaded to imagine, to think and then to believe.

2. Audio-Analgesia.

In the field of dentistry the original discovery and initial experimentation on Audio-Analgesia was initiated by Gardner, Licklider and Weisz.

The first systematic investigation of Audio-Analgesia was conducted by Gardner and Licklider.[10] One hundred and seventy patients were subjected to routine dental procedures while being tested under three different conditions: the effects of white noise on pain, music on pain, and a combination of both white noise and music (Audio-Analgesia) on pain. From their results, the authors suggested that neither condition alone was an effective suppressor of pain, but that the combination (Audio-Analgesia) was the successful one.[11]

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10 W.J. Gardner and J.C.R. Licklider, "Serendipitous Effects of Masking Noise Upon Sensations Produced by a Dentist's Drill", in the Journal of Acoustic Society of America, Vol. 31, 1959, p. 117.

11 Ibid., p. 117.

The validity of these results may be questioned. No details were given as to what was meant by routine dental procedure, nor were there any indications as to what levels of white noise and music were required to effect a successful suppression of pain. In addition to this, there was no report as to how many patients actually expressed complete suppression of pain.

This demonstrated positive effect of Audio-Analgesia was retested in a follow up experiment which consisted of submitting five hundred patients to routine dental procedures. The results reported suggested that ninety per cent of the patients stated successful suppression of pain.[12]

In the final series of these experiments, one thousand dental patients were subjected to routine dental procedures under the analgesic effects of Audio-Analgesia. It was concluded that in sixty-five per cent of the cases, successful suppression of pain was evident, while in twenty-five per cent of the cases suppression of pain was sufficiently effective so as not to require local anesthetic.[13]

The few reports that have been published and reviewed in the above section are impressive for their constancy in

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12 W.J. Gardner and J.C.R. Licklider, "Follow Up Report on Audio-Analgesia", in the Journal of the Acoustic Society of America, Vol. 31, 1959, p. 850.

13 Gardner, Licklider and Weisz, Op. Cit., p. 32-33.

illustrating successful dental use of Audio-Analgesia, but they have been extremely disappointing in their lack of experimental controls. There is considerable ambiguity as to how many of the dental patients from one study overlapped into other experiments. This possible overlapping and lack of experimental controls tend to cast a shadow of doubt on the high per cent of positive conclusions drawn by these authors.

Monsey,[14] in a preliminary experiment reported on the effectiveness of four hundred trials of Audio-Analgesia with 192 dental patients. He evaluated the degree of effectiveness according to the emotional characteristics of the patient and the particular type of dental procedure used with each patient. His results indicated that patients who had undergone minor dental procedures had reported "excellent" suppression of pain ninety-five per cent of the time. Patients who were subjected to average dental procedures reported eighty-three per cent effectiveness, while patients that had undergone major dental procedures reported only sixty-three per cent effectiveness. There were also indications that patients categorized as "nervous" expressed less effectiveness than those rated as either "placid" or

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14 Harold L. Monsey, "Preliminary Report on the Clinical Efficacy of Audio-Analgesia", in the Journal of the Nevada Dental Association, Vol. 36, December 1960, p. 432-437.

"average". Monsey concluded that the results of Audio-Analgesia varied with the emotional characteristics of each individual and the types of dental procedures used. Beyond this, he stated "all of our conclusions must be classed as opinions rather than proven fact and that the approach of the patient is critical".[15] Consequently, Monsey has placed the success or failure of Audio-Analgesia on the rapport established with the patient, i.e. the individual must be thoroughly convinced that this instrument will alleviate pain, and that he, the patient, must be thoroughly familiar with the operation of the apparatus.

The conclusions drawn by Monsey seem to support the earlier findings of Gardner, Licklider and Weisz. However, there appeared to be certain ambiguities in the statistical analysis. He did not indicate the number of patients grouped into the three emotional categories, nor did he state how many individuals were classified into each of the dental procedures. The issued report indicated only the number of trials of Audio-Analgesia per category. To confuse matters, he reported that fifty-six per cent of the total sample (N 192) received only 1 trial, while the remaining 44 per cent received anywhere from 2 to 23 trials under Audio-Analgesia.[16] Much of this leaves the reader unable to

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15 Monsey, Op. Cit., p. 437.

16 Ibid., p. 432-433.

decide how extensive was the overlapping between each of the emotional categories and the classification of the dental procedures.

In 1961, the Council on Dental Therapeutics[17] issued a report that Schermer had subjected twelve hundred patients to dental procedures under Audio-Analgesia. It was stated that he had effected successful suppression of pain in seventy-six per cent of the cases.

The Use of Audio-Analgesia in the Field of Psycho-physiological Experimentation.- Carlin et al.[18] assumed that successful suppression of pain by sound in the dental situation may have been the result of three factors: cross sensory masking, distraction, or suggestion or a combination of the latter two. They attempted to separate these factors by measuring the change in sensitivity to electrical stimulation of the teeth in dental patients when exposed to broad band white noise at 100 decibels. The results indicated that there was no reduction in the "tingle" sensation with or without the effects of white noise, either when the instructions to the patient were neutral, explicit, or implicit in suggesting that the instrument (Audio-Analgesic Apparatus)

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17 Council on Dental Therapeutics, Op. Cit., p. 517-520.

18 Sidney Carlin, W. Dixon Ward, Arthur Gershon and Rex Ingraham, "Sound Stimulation and Its Effects on Dental Sensation Threshold", in Science, Vol. 138, December 1962, p. 1258-1259.

would reduce their perception and reactivity to the "tingle" sensation. The authors suggested that Audio-Analgesia was not an example of cross sensory masking, but that its successful application probably depended on a combination of distraction and suggestion.

Although the authors rejected the neurophysiological hypothesis of cross sensory masking, a partial explanation to account for the absence of the Audio-Analgesic phenomenon in this experiment has been reported by Licklider.[19] He stated that "the reduction of pain under Audio-Analgesia to electrical stimulation has been less effective when compared to other types of noxious stimulation".[20] Furthermore, the validity of the technique can be questioned. From the reported procedure, it was evident that these experimentors disregarded the Audio-Analgesia technique by the omission of the music element. This factor has been postulated to act as a relaxant agent with its main objective the diversion of the individual's attention away from the original sensation, pain: consequently, an increase in the pain threshold would result.

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19 Licklider, Op. Cit., p. 49-72.

20 Ibid., p. 52.

In a more recent study, Camp et al.[21] used ten medical students to study what effect white noise had on the perceived pain threshold. The noxious stimulus was radiant heat which was directed over various areas of the forearm and forehead. Several trials were run using different intensities of heat. The subjects were instructed to report on their perceived pain threshold with and without the effects of white noise. The results suggested that no significant differences could be found under the two conditions. The authors concluded that neither the pain threshold nor the ability to distinguish between different intensities of mild pain had been altered under the condition of white noise.

The majority of the evidence tended to support the existence of an Audio-Analgesic phenomenon in the field of dentistry, but little or no support was indicated in the area of psychophysiological experimentation. It was generally noted in many of the reports reviewed that reference to experiment controls was either very sparse or completely absent. The data reported were stated in terms of the per cent of successful suppression, which had been mainly derived from the personal opinions and observations of the experimentor and patients. As it was noted in the section dealing

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21 Walter Camp, Robert Martin, Loring F. Chapman, "Pain Threshold and Discrimination of Pain Intensity During a Brief Exposure to Intense Noise", in Science, Vol. 135, 1962, p. 788-789.

with The Theory of Audio-Analgesia, considerable emphasis is now being placed upon the psychological factors of suggestion, relaxation and distraction. The implication of these variables on pain and its intensity have been recognized as major concepts in the effecting of a successful placebo reaction. Further elaboration of these concepts will be illustrated in the following section.

3. Pain.

"Pain has been considered to be a product of consciousness in which the basic element is awareness."[22] It is the main objective of this section to briefly illustrate the psychological effects of suggestion, attitude and relaxation on the individual's perception and reactivity to pain.

Wolff and Goodell[23] have attempted to investigate the elusive effects of attitude and suggestion on the individual's reaction to pain. From a series of several experiments they concluded that:

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22 W.K. Livingston, "What is Pain", in Scientific American, Vol. 188, No. 3, 1953, p. 59-66.

23 H.G. Wolff and H. Goodell, "The Relation of Attitude and Suggestion to the Perception and Reaction to Pain", in Research Publication, Association for Research in Nervous and Mental Diseases, Vol. 23, 1943, p. 434-448.

> If the subject despite his mood and lethargy maintains a detached 'unprejudiced' objective attitude towards the stimulus and if not exposed to suggestive words and procedures, then mood and lethargy have no effect on the level of pain threshold. But if the subject during anxiety, tension, doubt or lethargy or during suggestible states in a situation which detracts from attention or fosters conviction, then the pain threshold may be altered.
>
> It has been shown in these experiments that a placebo given in a setting of conviction that the agent has a pain threshold raising effect(...).[24]

Wolff and Goodell have, in effect, illustrated that success or failure of either a true analgesic agent or a placebo depended on the individual's psychological states of motivation and expectancy.

Barber,[25] after reviewing the literature on the psychophysiological aspects of pain and its relief through chemical agents and the psychological implication of suggestion, concluded that the placebo was an effective means in the reduction of various types of pain, if the proper conditions surrounding the situation were present.

Wolf,[26] in an earlier article described the various conditions and mechanisms in the coming about of a successful

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24 Wolff and Goodell, Op. Cit., p. 444.

25 Theodore X. Barber, "Toward a Theory of Pain: Relief of Chronic Pain by Pre-Frontal Leucotomy, Opiates, Placebos and Hypnosis", in the Psychological Bulletin, Vol. 56, No. 6, 1959, p. 453-454.

26 Stewart Wolf, "Effects of Suggestion and Conditioning on the Action of Chemical Agents in Human Subjects - The Pharmacology of Placebos", in the Journal of Clinical Investigation, Vol. 29, 1950, p. 100-109.

placebo reaction. He wrote that:

> (...) the above placebo reaction depended for their force on the conviction of the patient that this or that effect would result.[27]
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> . . . . . .
>
> The fact that the placebo effect occurs depends of course on the generalization established repeatedly by numerous workers that the mechanisms of the body are capable of reacting not only to direct physical and chemical stimulations but also to symbolic stimuli, words and events which have somehow acquired meaning for the individual.[28]

Essentially, the same psychological implications have been stated by Wolf that success or failure of the placebo reaction depended upon the individual's attitude; however, he also introduced a new concept, that of successful repetition of the situation. Wolf, strongly believed that the placebo reaction was reinforced by these repetitions.

In testing the hypothesis that the reduction of tension would increase pain threshold levels, Hall and Stride[29] found that the simple inclusion of the term pain in a set of instructions made tense subjects report as painful a level of electric shock that they did not previously regard as painful when the word was omitted from the instructions. This suggests that the mere presence of the word pain creates

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27 Wolf, Op. Cit., p. 106.

28 Ibid., p. 108.

29 K.R.L. Hall and E. Stride, "The Varying Responses to Pain in Psychiatric Disorders: A Study of Abnormal Psychology", in the British Journal of Medical Psychology, Vol. 27, 1954, p. 48-60.

an anticipatory set which can increase the individual's anxiety and consequently reduce his pain threshold.

Similar anxiety provoking experiments were conducted by Hill[30] and his associates. They suggested that if anxiety was reduced by reassuring the subject that he had full control over the noxious stimulus, a given level of electric shock or burning heat would be perceived as significantly less painful.

The literature reviewed in the above section is not entirely representative of the field of pain. It attempts to illustrate the variability in the individual's perception and reaction to pain. In summary, pain can be considered as a very personal experience, therefore subjective and variable with changing situations. Wolf, Wolff and Goodell have provided ample evidence that suggestion and relaxation are the major psychological principles in the successful placebo reaction. Hall, Stride and Hill illustrated that the same stimulus can cause different reactions in different individuals, and that the same stimulus can cause different reactions in the same individual. As a result of this brief review, a very general conclusion can be drawn, that it is not so much the neurological sensation that determines the

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30 Harris E. Hill, "Studies on Pain and Analgesia", in the Psychological Record, Vol. 6, 1956, p. 17-23.

individual's perception and reaction to pain, but the psychological implications.

4. Summary and Basic Hypotheses.

In the preceding sections of this chapter, evidence for and against the effectiveness of Audio-Analgesia has been considered, as well as the psychological implication influencing the individual's reaction and perception to pain. It has been postulated that the primary function of Audio-Analgesia is to diminish the individual's awareness to a pain sensation. The underlying principle inherent to this function is thought to be mainly psychophysiological in nature. The sensation of pain in the human body is a definite function of the brain. However, because of the brain's inability to concentrate efficiently on more than one effect or sensation at a time, it is considered possible to divert an individual's attention away from one sensation by subjecting him to another simultaneous sensation. In using sound from an Audio-Analgesic instrument, complete auditory stimulation is accomplished by employing two separate but distinct sounds: stereophonic music which acts as a relaxant agent and white noise which functions as a strong distractor. The interaction of both the stereophonic music and the white noise, in a sense, compels the individual into directing his fullest attention towards the music,

thus diverting his attention away from the original pain sensation.

In applying this theory to pain reduction, it is hypothesized that Audio-Analgesia will increase mean pain tolerance levels. Restated in the null form, three sub-hypotheses are evident:

1. there are no significant differences in mean pain tolerance levels obtained without and with the effects of white noise;

2. there are no significant differences between mean pain tolerance levels obtained without and with the effects of Audio-Analgesia (i.e., a combination of white noise and stereophonic music); and,

3. there are no significant differences between mean pain tolerance levels obtained wihout and with stereophonic music.

To test these hypotheses it was necessary to establish three experimental conditions. The first variable was designated as the white noise condition. It consisted of subjecting a group of individuals to pain tolerance measures without and with the effects of white noise stimulation. The second experimental variable was designated as the Audio-Analgesic condition. Individuals in this group were subjected to measures of pain tolerance without and with the effects of music and white noise. The third experimental variable was called the music condition. Under this condition, a group of individuals were subjected to pain tolerance measures without and with the effects of stereophonic music.

To determine the individual's mean pain tolerance levels an operational definition was designed. This definition is stated as follows: that point when the subject opened the pressure cuff-off valve which immediately released the pressure in the cuff.

CHAPTER II

EXPERIMENTAL DESIGN

This chapter presents a detailed description of the experimental design used in this study. The first section presents the underlying criteria used in the selection of the sample and a description of the sample. Section two describes and discusses the psychophysiological apparatus, its use and technical specifications. The third section elaborates upon the experimental procedures. Section four presents the statistical techniques used in analyzing the data.

1. The Sample Population.

Three criteria were established prior to the selection of the sample: a) That the subjects possessed no foreknowledge concerning the main objectives of the experiment; to insure this, the subjects, when contacted, were informed that this was an experiment involving the use of stereophonic sound; b) The selection of male individuals between the ages of seventeen years to fifty years with no noticeable signs or symptoms of vertigo when exposed to white noise.[1]

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1 Davis Hallowell and Aram Glorig, "Minimum Requirements for Apparatus for Audio-Analgesia", in the Journal of the American Dental Association, Vol. 63, p. 520-525.

This criterion was formulated on the basis that excessive tinnitus was often accompanied by severe vertigo which, in some cases, has been indicative of auditory defects. If the subject had reported being very susceptible to vertigo or tinnitus, he was merely eliminated from the sample.
c) The selection of subjects from the various faculties of the University of Ottawa with the exception of the School of Psychology and Education. This exclusion was made to avoid contamination of the experimental data because this student body had foreknowledge of the main objectives of the experiment.

The entire sample consisted of seventy-nine subjects who were divided into three groups, designated as I, II, and III. This division was based upon mean pain tolerance levels obtained during the first testing session. The age range of the entire sample was from seventeen to forty years. Group I contained twenty-eight individuals with a mean age of 20 years; group II consisted of 28 individuals with a mean age of 21 years; and group III contained 23 individuals with a mean age of 21 years. Each of the groups was then assigned to one of the three experimental conditions: white noise, Audio-Analgesia or stereophonic music. This designation was accomplished by a random selection from two containers: the number of the group and the experimental condition.

2. The Psychophysiological Apparatus.

The instrument used in producing the noxious stimulation was a modification of Poser's[2] pain apparatus. This instrument consisted of a standard sphygmomanometer cuff, the inner surface which had been altered by the addition of four hard rubber plates with 94 pointed seven millimeter projections. The maximum recordable pressure was three hundred millimeters of mercury.[3]

For this experiment, however, several modifications were incorporated into the instrument. First, the inner surface of the cuff was replaced with one hundred and thirty-six pointed 7 millimeter projections. The cuff was then inflated by using a surge tank of compressed air. This air was transmitted to the cuff through a "pressure regulator valve"[4] which controlled the rate of inflation at 5.1 millimeters of mercury per second. In order to obtain peak tolerance levels the manometer scale was expanded to a maximum range of 650 millimeters of mercury. The final change

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2 Ernest G. Poser, "Simple and Reliable Apparatus for the Measurement of Pain", in the American Journal of Psychology, Vol. 75, No. 2, 1962, p. 304-305.

3 Ibid., p. 305.

4 Pressure regulator valve, designed by E. Crittle of the National Research Council.

consisted in designing a "pressure release valve".[5] This change was prompted by the operational definition of pain tolerance, "that point when the subject released the pressure in the cuff". In the opened position, the pressure was immediately released in the cuff and the manometer. To avoid losing the final pressure reading, a rider (inner index) consisting of a plastic slug was inserted into the manometer tube. (See Figure 1.)

The instrument used in producing the Audio-Analgesia was the Philips Sonalgenic, Model CP 9100.[6] This system consisted of two separate units: the white noise generator and the programme source. The manufacturer's stated technical specifications were that the white noise generator was capable of producing a random multi-frequency signal ranging from 500-8000 c.p.s. at -6 Dd and 120-22,000 c.p.s. at -20 Dd with a maximum amplification level of 120 decibels. In addition to the white noise generator a second amplification system within the Sonalgenic was used to control the volume level from the programme source. The related specifications for this system were stated as follows: the frequency response ranges from 80 to 45,000 cycles per second with a maximum

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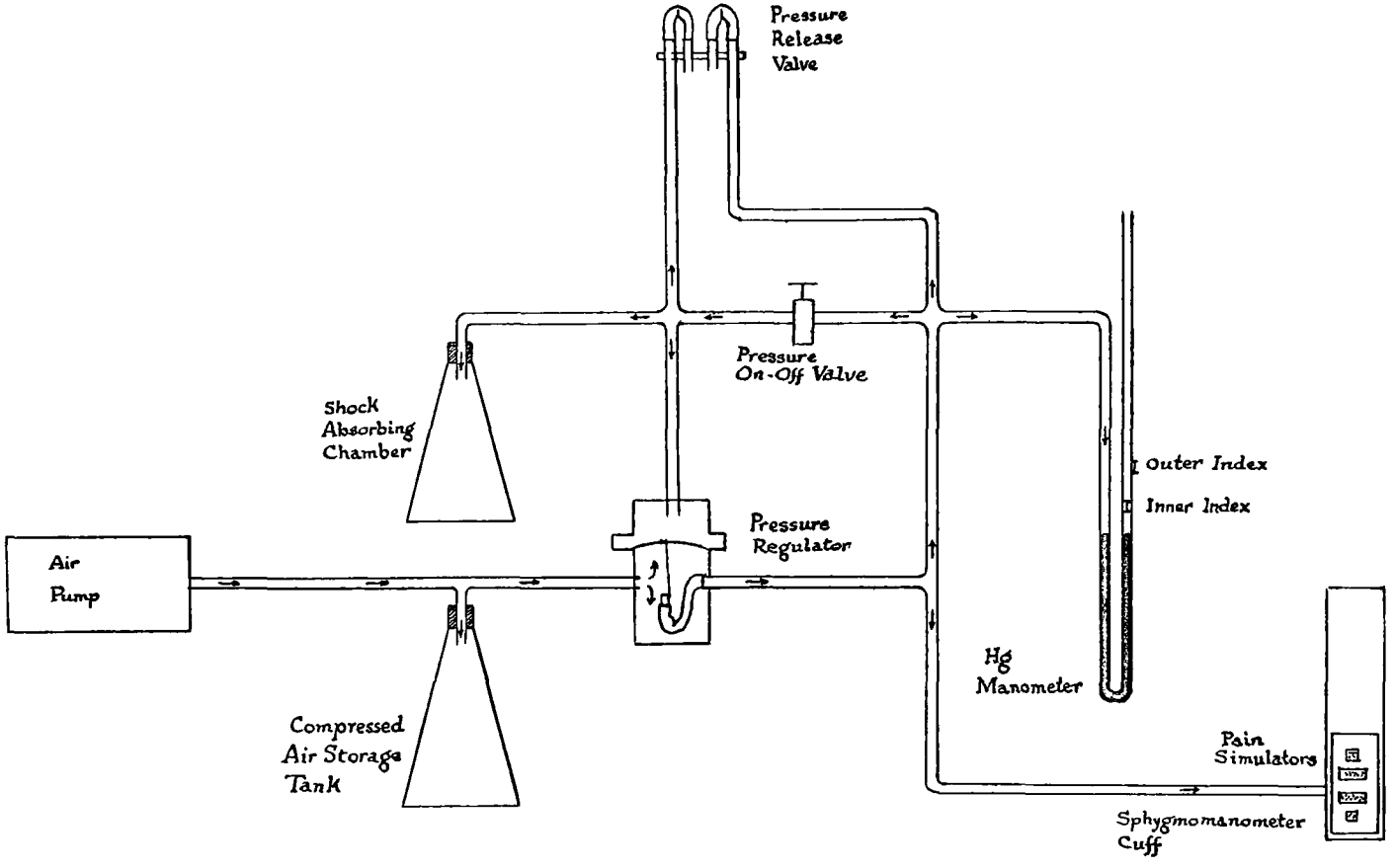
5 Consisted of gum rubber outlets which were crimped over to close the air system to the cuff and the manometer.

6 Philips Medical and Dental Division Ltd., Instruction Booklet, Sonalgenic Model CP 9100, Philips Electronic Industries Limited, Toronto, Ontario, 1-6 p.

FIG 1. APPARATUS FOR THE MEASUREMENT OF PAIN



amplification level of 120 decibels. The two sub-systems within the Sonalgenic were designed to integrate both sources of sound simultaneously, the final sound being transmitted to the subject via a specifically designed set of headphones which produced less than 1.5 per cent sound distortion. (See Figure 2.)

The programme unit employed with the Sonalgenic was a Telectro Stereophonic Tape Recorder, Model SR 441. The technical specification stated by the manufacturer[7] was that the machine was capable of reproducing a sound frequency within the ranges of 50 to 15,000 cycles per second at a tape speed of 7½ inches per second. The instrument was designed with pre-amplifier outputs which transmitted a balanced signal to the programme amplifier within the Sonalgenic. This feature permitted the Sonalgenic's systems to have full control over the decibel level from the programme source.

3. The Experimental Procedures.

The procedures used to measure pain tolerances without and with the effects of the experimental conditions were the same for the entire sample. The only variation introduced into the procedure was the instructions to the subject

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7 Telectrosonic Corporation, Operating Instructions for the Twin Speaker Stereo Fidelity Recorder Model SR 441, Telectrosonic, Long Island City, New York, 1960, p. 2-11.

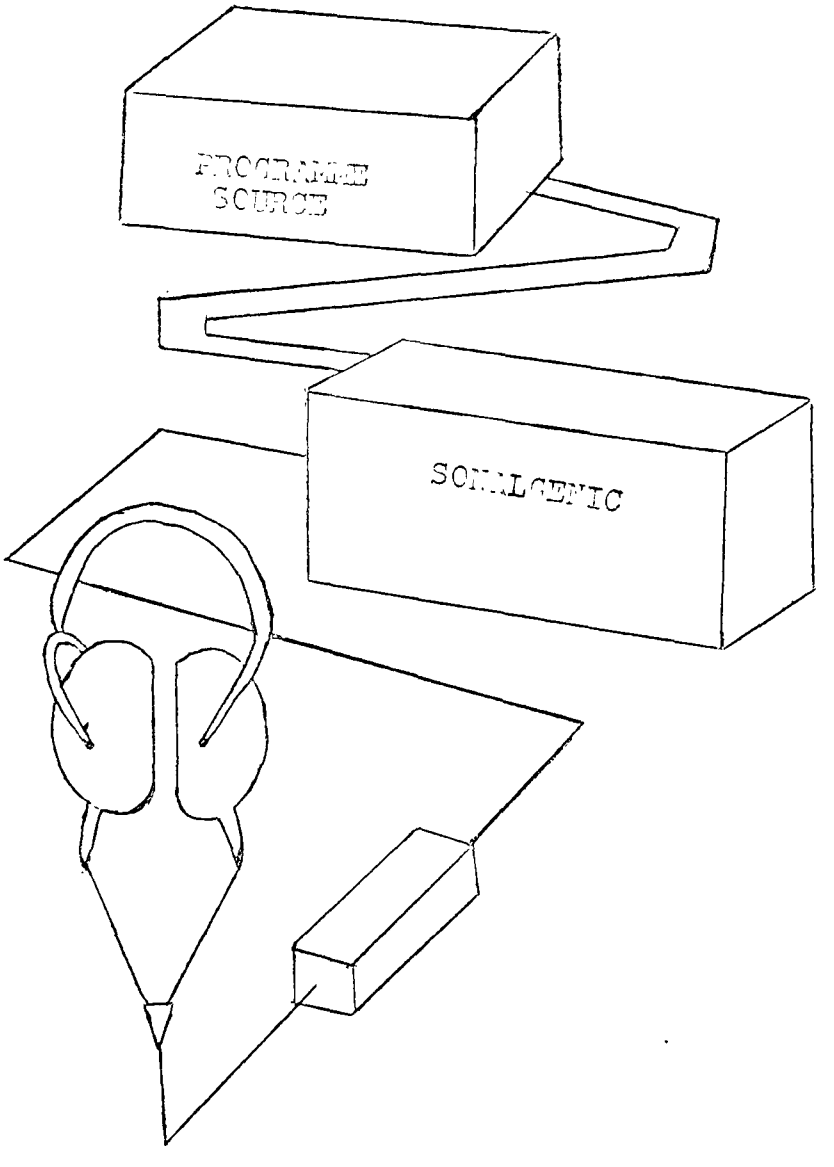

Figure 2.- The Audio-Analgesic Apparatus.

as to what was required of him when the experimental conditions were being tested.

a) The Measurement of Pain Tolerance Without the Effects of the Experimental Condition.- The subject was asked to remove his shirt and be seated, facing in a direction away from the pain apparatus. The latter was an important factor because knowledge of the pressure attained by the subject on the first testing might have influenced additional measurements. The subject was then given instructions which read as follows:

> I am going to place a standard blood pressure cuff on your upper arm. I will then turn on the air pressure which will cause the cuff to inflate. When the pressure in the cuff reaches a point that to you is very uncomfortable and possibly irritating, and when continuing on with this procedure would be very annoying, I want you to release this valve (demonstrated). The releasing of this valve will cut off the flow of air.

The stimulator plates were then placed against the inner surface of the subject's upper arm. Once the cuff was in position, the subject was asked to place the strapped arm upon his knee and then was instructed not to move this arm while the cuff was being inflated.

The procedure was terminated when the subject opened the release valve which he held in his free hand. The final pressure was recorded, and a time interval of three minutes was allowed to elapse. This time interval was used to reduce the possible effects of hyperalgesia on the stimulated arm,

and thus not to interfere with the measurement of pain tolerance on the opposite arm. The same procedure was then duplicated on the subject's left arm. At the termination of this procedure, the subject was asked to return in two weeks for the second stage of the experiment.

b) The Second Stage.- The measurement of pain tolerance under the experimental conditions remained the same, while the only procedural variation consisted in the use of the Audio-Analgesic apparatus. Because of the nature of the experiment at this stage, additional instructions were incorporated into the basic instructions. These read as follows:

> In this part of the experiment, I am again going to place the cuff on your upper arm and again, as we did in the previous part of the experiment, I am going to inflate the cuff. When you feel the cuff's pressure reach a point that to you is very uncomfortable and possibly irritating and when continuing on with the procedure would be annoying, I want you to release this valve. It will cut off the flow of air pressure. Now, while you are wearing the cuff you will also be wearing these headphones; what I want you to do is to concentrate on-

Depending upon what experimental condition was being tested, the following interchangeable phrases were used with the instructions:

Group I the white noise;
Group II the stereophonic music through the white noise;
Group III the stereophonic music.

After the cuff had been strapped into position and the subject's arm placed upon his knee, the headphones were

then set into position. A period of one minute was allowed to elapse while the subject adjusted himself to the intense sound stimulation.[8] Following the one minute sound stimulation the air pressure was turned on. This stage of the experiment was terminated when the subject opened the release valve. He was then asked to return in two weeks for the final stage of the experiment.

The procedures employed in the final stage of the experiment were identical to those mentioned in the above paragraph. The main purpose of this stage was to obtain retest measurements which were used in evaluating the reliability of the experimental procedures.

4. Analysis of the Data.

The scale employed in the measurement of pain tolerance levels was a manometer of the "U" tube variety. This particular manometer had a "zero" point equivalent to 360 millimeters of mercury. Because of this scale, it was necessary to convert the raw scores into corrected scores which were based on a real zero point. The formula derived for this conversion reads as follows:

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8 Licklider has indicated that the procedure is more effective if the white noise is turned up before the pain process develops, than if the noise is withheld until the pain process has fully developed.

$$2(X) - 720 \text{ mm.} = x$$

where, 2 was used as a constant multiplier.
X the raw score in millimeters of mercury.
-720 a constant subtraction factor.
x equals the corrected score in millimeters of mercury.

The means and the standard deviations were then computed from the corrected scores. These calculations were then used to test the assumption that there were no significant differences between the mean pain tolerance levels of the three groups. The following formulae were used:

$$t = \frac{Diff}{\sigma d_M}$$

where, $\sigma_M = \sqrt{\frac{\Sigma x^2}{N(N-1)}}$

and $\sigma d_M = \sqrt{\sigma_{M_1}^2 + \sigma_{M_2}^2}$

In testing the hypotheses of no significant differences between the mean pain tolerance levels obtained without and with the effects of the experimental conditions for the three groups, the following formulae were used.

$$t = \frac{Diff}{\sigma d_M}$$

where, $\sigma_M = \sqrt{\frac{\Sigma x^2}{N(N-1)}}$

and $$\sigma_{dM} = \sqrt{\sigma^2_{M_1} + \sigma^2_{M_2} - 2r^2(\sigma_{M_1})(\sigma_{M_2})}$$

and $$r_{xy} = \frac{N\Sigma XY - (\Sigma Y)(\Sigma X)}{\sqrt{[(N\Sigma X^2 - (\Sigma X)^2][(N\Sigma Y^2 - (\Sigma Y)^2]}}$$

To determine the reliability of pain tolerance measures, the entire sample was retested. This datum was then used to calculate a Pearson r. The formula for this computation reads as follows:

$$r_{xy} = \frac{N\Sigma XY - \Sigma X \Sigma Y}{\sqrt{[(N\Sigma X^2 - (\Sigma X)^2][(N\Sigma Y^2 - (\Sigma Y)^2]}}$$

CHAPTER III

PRESENTATION AND INTERPRETATION OF RESULTS

This chapter presents the results of the experiment and a discussion of these findings with regard to the three sub-hypotheses of no significant differences. The first section presents the test-retest reliability of pain tolerance measures; section two presents the mean pain tolerance measures obtained from the three groups; section three presents the results of mean pain tolerance levels obtained without and with the experimental conditions; and section four presents a specific discussion of each experimental condition, as well as suggesting further research hypotheses.

1. Test-Retest Reliability.

One of the basic principles that must be taken into consideration before any interpretation is forthcoming is that of the experimental reliability of the pain tolerance measures.

To determine an index of reliability for the measures of pain tolerance, the entire sample was retested on two occasions.

The first occasion consisted of a test on the right arm and a retest on the left arm with a time lapse of three minutes between testings. As previously noted, this time

interval served the purpose of preventing the possible effects of hyperalgesia from influencing the pain tolerance measures on the opposite arm.

The Pearson r computed from these data was used mainly in testing the assumption that pain tolerance measured on the right arm was the same as that measured on the left arm. An r of .80 was obtained which is significant at the .01 level of probability. Because an r was employed rather than a t test in testing this assumption, it was necessary to estimate the amount of accountable variability between the two arms. The value for the Coefficient of Determination was .64; consequently, sixty-four per cent of the variance in the right arm could be accounted for in the left arm. The tested assumption was substantiated.

The second occasion consisted of a test-retest of the subject's right arm only, with a two-week interval between testings. The data obtained on this occasion were mainly used to determine the subject's consistency in reporting pain tolerances. This r was .74 which is significant at the .01 level of probability.

The value of these r's appears to be moderately high and demonstrates to some degree marked relationships between the two measures of pain tolerance. However, in view of the fact that pain tolerance measures are basically psychophysiological in nature, it would have been desirable to have

secured higher r values. It is possible that several contaminating factors were involved in the measuring procedure. Perhaps the two major elements influencing this contamination were: the individual's judgment in estimating his pain tolerance level and the variability in the positioning of the cuff on the subject's upper arm. Assuming that judgment was a major factor, it is necessary to review the basic instructions used with the measurement procedure. The phrase, "a point that to you is very uncomfortable and possibly irritating and when continuing on with the procedure would be annoying(...)", is questionable and probably misleading, since the terms unbearable and painful were not directly stated, but only implied. This, in itself, could have confused the subject as to what the experimentor required. A second factor in question is the positioning of the cuff on the inner surface of the subject's upper arm. Because of the different circumferential sizes of the subjects' upper arms, it is most probable that the cuff's position between individuals may have been shifted, thus causing a possible change in measurement.

2. Mean Pain Tolerance Levels.

The assumption underlying the division of the entire sample into three groups was that the mean pain tolerance levels between the first twenty-eight subjects, the second

28 and the last 23 were not statistically different. The data manipulated in this manner provided an anchor point on which statistical comparisons could be made between the three groups. The means, standard deviation and t values for the three groups were computed. The minimum requirement for statistical significance is a t value of 2.47 with twenty-seven degrees of freedom. It was evident that all the t's calculated were not statistically significant at either the .05 or .01 level of probability when utilizing a one tail test. These values are summarized in Table I.

The entire procedure for mean pain tolerance levels was then repeated twoo weeks later. From these data a second series of t values were computed. The results of these calculations are listed in Table II. It should be noted that when the t's of the first trial are compared to the t's of the second trial by inspection the magnitude of these values remain essentially the same. Although the numerical values of the means tend to shift, the change is probably due to chance fluctuation in the sample or an error in measurement. The essential conclusion derived from these data: the means of pain tolerance levels between the three groups were not statistically different, and could be, for all practical purposes. considered as statistically equivalent.

Table I.-

Statistical Comparisons of Mean Pain Tolerance Levels Between the Three Groups: White Noise, Audio-Analgesia, Music.

Groups	N	Mean	SD	σ_M	Diff	σ_{d_M}	t
White Noise	28	286.43	125.65	24.18	43.82	40.63	1.078
Audio-Analgesia	28	330.25	135.73	26.13			
White Noise	28	286.43	125.65	24.18	6.44	33.57	0.192
Music	23	292.87	153.59	32.74			
Audio-Analgesia	28	330.25	135.73	26.13	37.38	40.09	0.932
Music	23	292.87	153.59	32.74			

Table II.-

Statistical Comparisons of Retested[a] Mean Pain Tolerance Levels Between the Three Groups: White Noise, Audio-Analgesia, Music.

Groups	N	Mean	SD	σ_M	Diff.	σ_{d_M}	t
White Noise	28	293.86	133.39	22.69	33.43	32.49	1.028
Audio-Analgesia	28	327.29	125.95	24.24			
White Noise	28	293.86	133.39	22.69	5.77	37.98	0.152
Music	23	288.09	142.87	30.46			
Audio-Analgesia	28	327.29	125.95	24.24	39.20	38.32	1.022
Music	23	288.09	142.87	30.46			

a Mean Pain Tolerance Levels obtained two weeks later.

3. T-Test of Significance Between Pain Tolerance Means Obtained Without and With the Experimental Conditions.

To test the three sub-hypotheses of no significant differences, the study was designed so that each group acted as its own control. Thus, all the groups were subjected to pain tolerance measures without and with the experimental conditions.

The means, standard deviations and the standard error of the means were calculated. Because each subject acted as his own control, the standard error of the differences between the correlated means of each group had to be computed. None of the t values reached statistical significance at either the .05 or the .01 level of probability with the one tail test. The statistical values for these calculations are summarized in Table III.

A second series of t's were computed from the retest data obtained two weeks later. The t values for the White Noise and the Music groups were not statistically significant, but the t value for the Audio-Analgesic group attained a level of 2.12 which is significant at the .05 level of probability. The results of these calculations are presented in Table IV.

The following section will discuss these results and consider possible explanations as to why the Audio-Analgesic phenomenon did not appear to attain statistical

Table III.-

T-Evaluations of Mean Pain Tolerance Levels Obtained Without and With the Experimental Conditions for: White Noise, Audio-Analgesia and Music Groups.

Groups	N	Mean	SD	σ_M	r	Diff.	σ_{d_M}	t
Pain Tol.[a]	28	286.43	125.65	24.18	.78	1.00	21.34	0.047
Pain Tol.	28	285.43	125.45	24.14				
Pain Tol.[b]	28	330.25	135.73	26.13	.74	33.75	25.57	1.32
Pain Tol.	28	364.00	144.25	27.70				
Pain Tol.[c]	23	294.52	153.59	32.74	.93	1.7	18.18	0.094
Pain Tol.	23	292.82	165.79	35.35				

a Abbreviation for pain tolerance obtained under the experimental condition of white noise.
b Abbreviation for pain tolerance obtained under the experimental condition of audio-analgesia.
c Abbreviation for pain tolerance obtained under the experimental condition of stereophonic music.

Table IV.-

T-Evaluations of Retest Data* of Mean Pain Tolerance Levels Obtained Without and With the Experimental Conditions for the: White Noise, Audio-Analgesia and Music Groups.

Groups	N	Mean	SD	σ_M	r	Diff.	σ_{Diff_M}	t
Pain Tol.	28	293.86	133.39	22.69				
Pain Tol.[a]	28	291.64	129.03	24.83	.70	2.22	24.07	0.092
Pain Tol.	28	327.29	125.95	24.24				
Pain Tol.[b]	28	378.00	153.81	39.60	.79	50.71	23.29	<u>2.12</u>
Pain Tol.	23	288.09	142.87	30.46				
Pain Tol.[c]	23	303.22	159.33	33.63	.93	15.13	17.23	0.878

* Retest data obtained two weeks later after second stage of the experiment was completed.

a Abbreviation for pain tolerance obtained under the experimental condition of white noise.

b Abbreviation for pain tolerance obtained under the experimental condition of audio-analgesia.

c Abbreviation for pain tolerance obtained under the experimental condition of music.

Single underline indicates statistical significance at the .05 level of probability.

significance on the first trial, but why it did attain significance on the second trial.

4. Discussion.

The discussion will center around the three sub-hypotheses of no significant differences. However, before a detailed discussion is forthcoming it will be necessary to analyze some of the weaknesses in the design which may have exerted a biased influence on the present results.

Two major inadequacies of the design shall be taken into consideration: the size of the sample groups, and the decibel level of the Audio-Analgesic equipment, as well as the quality of white noise produced by this equipment.

a) The Size of the Sample Groups.- The initial question to be considered is whether an increase in the number of subjects within each of the groups would have facilitated a statistically significant mean difference in pain tolerance levels obtained without and with the experimental conditions. In the preceding section of this chapter, Tables III and IV presented the t values for the first and second trials of the experiment. On inspection the values for the White Noise group and the Music group appear to be of a very low magnitude. It is most probable that an increase in the number of subjects within each of these groups would not have facilitated a significant

difference in the mean pain tolerance levels. The t value of the Audio-Analgesia group, though not statistically significant on the first trial, tends to approach significance. Appendices one and two illustrate test-retest measures of pain tolerance levels of each individual obtained without and with the experimental condition of Audio-Analgesia. From these data, there appears to be a trend for the pain tolerance scores to increase under the effects of Audio-Analgesia. For example, on the initial trial, the increase of scores under Audio-Analgesia was 60.8 per cent, and on the second trial the increase was 71.4 per cent. It is plausible, therefore, to hypothesize that an increase in the number of individuals within this group might have resulted in a possible significant mean difference on the first trial.

b) The Audio-Analgesic Equipment.- The question has arisen as to whether the predetermined setting on the white noise generator (64 decibels) was sufficient to suppress pain. Licklider[1] and Monsey[2] have suggested that a level of 70 to 90 decibels is required if the white noise is to be an effective suppressor of pain. However, in the literature,

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1 J.C.R. Licklider, "On Psychophysiological Models", in Sensory Communications, 1962, p. 52.

2 Harold Monsey, "Preliminary Report on the Clinical Efficacy of Audio-Analgesia", in the Journal of the Nevada Dental Association, Vol. 36, December 1960, p. 432.

it was indicated that these authors utilized an Audiac instrument in their experimentation. It must be noted that the Audiac and the Sonalgenic are not comparable instruments. The Audiac produces a white noise frequency ranging from 500 to 5,000 cycles per second, while the Sonalgenic produces a white noise frequency ranging from 120 to 22,000 cycles per second at 64 decibels. By using this frequency range, Licklider and Monsey have in fact employed a narrow band of white noise, whereas, in the present experiment, a wide band of white noise was employed. Kessler[3] has investigated the potential differences between the two bands, and has concluded that there is a possibility that the decibel levels of the two bands are not similar. He suggested that, "when the level in a given narrow frequency band is only 81 decibels, the overall sound pressure level could reach 105 decibels".[4] Consequently, a setting of 64 decibels on a wide band of noise is not comparable to the narrow band. Thus it is estimated that a 70 to 90 decibel level on a narrow band of white noise would possibly be equivalent to a 50 to 70 decibel level on the wide band.

The differentiation between the two bands of noise draws another concept into view which may account in part

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3 Howard Kessler, "Auditory Distraction Analgesia", in Dental Survey, Vol. 36, November 1960, p. 1458-1460.

4 Ibid., p. 1459.

for the present results. The quality of the white noise produced by the both bands is not comparable. Narrow band noise resembles a low rumble waterfall sound which is apparently more pleasant to some listeners' ears, while the wide band seems to have a harsh rasping quality produced by the higher frequencies, and these appear to be unpleasant and irritating to some individuals.

5. White Noise.

The sub-hypothesis that there is no significant difference between mean pain tolerance levels obtained without and with the effect of white noise was not rejected on either the first trial or the second trial.

Because these conclusions are contrary to Gardner et al.'s[5] theory that white noise is the direct suppressive agent which confuses the areas surrounding the geniculate body of the thalamus and promotes a cross-sensory blocking, several procedures within the experiment must be discussed.

Licklider[6] specifically reported that if sound stimulation occurred prior to the noxious stimulation, then the pain process should be held in abeyance. The design of

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5 W.J. Gardner, J.C.R. Licklider and A.Z. Weisz, "Suppression of Pain by Sound", in Science, Vol. 132, 1960, p. 54-55.

6 Licklider, Op. Cit., p. 49-71.

this experiment took this factor into account, i.e., the subject was stimulated with 64 decibels of white noise for a period of one minute prior to the noxious stimulation. As noted in the conclusion, white noise failed to suppress the pain process. However, what the design did not account for and could be considered as a partial explanation for the present findings was Licklider's[7] sub-hypothesis that the effectiveness of white noise increases with sound intensity and decreases with the intensity of the noxious stimulation. In this experiment, the subject was not at liberty to control the intensity of the white noise as the noxious stimulation increased. It could be speculated that the potential effectiveness of the white noise was dissipated as the pain process increased.

A second factor to be considered is the quality of the white noise produced by the Sonalgenic apparatus. Mittleman[8] has reported varied degrees of success in relation to different spectra of white noise. As previously mentioned, there is a vast difference in the tonal qualities of narrow and wide band noise. The wide band noise produces mainly a harsh and rasping sound which to some individuals could be

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7 Licklider, Op. Cit., p. 52.

8 Jerome Mittleman, Understanding Audio-Analgesia, paper presented at the 15th Annual Meeting of the Audio Engineering Society, Preprint No. 289, October 14-18, 1963.

very irritating and annoying. Perhaps this irritating quality induced a sudden fear on the part of the subject that a sound as intense as this could cause possible auditory damage. Consequently, if this was so, the fear may have reduced his tolerance levels.

In general, it is concluded that the results found under this condition are similar to that found by Carlin et al.,[9] and Camp et al.,[10] that Audio-Analgesia is probably not an example of cross-sensory masking, and that the effects of white noise do not alter an individual's ability to differentiate between different intensities of pain.

6. Audio-Analgesia.

The sub-hypothesis that there is no significant difference in the mean pain tolerance levels obtained without and with the effect of Audio-Analgesia was not rejected on the first trial, but was rejected on the second trial. Because of the apparent contraindications between the two experimental sessions both conclusions will be dealt with separately.

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9 Sidney Carlin, W. Dixon Ward, Arthur Gershon and Rex Ingraham, "Sound Stimulation and Its Effects on Dental Sensation Threshold", in Science, Vol. 138, December 1962, p. 1258-1259.

10 Walter Camp, Robert Martin and Loring F. Chapman, "Pain Threshold and Discrimination of Pain Intensity During a Brief Exposure to Intense Noise", in Science, Vol. 135, 1962, p. 788-789.

The explanations dealing with these conclusions will be centered around what has been recently dubbed the Principle of Psychological Sound of Audio-Analgesia.[11] The underlying rationale of this principle is that the interaction of white noise and music produce a diminished awareness to one sensation (pain) while producing an increased awareness to another sensation (music).

To understand the essential function of Audio-Analgesia, it is necessary to analyze the components inherent in this condition. On one side there is the white noise, on the other music. Both operate in a similar manner, that is to achieve complete auditory stimulation. The white noise introduces the function of distraction, while music introduces two sub-functions: a) the diversion of attention through the use of meaningful sound; and b) relaxation achieved through melodic rhythms. The interaction of both components depends upon two factors: the distracting capacity of the white noise and the absorbing and compelling nature of the music.

To obtain a clearer understanding of the meaning of Audio-Analgesia, it is necessary to consider the actual situation as it occurred in this experiment. Prior to any

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11 Philips Medical and Dental Division, Instruction Booklet, Sonalgenic Model CP 9100, Philips Electronic Industries Ltd., Toronto, 1964, p. 2.

stimulation, the subject was instructed "to concentrate on the stereophonic music through the white noise". By using this phrase, it was hoped to set up a psychological state of expectancy. This state could be considered as the first step in attempting to diminish the subject's awareness to the painful stimulation on his arm. The subject was then simultaneously stimulated with pain and Audio-Analgesia. Under the stimulation of Audio-Analgesia, the white noise is apparently functioning as a distractor which should urge the subject to utilize his fullest concentration on the music. It is at this point that it may be possible to postulate that the brain can efficiently attend to only one sensation at a time. Thus, the subject's awareness to the original sensation (if he is responding in the described manner to the music and the white noise) should be gradually dissipating. As the subject's "pre-supposed" attention gains apparent control over the distractor, the melodic rhythm of the music should increase in intensity and result in the reduction of his tensions and anxieties; consequently, the experimental hypothesis of increased tolerance levels should result.

If the above-mentioned functions were operating according to the proposed rationale, then significant increases in mean pain tolerance levels should have been evident. On the first trial, this did not appear to be the case. All t values were insignificant; however, when a

comparison of the t values were made, white noise (.047) and music (.094) appeared to be of a low magnitude, while the t value of the Audio-Analgesic group (1.32) appeared to approach significance. This value is important by reason that the t value, though not statistically significant, was showing up in a greater magnitude than the two other conditions. A similar inspection of the data obtained on the second trial indicated that the t values for the white noise (.092) and music (.878) were not significant, but the t value for the Audio-Analgesic (2.12) condition achieved statistical significance. As a result of this finding, the question has arisen as to why the phenomenon (suppression of pain by sound) occurred on the second trial. In all probability, it is felt that a general process of adaptation may have occurred. By using the term adaptation, the occurrence of the phenomenon can be described from two points of view: 1) a general interpretation; and 2) a specific interpretation. Generally, adaptation is a progressive alteration or change in a sensory response followed by, or as a result of, continual stimulation. More specifically, in the sense of Audio-Analgesia, a process known as attentional adaptation could have occurred. This type of adaptation is a diminished awareness to the original stimulus (pain) when concentrating on another stimulus (music). With the possibility that attentional adaptation may be a partial explanation to

account for the presence of the phenomenon (suppression of pain by sound), the question has arisen as to what does the subject adapt to. On the basis of speculation, it would be necessary to consider each element present within the Audio-Analgesic condition. Adaptation to pain does not generally occur if the stimulus is in constant motion, nor does total adaptation to music occur because of its variations in rhythm. The remaining element, white noise, presents a possible potential for adaptation. It must be noted that the so-called waterfall sound produces a somewhat constant drone effect and is liable to attentional adaptation.

7. Stereophonic Music.

The third sub-hypothesis that there is no significant difference between mean pain tolerance levels obtained without and with the effect of stereophonic music was not rejected on either the first trial, or on the second trial.

The underlying rationale of this hypothesis was that the essential function of music was to induce within the individual a state of relaxation through a diversion of attention away from the original stimulus (pain). It is apparent from the above conclusions that it failed to do so in this experiment.

Two possible factors may be able to account for the present results: the type of music used, and the subject's

own personal likes and dislikes of particular selections of music.

For the best possible diversion of attention, Hallowell and Glorig[12] believed that the characteristics of the music should be substantially continuous with a restricted frequency range, so that there are no great differences in volume levels between the louder and softer passages. In this experiment, the selection used was Zing Went the Strings of My Heart[13] which does create a vast amount of volume variations. It is possible that the low volumes or softer passages would tend to cause a waning of the individual's attention, while the stronger passages might have attracted it. These wide fluctuations in attention may have defeated the proposed hypothesis, thus resulting in no significant differences in the mean pain tolerance levels.

The second point is the fact that a single selection of music was employed for all subjects. It could be considered possible that some individuals actually enjoyed the selection, but to others it may have been distasteful.

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12 Davis Hallowell and Aram Glorig, "Minimum Requirements for Apparatus for Audio-Analgesia", in the Journal of the American Dental Association, Vol. 63, October 1963, p. 520-525.

13 Enoch Light, Zing Went the Strings of My Heart, Recorded in Stereo 35/MM, Tape No. RS4T826, Command Tapes.

Although no definitive conclusion as to the effectiveness of Audio-Analgesia was established, there are several indications for further experimental investigations in the area of psychophysiology.

It is apparent that not all individuals are equally responsive to the effects of Audio-Analgesia. It would be interesting to determine if there is a relationship between non-responsiveness and responsiveness and personality characteristics.

Secondly, about the question of suggestion, it has been indicated, by some authors, that suggestion is a major element in the successful use of Audio-Analgesia, while others have indicated that the effectiveness of pain suppression by Audio-Analgesia is specifically neurological. It would be interesting to determine what effect positive and negative suggestions have on Audio-Analgesia.

SUMMARY AND CONCLUSIONS

The main purpose of the present research was to investigate and evaluate the effectiveness of Audio-Analgesia in the suppression of brachial pain. Secondary objectives were to study the possible effect of white noise on pain, and stereophonic music on pain.

In the analysis of the three experimental conditions, (white noise, Audio-Analgesia, and stereophonic music) it was found that the three sub-hypotheses of no significant difference were not rejected on the first trial. On the second trial, however, the hypotheses of no significant difference were not rejected in two of the experimental conditions (white noise and stereophonic music), but were rejected in the Audio-Analgesic condition.

Several main conclusions were drawn from the present research. First, white noise which had been postulated to be the direct analgesic agent by causing a confusion in particular thalamic nuclei failed to do so in this experiment (using this particular design). It was suggested that the potential effectiveness of the white noise was dissipated as the noxious stimulation increased. This conclusion was in reference to Licklider's[1] sub-hypothesis that the

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1 J.C.R. Licklider, "On Psychophysiological Models", in Sensory Communications, 1962, p. 52.

effectiveness of white noise increases with higher intensities as the intensity of the noxious stimulation increases. Secondly, music which had been postulated to induce a state of relaxation through its rhythmical and melodic variations also failed to suppress pain. It was suggested that the characteristics of the music be substantially continuous, that is, the selection should possess no great difference between the louder and softer passages, and that the music used be the personal selection of the subject.

The Audio-Analgesic condition which was based on the postulation of diminished awareness to the original sensation and an increasing awareness to another auditory stimulation appears to be effective. However, its ability to suppress pain appeared to potentially depend on adaptation. By analysis of the essential components of Audio-Analgesia, it was inferred that attention adaptation occurs to the white noise. As the subject adapts to the white noise, he concentrates more fully upon the music, thus his awareness to the original sensation (pain) is gradually diminished.

Two major suggestions for future research emerged from this experiment: 1) that it was apparent that not all individuals are equally responsive to the effects of Audio-Analgesia. It would prove interesting to determine if there is any relationship between responsiveness and non-responsiveness and personality characteristics. 2) Some investigators have

indicated that suggestion has no result on the effectiveness of Audio-Analgesia, while others indicated that it is a very essential element. It would be interesting to investigate what the effect of positive and negative suggestions have on Audio-Analgesia.

If further experimental research is conducted in this area, it is advised that the experimentor utilize a higher level of white noise (70 to 90 decibels). If it is at all possible, it is suggested that the experimentor allow the subject to control the intensity of the white noise and the music while the noxious stimulation is increasing. The music employed should be the subject's own personal selection. The use of the experimental method latin squares, in which each individual would undergo all experimental conditions, would probably have improved the design of this study in that it would render control over some attitudinal variables towards pain.

BIBLIOGRAPHY

Camp, Walter, Robert Martin, and Loring F. Chapman, "Pain Threshold and Discrimination of Pain Intensity During a Brief Exposure to Intense Noise", in Science, Vol. 135, 1962, p. 788-789.

One of the few experiments conducted in the area of psychophysiology, its main objective was to determine if the intensities of different pain could be altered with the effects of white noise. The authors concluded that neither pain threshold nor the ability to differentiate different intensities of mild pain had been altered under the effects of the noise. The present study was designed in a manner that approximated Camp et al.'s. The results of this study are in close agreement with the above experiment.

Carlin, Sidney, W. Dixon Ward, Arthur Gershon and Rex Ingraham, "Sound Stimulation and Its Effects on Dental Sensation Threshold", in Science, Vol. 138, December 1962, p. 1258-1259.

This study assumed three basic hypotheses for the effective functioning of Audio-Analgesia: cross-sensory masking, suggestion, distraction, or a combination of the last two. The authors concluded that Audio-Analgesia was not an example of cross-sensory masking, but that successful use probably depended upon a combination of suggestion and distraction.

Gardner, W. J. and J.C.R. Licklider, "Serendipitous Effects on Masking Noise Upon Sensation Produced by a Dentist's Drill", in the Journal of Acoustic Society of America, Vol. 31, 1950, p. 117.

This study and the one presented in this thesis were designed on similar lines. The authors assumed experimentally that Audio-Analgesia was effective. Although they questioned the fact, how effect was white noise alone and music alone one pain, they concluded that neither condition of noise or music was an effective suppressor of pain, but the combination of the two was very effective. The results of the present study are in close approximation to the experiment discussed in this thesis.

--------, and J.C.R. Licklider, "Follow Up Report on Audio-Analgesia", in the Journal of Acoustic Society of America, Vol. 31, 1959, p. 850.

The design of this study was based upon the findings of the above study. Ins main objective was the assessment of Audio-Analgesia in the dental situation. The results were indicative of successful suppression of pain.

Gardner, W.J., J.C.R. Licklider and A.Z. Weisz, "Suppression of Pain by Sound", in Science, Vol. 132, 1960, p. 32-33.

The authors again tested the hypothesis that Audio-Analgesia would suppress pain. They concluded that it was effective in the dental situation. In addition to this, they postulated a neurophysiological theory as to how Audio-Analgesia functions. The essential element in this theory was the cross-sensory interaction between pain and auditory stimulation.

Kessler, Howard E., "Auditory Distraction Analgesia", in Dental Survey, Vol. 36, November 1960, p. 1458-1460.

In this report, the author comments upon the safety factors involved in the use of the Audio-Analgesic apparatus, as well as the varied decibel settings between wide and narrow band white noise. He also reiterates the neuor-physiological theory, as well as proposing a psychological theory of adaptation.

Licklider, J.C.R., "On Psychophysiological Models", in Sensory Communications, 1962, p. 49-71.

This is a report whereby the author attempts to explain the function of white noise in the suppression of pain. He illustrates these functions by utilizing a computer to simulate the pain and auditory systems. He attempts to demonstrate the interaction of each system and how the pain is suppressed.

APPENDIX 1

INDIVIDUAL PAIN TOLERANCE SCORES OBTAINED WITH AND WITHOUT AUDIO-ANALGESIA

APPENDIX 1

Table V.-

Individual Pain Tolerance Scores Obtained Without (Right Arm) and With (Left Arm) the Experimental Condition of Audio-Analgesia. N:28

Right Arm	Left Arm	Direction
454	416	-
142	116	-
252	300	/
282	420	/
414	416	-
500	530	/
226	570	/
396	234	-
272	242	-
520	476	-
250	306	/
174	292	/
276	508	/
500	560	/
520	562	/
562	566	/
432	542	/
504	364	-
252	242	-
442	524	/
402	306	-
360	302	-
102	136	/
164	270	/
257	430	/
198	194	-
270	248	-
124	120	-

(-) Indicates a decrease of pain tolerance score on the Audio-Analgesic condition (39.2% decreased).

(/) Indicates an increase in the pain tolerance score under Audio-Analgesic condition (60.8% increased).

APPENDIX 2

RETEST OF INDIVIDUAL PAIN TOLERANCE SCORES OBTAINED WITH AND WITHOUT AUDIO-ANALGESIA

APPENDIX 2

Table VI.-

Retest of Individual Pain Tolerance Scores Obtained Without (Right Arm) and With (Left Arm) the Experimental Condition of Augio-Analgesia.

Right Arm	Left Arm	Direction
232	212	-
120	174	/
320	338	/
282	502	/
454	376	-
398	572	/
388	462	/
176	216	/
466	260	-
442	524	/
264	310	/
216	322	/
400	482	/
426	542	/
430	598	/
594	612	/
450	536	/
344	532	/
278	288	/
434	578	/
408	320	-
242	280	/
92	82	-
168	290	/
352	342	-
230	230	o
308	504	/
150	100	-

(-) Indicates a decrease of pain tolerance scores on the Audio-Analgesic Condition (28.6% decreased).

(/) Indicates an increase in the pain tolerance scores under the Audio-Analgesic Condition (71.4% increased).

(o) Indicates no change.

APPENDIX 3

ABSTRACT OF

An Exploratory Study on the Effectiveness of Audio-Analgesia

APPENDIX 3

ABSTRACT OF

An Exploratory Study on the Effectiveness of Audio-Analgesia[1]

This thesis has reported on the effectiveness of Audio-Analgesia in the suppression of pain.

The survey of the literature indicated that Audio-Analgesia was probably successful in dental situations, but little indication as to its effectiveness was given in the area of psychophysiological research.

The null hypothesis was stated as: there are no significant differences between mean pain tolerance levels obtained without and with the experimental conditions of: white noise, Audio-Analgesia, music.

A sample of seventy-nine subjects was divided into three groups. Each group was exposed to pain tolerance measures without and with the effect of one of the experimental conditions.

T-tests were employed to determine if there was a statistically significant difference between the mean pain tolerance levels obtained without and with the experimental conditions.

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1 Joseph G. Marone, master's thesis presented to the School of Psychology and Education, University of Ottawa, Ontario, August 1964, viii-59 p.

The findings on the first trial suggested that neither condition of white noise nor music alone was effective in increasing brachial pain tolerance levels. There was some indication, however, that the Audio-Analgesic condition had effected a mean pain level change, though it was not statistically significant. The results obtained on the second trial,held two weeks later, confirmed in part the findings obtained on the first trial. That is, neither condition of white noise nor music was successful in increasing brachial pain tolerance means. However, at this time, the Audio-Analgesic condition demonstrated a statistically significant shift in mean pain tolerance levels.

Three basic aspects of the design were discussed in considering the present findings. These factors were the size of the sample groups, the decibel level of the Audio-Analgesic equipment, as well as the quality of the white noise employed.

No definitive conclusion was reached concerning the effectiveness of Audio-Analgesia because of the contra-indications of findings between the first and the second trials. However, the possibility of attentional adaptation was discussed as a probably causal factor for the significant mean difference obtained on the second trial.

Suggestions for future research were presented as well as some suggestions on the improvement of future experimental designs.