AN INVESTIGATION OF THE EFFECTS OF HIGH FREQUENCY SOUND ON CERTAIN COGNITIVE TASKS

CONSTANTINE MINETOS

AN INVESTIGATION OF THE EFFECTS OF HIGH FREQUENCY SOUND ON CERTAIN COGNITIVE TASKS

An Abstract

Presented to

the Graduate Council of

Austin Peay State University

In Partial Fulfillment

of the Requirements for the Degree

Master of Arts

---

by

Constantine Minetos

August 1972

ABSTRACT

The purpose of this study was to experimentally investigate the effects of ultrasonic sound (a 23 KHz tone at a constant 85 db pressure level) on certain cognitive tasks.

A test of concentration consisting of two equivalent forms was developed for this experiment. A coefficient of equivalency of .87 was obtained between the two forms and a split-half reliability coefficient, using the Spearman Brown Prophecy formula, of .9 was obtained for form A.

The subjects were administered part one of form A and then were required to complete part two of form A. This involved the recall of the original matching association between symbol and character in part one.

The treatment condition, beginning at the completion of form A and terminating at the completion of form B, consisted of exposing the subject to a 23 KHz signal at a constant 85 db pressure level.

The mean scores of form A and B of the TOC were statistically analyzed using an appropriate conventional t ratio. Analysis revealed that the treatment significantly (.01 level) affected the subject's ability to concentrate on an assigned cognitive task as measured by the TOC.

AN INVESTIGATION OF THE EFFECTS OF HIGH FREQUENCY SOUND ON CERTAIN COGNITIVE TASKS

A Thesis

Presented to

the Graduate Council of

Austin Peay State University

In Partial Fulfillment

of the Requirements for the Degree

Master of Arts

by

Constantine Minetos

August 1972

To the Graduate Council:

I am submitting herewith a Thesis written by Constantine Minetos entitled "An Investigation of the Effects of High Frequency Sound on Certain Cognitive Tasks." I recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Arts, with a major in Psychology.

Major Professor

We have read this thesis and recommend its acceptance:

Minor Professor

Third Committee Member

Accepted for the Council:

Dean of the Graduate School

ACKNOWLEDGEMENTS

The writer wishes to express his appreciation to the members of his committee, Dr. Peter Minetos, Dr. Garland Blair, and Dr. John Martin, who individually and collectively exposed me to a unique learning experience. A special thanks is given to my fellow graduate students who helped in the preparation of this study.

Mere "thanks" are not enough to express my gratitude to my father, Jerry, and Melpo, who transmitted to me a philosophy of life that has enabled me to persevere and which will be long remembered.

The writer is especially grateful to his wife, Joy Constance, for her patience, understanding and love.

TABLE OF CONTENTS

LIST OF TABLES

CHAPTER I

INTRODUCTION

An old riddle asked, "What comes with a carriage and goes with a carriage, is of no use to the carriage, and yet the carriage cannot move without it?" The answer: "A noise." (S.S. Stevens, F. Warshofsky, 1965).

Contrary to the popular conception regarding noise: that it is annoying, distracting, and irritating; noise can be of great use to us and animals. Many events of nature, whether the meeting of two objects or the turbulent flow of air, radiate a tiny part of their energy as pressure waves in the air. A small part of this energy enters our ears, and thus we know of the event.

But, there is more to noise than meets the ear, i.e., it produces many physical reactions that have nothing to do with hearing. The most familiar of these is the so-called startle reaction caused by a sudden unexpected noise. The head jerks forward, the face tightens, the heart beat quickens, blood sugar increases, and the muscles tense (Stevens, 1963).

Noise also appears to affect the body in ways that are less noticible but still disturbing. Stevens found that continued exposure to any steady, moderately loud noise tends to constrict the blood vessels of the skin and may, in fact, affect vision.

Davis (1955) elicited a series of physiological responses from subjects when he exposed them to sound pressure levels approaching 70 decibels (db) at 1000 Hertz (Hz). He classified these elicited responses under the heading of an "N" response. This is a type of response which includes changes in the individual's heart rate, galvanic skin response, breathing rate, blood pressure and changes in the skeletal muscle tension.

It is apparent from the Stevens (1963) and Davis (1955) experiments that consciously perceived sound has a physiological effect upon the body which can interfere with the normal functioning processes of the individual. However, noise need not be in the audible range (20 Hz through 20 KiloHertz (KHz)) or be perceived by the ear's mechanism to have its effect felt by the subject (Davis, 1960). For example, Belluci and Schnieder, (1962); Heatherage, (1954); reported that ultrasonic sound (20 KHz through 108 KHz) when applied with enough intensity to the skeletal and tissue structure of the subject's head enabled the subject to perceive audible tones in the 10 KHz region.

Von Gierke, in a personal communication to Kryter (1970), suggested that the middle ear may have the innate capacity to produce tones in the audible range when stimulated by ultrasonic sound of sufficient intensity. From the available research, (Corso, 1965; Lawrence, 1954) it appears that audible noise of any frequency has an initial distracting affect on an individual.

Broadbent (1955), investigating the effect of noise on work performance, concluded that the noise level must approach 90 db for it to affect work performance, and that frequencies above 2 KHz have a greater adverse affect on performance than frequencies below the 2 KHz level. Kirk and Hicht (1963) found that noise which was variable in pitch but was maintained at an average decibel level of 64.5 db was of a greater detriment to performance than was a steady pitched noise held at a constant 64.5 db level.

Kryter (1970) maintains that the physiological effects of noise tend to vanish after a while because the organism seems to adapt to the exposure to noise, except at the higher levels of sound pressure of 80 db through 130 db. This view is not shared by Broadbent (1957) as reflected by his research.

Although there seems to be strong disagreement regarding the limits of human hearing with regards to the frequency spectrum (Olson, 1947; Beranek, 1954; Davis, 1960; Hilgard, 1962; Lawrence, 1954): Geldard (1963) has found that for all practical purposes, the bandwidth of human hearing extended from 20 Hz to 20 KHz. Bekesy (1960) suggested that the ability to hear a particular frequency is not entirely dependent upon the frequency spectrum involved, but it is also affected by the energy level of the tone and the chronological age of the listener. Table 1 shows the relationship between threshold sensitivity and frequency, (Harlow, 1970).

TABLE 1

Auditory Threshold Sensitivity as a Function of Frequency

Sound Pressure in Decibels	Frequency in Hertz
100	10
80	50
50	100
20	500
0	1000
-5	2000
-10	3000
0	5000
10	10000
15	14000
20	20000

Garner and Morgan (1949) established the absolute threshold of hearing and designated that position as the zero decibel level. This level is reached when the intensity of a 1000 Hz pure tone signal reaches a power level of 0.0002 dyne/cm^2. Table 2 shows the relationship between decibel level and common scores of sound (Harlow, 1970).

TABLE 2

Decibel Scale of Typical Sound Levels

Sound Pressure in Decibels	Source of Sound
0	Threshold of hearing
20	Whisper
25	Average room
40	Quiet office
50	Quiet automobile
60	Normal conversation
70	Busy street
80	Pneumatic drill
100	Subway train
110	Twin engine plane
120	Thunder
130	Painful sound

Purpose of the Study

The purpose of this study was to experimentally investigate selected cognitive responses of an individual while exposed to unperceived high frequency sound. Specifically, this study was limited to an evaluation of an individual's ability to concentrate on a given cognitive task while exposed to a tone at a frequency of 23 KHz at a constant 85 db pressure level.

Hypothesis

Within the context of this study, the hypothesis is stated in the null form. The hypothesis is that there is no statistically significant difference between the control and experimental group in their ability to concentrate while exposed to 23 KHz tone at a constant 85 db pressure level as measured by their scores on a test of concentration.

The appropriate t test design using the five percent level of significance was employed to reject the null hypothesis.

Definition of Terms

For the purpose of this study, the following definitions of the technical terms used in this proposal will be adhered to.

1. Bandwidth: The spectrum of frequencies which lie between the lower and upper most frequency in the frequency spectrum under analysis.

2. Decibel: One tenth (1/10) of a Bel, which is the common unit of the measurement of sound pressure.

3. Frequency: The number of times acoustical waves go through one complete cycle in one second of time.

4. Hertz: The number of repititions of similar pressure variations per second of time.

5. Noise: Sound which may be audible or inaudible and is unwanted by the receiver.

6. Pure tone: A fundamental sine wave frequency with the total absence of even and odd ordered harmonics.

7. Sound: Acoustical energy in the frequency domain of 2 Hz through 100,000 Hz.

8. Ultrasonic: Acoustical energy above 20,000 Hz.

9. Wavelength: The physical length of an acoustical wave measured in meters or feet.

10. Subsonic: Acoustical energy below 20,000 Hz.

Limitations of the Study

The study was confined to students enrolled in various undergraduate and graduate courses at Austin Peay State University during the Spring quarter of 1972. The sample consisted of males and females who volunteered to take part in the study. There was no attempt to assess or to determine whether any differences existed according to age or sex.

Review of Literature

The bulk of the literature in the area of audition deals primarily with experiments conducted using frequencies in the subsonic range, 20 Hz through 20 KHz. There does not appear to be any current research dealing with the effect of ultrasonic sound on an individual's ability to deal with certain cognitive tasks.

In the research dealing with air conducted sound, Corso (1965) reported that 12 percent of his subjects indicated that they could consciously perceive sound at 23,000 Hz. This finding agrees with an earlier study conducted by Weaver (1949). Weaver concluded that due to natural anatomical deterioration, the upper limits of hearing air conducted sound was about 10,000 Hz for most adults, while young people came up to the area of 24,000 Hz.

Corso (1963) using an energy transducer pressed against a subject's mastoid bone, reported that the subjects were able to perceive sound into the ultrasonic region of 95,000 Hz. He suggested that the neural receptive processes are more capable of responding to ultrasonic sound by way of bone conduction than by an air conducted sound.

Garner's (1947) experiments show that the threshold intensity needed to hear a tone varied as a function of time. If the tone was presented as a constant long term tone, less pressure (decibels) would be needed to hear it than if the same tone was presented to the listener for short periods of time. Table 3 shows the relationship between sound pressure and time required to hear the tone.

Table 3

Auditory Threshold Sensitivity as a Function of Time

Sound Pressure In Decibels	Duration of Tone In Seconds
29	1
25	2
23	4
18	8
15	15
13	25
11	50
9	100

Acton and Carson (1968) reported that none of the subjective effects of noise (dizziness, nausea, headache) were present unless the subject's auditory acuity extended to at least 17,000 Hz and the sound level exceeded 70 db. However, Davis (1948) contends that it is the high frequency elements of sound that produce the subjective adverse effects in humans, rather than the intensity of tone.

Kryter and Reese (1944) concluded that the annoyance value of sound is proportional to its' decibel level. They also found that the higher frequencies are more annoying than lower frequencies of a similar decibel level.

Barrett (1950) found that people who are anxious or introverted, as judged by a series of self-report inventories, were more likely to be affected by noise than subjects who were better adjusted. However, Blau (1951) reported no difference in performance between groups of well adjusted subjects and the less well adjusted subjects when exposed to noise.

In visual-motor tasks, Grimaldi (1958) found that the reaction time of his subjects was generally better when the assigned tasks were carried out in a noise-free environment. This confirmed Jerrison's (1954) finding that noise appears to adversely affect reaction time.

Pascal (1953) in a study investigating the effect of noise on motor and mental performance of mental defectives, reported that noise had a minimum adverse effect.

Generally, the literature reporting the effects of sound on visual and motor performance is fraught with contradictions. However, the research reporting the effects of noise on cognitive tasks is more consistent. Lienert and Janson (1964) reported that noise had a significant negative effect on performance as measured by a series of intelligence tests.

CHAPTER II

DESCRIPTION AND APPLICATION OF THE MEASURING INSTRUMENT, SELECTION AND CLASSIFICATION OF THE SAMPLE, AND THE EXPERIMENTAL PROCEDURE

Description of the Instrument

A test of concentration (TOC), which required the subjects to match letters with symbols, was employed as the measuring instrument for the pre- and posttest. The test consists of two equivalent forms (A and B), with two parts on each form. Form A was used as the pretest and form B for the posttest. Part one consists of 13 geometric symbols with an accompanying upper case English character. Part two contains the same 13 geometric symbols in random sequence along with a blank space in which the subject placed the corresponding English character. Since this instrument was designed by the experimenter for this study, the data may be interpreted with this limitation in mind.

Since reliability and normative data were not available it was necessary to establish, at a minimum, two forms of the test that would measure consistently whatever the instrument was evaluating.

Permission was granted by several instructors in the Psychology Department at Austin Peay State University to administer the TOC to their classes.

Each form of the TOC was administered to 70 graduate and undergraduate students. The subjects were administered form A and instructed to look at the symbols and the corresponding English character for 45 seconds. They were then given 30 seconds to match the symbol with the appropriate English character on part 2 of form A.

After three minutes of rest they were administered both parts of form B of the TOC. The same directions were stated and the same procedure was followed as with form A. An equivalent form reliability coefficient of .87 was obtained between forms A and B, and a split-half reliability coefficient of .9, using the Spearman Brown Prophecy formula, was obtained on form A of the TOC.

Table 4 shows the result of the analysis.

Table 4

Reliability Data Between Forms A and B of the TOC

Total Number of Subjects	Mean Score Form A	Mean Score Form B	Pearson r. Forms AB
70	8.9	8.2	.87

A statistical analysis using an appropriate t test technique revealed that the mean difference (.7) between forms A and B on the normative sample was not significant.

Selection of Subjects

There were 48 students who either volunteered directly to become part of the experiment or consented to do so upon request of the experimenter. The students who participated in this experiment represented a cross-section of the Austin Peay State University students. There were 18 males and 16 females with a median age of 22.

Because of the relatively small sample and scheduling conflicts, the experimenter decided to use the same subject in the control and experimental group; viz. the subject serving as his own control.

Experimental Procedure

The following equipment was used in this study:

1. two speakers (tweeters) rated at 20 watts RMS with a 3 db roll-off at 25 KHz, rated by the manufacturer;
2. one Radio Shack decibel meter with a range of 60 through 116 dbs;
3. one stereo amplifier, Pioneer Model SA810, rated at 20 watts per channel RMS at 8 ohms, with a power bandwidth of 5 Hz to 50 KHz plus or minus 3 db;
4. one Heathkit ocilliscope;
5. one Heathkit Sigmac signal generator capable of producing a sine wave at the experimental frequency;
6. one Simpson Model 260 volt meter.

The subjects were each individually administered the TOC under essentially the same conditions. The only variable not under direct control of the experimenter was the time of day at which the experiment was conducted with each subject. The experiment was conducted in a 8 by 10 by 8 foot room containing two chairs, a table, and an enclosure which housed the equipment. At no time during the experiment was the subject aware of the beginning and duration of the treatment condition. Each complete run, consisting of pretest - treatment - posttest, lasted for five minutes and twenty seconds.

During the no treatment period, the subject was required to learn as much as possible of part 1 of form A in 45 seconds. At the end of this time the subject was allowed 30 seconds to complete part 2 of form A, which required that he recall the original matching association between symbol and character in part 1.

After completing form A of the TOC the subject was informed that he may relax for three minutes. During this three minute interval, and unknown to the subject, the treatment condition was begun. The treatment condition, beginning at the completion of form A and terminating at the completion of form B, ran for 4 minutes and 15 seconds. It consisted of exposing the subject to a 23 KHz signal at a constant 85 db pressure level - through two mounted speakers placed approximately 6 inches from the subject's ears.

The subject was administered form B of the TOC while exposed to the 23 KHz signal. The treatment condition continued through parts 1 and 2 of form B.

The output of the amplifier was monitored by the examiner during the treatment condition and consistently showed an undistorted sine wave to the speakers.

CHAPTER III

PRESENTATION AND ANALYSIS OF DATA

This chapter is concerned with the presentation and interpretation of the pre- and posttest scores on the TOC.

The t test for correlated groups was employed to determine whether a significant difference existed between the pre- and posttest means.

It was found that there was a significant difference at the .01 level between the pre- and posttest means. Table 5 shows the results of the analysis.

Table 5

Pre- and Posttest Scores of the TOC

Number of Subjects	Pretest Mean	Posttest Mean	df	t	P
34	6.32	5.26	33	2.94	.01

Interpretation of Data

Results of the t test suggest that unperceived noise may have a negative effect on certain cognitive tasks, especially the retention and recall of information. This conclusion is in agreement with the findings of Boadbent (1957) and Lienert and Jansen (1964), although their experiments dealt with subsonic acoustical energy.

CHAPTER IV

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

A statistical analysis of the mean scores of both the pre- and posttest of the TOC indicated that a significant difference existed between their means. Therefore, the null hypothesis was rejected suggesting that continued exposure to ultrasonic sound has an adverse effect on certain cognitive tasks.

Although there is a limited amount of research suggesting that sound interferes with certain cognitive tasks, Broadbent (1957); Lienert and Jansen (1964); Barrett (1950); Pascal (1953); it is well to note that these studies were conducted using subsonic frequencies in the range of 70 Hz through 10,000 Hz.

An exhaustive review of the pertinent literature revealed an absence of investigations dealing with the effects of ultrasonic sound on cognitive or motor tasks. The results of this study indicated that unperceived noise may have negative effects on certain cognitive tasks. This finding is supported by Liernert and Jansen's (1964) study which suggested that noise has a significant negative effect upon certain mental tasks.

Recommendations for Further Study

During the course of this study it became apparent that there were several areas dealing with this experiment that need to be more fully developed. Therefore, the following topics are suggested for further study:

1. Improving the equivalence between both forms of the TOC. According to Kryter (1970) the overall effect of noise on individual test scores is generally very small when compared to the test results obtained in a quiet environment. Therefore, the assumption that both forms of the test are equal becomes a risky one. The TOC which was developed for this study showed a correlation of .87 between the means of both of it's forms. However, in view of Kryter's findings, effort should be made to increase the equivalency between both forms of the TOC. One way this might be accomplished is by lengthening both forms of the TOC.

2. Evaluate the effects of several variables on cognitive tasks.

This study explored the effects of ultrasonic sound, held at a constant frequency and decibel level, on cognitive tasks. The effect on cognitive performance, due to changing the frequency and intensity of the ultrasonic sound, should also be investigated, along with other variables such as the age and sex of the experimental subjects.

BIBLIOGRAPHY

Acton, W. I., and Carson, M. B. Auditory and subjective effects due to air-borne noise from ultrasonic sources. Annual Occupational Hygine, 1968, 11, 227-234.

Barrett, A. M. Personality characteristics under stress of high intensity sound. Unpublished doctoral dissertation, Pennsylvania State University, 1950.

Bekesy, G. VON. Experiments In Hearing. McGraw Hill, 1960.

Bellucci, R. J. and Schneider, D. E. Some observations on ultrasonic perception in man. Annual of Otol-Rhinol-Laryngology, 1962, 71, 719-726.

Beranek, Leo L. Acoustics. McGraw Hill, 1954.

Blau, T. H. Effects of High Intensity noise on certain Psychological variables. Unpublished doctoral dissertation, Pennsylvania State University, 1951.

Broadbent, D. E. Handbook of Noise Control. McGraw Hill, 1957.

Broadbent, D. E. Effect of Noise on an Intellectual task. Journal of Acoustical Society American, 1958, 30, 824-827.

Corso, J. F. Air conduction thresholds for high frequency tones. Paper presented at the Eastern Psychology Association, Atlantic City, N. J., April 22-24, 1965.

Davis, H. Biological and psychological effects of ultrasonics. Journal of Acoustical Society American, 1948, 20, 605-607.

Davis, H. Hearing and Deafness. Holt, Rinehart and Winston, 1960.

Davis, R. C. Autonomic and Muscular responses and their relation to simple stimuli. Psychological Monographs. 1955, 69, No. 405.

Deatherage, B, Jeffers, L. A., and Blodgett, H. C. A note on the audibility of intense ultrasonic sound. Journal of Acoustical Society American, 1954, 26, 582.

Garner, W. R. The effects of frequency spectrum on temporal integration of energy in the ear. Journal of Acoustical Society of America, 1947, 19, 600-608.

Garner, W. R. and Morgan, C. T. Applied Experimental Psychology. John Wiley and Sons, 1949.

Geldard, F. A. The Human Senses. John Wiley and Sons, 1956.

Grimaldi, J. V. Sensorimotor performance under varying noise conditions. Ergonomics. 1958, 2, 34-43.

Haeff, A. W. and Knox, C. Perception of Ultrasound Science, 1963, 139, 590-592.

Harlow, F. H., McGaugh, L. J. and Thompson, F. R. Psychology. Albion Publishing Company, 1971.

Jerison, H. J. Paced performance on complex counting tasks under noise and fatigue conditions. American Psychology, 1954, 9, 399-400.

Kirk, R. E. and Hecht, E. Maintenance of Vigilance by Programed Noise. Perception Motor Skills. 1963, 16, 553-560.

Kryter, K. D. and Reese, T. W. The relative annoyance produced by various bands of noise Report IC-65. Psychology Acoustics Laboratory, Harvard University. March 17, 1944.

Kryter, K. D. The Effects of Noise on Man. Academic Press, Inc., 1970.

Lawrence, M. Physiological Acoustics. Princeton University Press, 1954.

Lienert, G. A. and Jansen, G. Effects of noise on test performance. Intern. z. Angew. Physiology. 1964, 20, 207-212.

Olson, F. H. Elements of Acoustical Engineering. D. Van Nostrand, Inc., 1947.

Pascal, G. R. The Effects of disturbing noise on the reaction time of mental defectives. American Journal Mental Defectives. 1953, 54, 691-699.

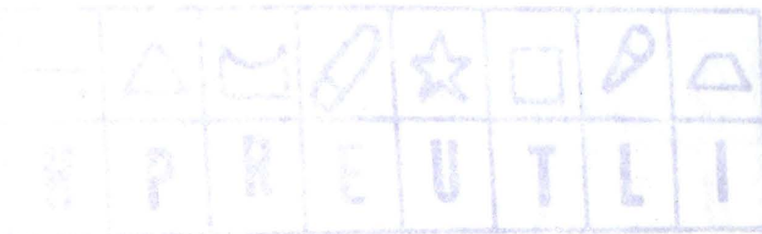
Stagner, R. and Solley, M. C. Basic Psychology. McGraw Hill, 1970.

Stevens, S. S. Hearing, Its Psychology and Physiology. John Wiley and Sons, 1963.

Stevens, S. S. , and Warshofsky, F. Sound and Hearing. Life Science Library, Time Life Books, p. 2, 1965.

Wever, E. G. Theory of Hearing. John Wiley and Sons, 1949.

APPENDIX

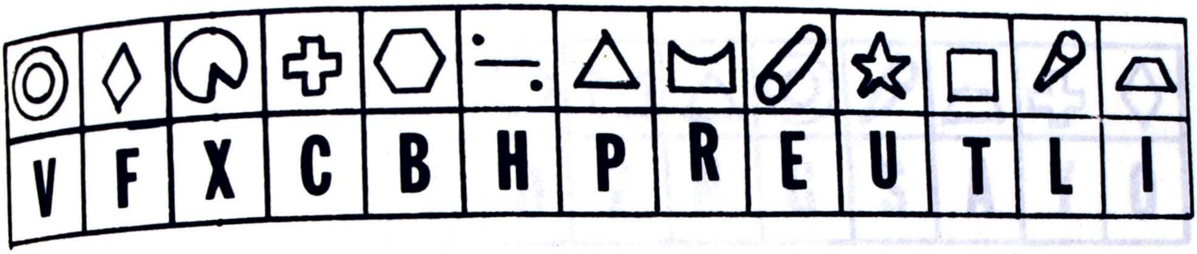


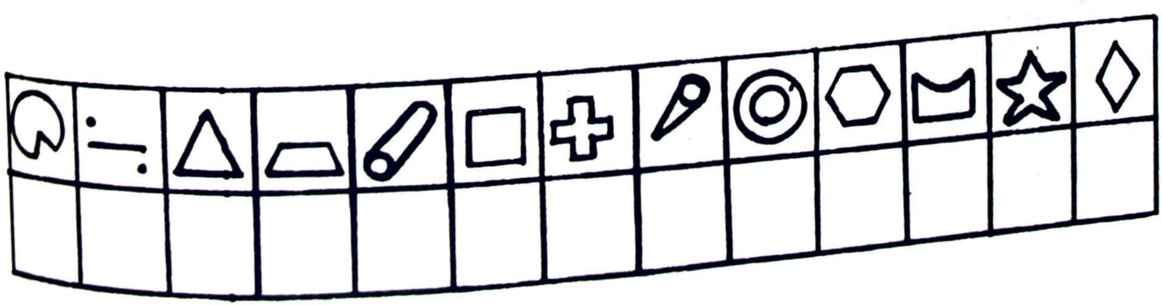
Test of Concentration (Form A)

Sex ________

Date: ____________________

Age ________





Test of Concentration (Form B)

Sex ____________

Date: ______________________

Age ____________