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Effect of White Noise on Visual Memory

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Abstract: The purpose of the present study was to measure the effect of white noise on visual memory. White noise significantly impacts executive functioning of children. Visual memory was measured using free recall memory task. The sample of the present consists of 100 school going children falling in the age range of 11-13 years (Mean=11.99) selected usingpurposive sampling technique. The boys and girls were divided in equal numbers to control the gender differences. It was assumed that there will be a difference in the performance in free recall memory task in absence of white noise and in presence of white noise. Results were analyzed using independent sample t-test and paired sample t-Test. Results suggested that there was gender difference in the visual memory in absence of white noise and in presence of white noise. There wassignificant difference noticed in the performance on free recall memory task in absence and presence of white noise. The results support the concept of stochastic resonance which propose unique contribution of white noise in improvement of executive task. The study provided interesting insights on uses of white noise which has been discussed in detail in the paper.

Keywords: white noise, visual memory, short-term memory, stochastic resonance, gender difference.

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I. INTRODUCTION

There is a growing body of literature that deals with effect of noise on neural processing ability of the human brain. It has been known since a long time that environmental disturbances interfere with cognitive processing ability of an individual[14]. The environmental stimuli compete with the cognitive stimuli that has to be processed. Hence, the attention gets divided between two stimuli, thus, affecting the cognitive processing ability negatively.

Contrary to this, it has been observed that certain kinds of noises enhance the cognitive functions of the participant. Concept of noise has been studied in creative manner and in depth in the recent past[10,63,84].On basis of interval of frequency and power, sound has been divided into colour spectrum. In context of cognitive psychology, 3 kinds of noises have been studied widely- Pink noise, brown noise and white noise.Pink noise precisely contains same frequencies as white noise. But higher end of the spectrum of frequency is altered in such a way that all octaves carry equal amount of energies. With every rising octave, power density is decreased by 3 decibels as compared to the profile of white noise frequency. Hence, higher frequencies become less powerful and seamlessly blend with other sounds. Pink noise can be heard in the incoming tidal waves, heartbeats, some stellar light emissions and a few electronic devices. Pink noise changes the complexity of the activities of human brain and may have significant effect on the stability of sleep[103].Brown noise has been named after a Scottish botanist- Robert Brown. It is also called as red noise. Brown noise is deeper than the pink noise and white noise. It resembles the sound of waterfall or rainfall from distance. Power density decreases by 6 decibels with every rising octave as compared to white noise. Thus, highest end of the frequency spectrum is almost silent in brown noise.

White noise is defined as a sound or electrical noise that has a relatively wide continuous range of frequencies of uniform intensity[86].The adjective "white" has been used to describe this type of noise due to the way white light works. White light is light that is composed of all of the different frequencies of light combined together (a rainbow or prism segregates all the different frequencies of light into individual colour. In the similar way, white noise is the combination of all the different frequencies of sound. White noise is similar to 20,000 frequencies of sound all playing at the same time.White noise has been studied extensively with respect to cognitive and neuropsychology in the last two decades. Continuous white noise reduces the resistance in going to sleep and the intermittent awakening at night in toddlers[36]. White noise has also been used extensively for masking the unwanted noise in the work place and to improve the performance in simple attention tasks[55]. White noise is also being used successfully to mask the ringing noise in patients suffering from tinnitus[51]. Researchers have reported that listening to white noise while performing a cognitive task has a positive

influence on cognitive processing[87].In line with these researches, it is possible to say that white noise affects every stage of nervous system, thus, affecting all the aspects of human cognition. Stochastic theory of resonance has been identified as one of the possible explanations that how white noise enhance verbal memory.Stochastic resonance concept explains how random noise have an effect on cognitive processing. To illustrate the concept, if a weak stimulus is gives in presence of random noise, the stimulus becomes detectable. Noise- stimulus interaction gives a person motivation to attend to the weak stimulus, thereby, enhancing the cognitive processing of the stimulus[86]. It helps to improve the touch, visual and auditory sensory. Some researchers have demonstrated that white noise enhances the verbal, arithmetic and spatial tasks[11, 47]. This theory lends support to possibility of improving visual verbal memory using white noise in school-children.

When white noise is presented during encoding of words to ADHD children, the subsequent free recall gets enhanced[87]. Since ADHD is known to be a condition caused by imbalanced dopaminergic functioning, it can be said that there is a link between enhanced learning by white noise and dopaminergic neuromodulation[87].White noise presented when encoding scene images decreases sustained BOLD activities in the auditory cortex and substantianigra of the brain[72]. The Substantianigra is the origin of dopaminergic neurons projecting to various target sites that are key areas of cognitive control[31]. Gating and maintenance of memory representations in working memory have also been shown to rely on dopaminergic signaling[21, 35, 60]. Effect on learning by auditory white noise depends on dopaminergic neuromodulation and enhancement in connectivity between midbrain regions and superior temporal sulcus of the brain. It indicates that white noise may be particularly useful in learning in cases where changes in mesolimbic regions are related to memory deficits[72].

There is a significantly high correlation between verbal memory and academic achievement[40, 52]. To illustrate on the concept of memory, working- memory model is an integrative approach towards memory. It states that working memory consists of 5 elements[4]

1. Visuo-spatial sketchpad
2. Phonological loop: It comprises of 2 elements. Phonological storage and subvocal rehearsal
3. Central executive
4. Subsidiary slave system.
5. Episodic buffer

Neuropsychological studies have demonstrated evidence of episodic buffer which is different from long-term memory [79, 89]. Investigators have used PET techniques to study role of different areas of brain in different elements of working memory. Phonological loop involves activation of lateral frontal lobe, inferior parietal lobe and temporal lobe of the left hemisphere[4, 41]. The areas that visuo-spatial sketchpad appears to activate depends on the difficulty level of the task and length of retention interval[56]. Central executive appears to activate frontal lobes [4,75]. Episodic buffer operation appears to activate frontal lobes of both the hemispheres temporal lobe as well as the left hippocampus[79].Study of verbal material tend to engage the left hemisphere of the brain more than the right hemisphere whereas study of pictorial material tends to engage left hemisphere of the brain more than right hemisphere[1].

It has been reported that women perform better than men at tasks that involve verbal episodic memory tasks like remembering and recalling words, objects, images and daily life events whereas men outperform women in tasks that involves visuo-spatial working memory[37]. However, this concept have not been studied much in the Indian context. The present study is an attempt to explore the effect of white noise on verbal memory of school children in Indian setting. As explained above the study is based on the premise of stochastic resonance, neuropsychological effect of white noise of structures and neurotransmitter in brain.

II. MATERIAL AND METHODS

Sample:The present study has been conducted on 100 school going students with a mean age of (mean age=11.99 years) and equally consists boys (mean age = 11.98 years) and girls (mean age=12.00 years).For selection of the sample in the present study some criteriawere followed, therefore, a purposive sampling method was used for the selection. After the selection of the sample, students were randomly assigned in two groups (group A and Group B).

Inclusion Criteria:

1. Participant should be in the range of 11 to13 years of age.
2. Participant should be able to communicate in English.
3. Participant should belong to a middle-class economic background.
4. Participant should have scored above 50% in the last semester exam attended in the school.

Exclusion Criteria:

1. Participants who have a visual impairment were excluded from the study.

2. Participants who are diagnosed with any mental illness and/or chronic physical illness were excluded from the study.
3. Participants who have a history of any mental illness and/or chronic physical illness were excluded from the study.

Research design:

Quasi-experimental design was used to conduct the research as purposive sampling technique was used to enlist participants and then they were randomly assigned to the group. Sample size was divided into 2 groups in order to control confounding variable.

Experimental design may be represented as: R X1 Y2
X2 Y1

X1: List A administered in presence of white noise.
Y2: List B administered in absence of white noise.
X2: List A administered in absence of white noise.
Y1: List B administered in presence of white noise.

Materials Used:

1. Demographic sheet: Demographic sheet includes details including participant's name, age, gender, date of birth and academic performance in last grade attended which was developed by researcher.
2. Measurement of memory: Participant's memory was measured using free recall memory task. The free memory task was developed to measure the visual verbal memory performance of participant using standard procedure[70]. In the present task a list of 30 words which were selected from the standard list and divided into two lists of 15 words each using fish-bowl technique.PowerPoint presentation were made of 15 words each and shown to the subject using laptop screen. Each word was displayed for the period of two seconds. Each list consisted of 15 words. Hence, each presentation was of 30 seconds. Screen size is 34 CMS* 19.5 CMS. Stop- watch was used to give subjects rest of 30 seconds after presentation of stimulus and then the participant was asked to recall. It was also used to give 1 minute of rest to the participant between each trial. Speakers were used to play the background white noise as per the design of the experiment. White noise was played at 45 decibels to 50 decibels.
3. White noise audio clip: White noise audio clip was obtained from British Tinnitus Association. It is a part of sound therapy used for treatment of tinnitus. This audio CD has been developed by a sound effects company many years ago. British tinnitus association sells this audio clip to help patients of tinnitus to mask ringing noise with white noise.

Procedure:

The permission from the principal of the school was obtained for the conduction of the study. Consent forms were given to the students who volunteered to be a part of this research. The signed consent from the parents were also obtained. The experiment was conducted in controlled setting using the school scientific laboratory. Subjects were called to the lab on the specific, predetermined date and time. Demographic details were verified. Based on the group they were assigned; experiment was conducted using specific list and in specific condition. Three trials were conducted for each list and condition.Medium of instructions used was English.

Before each trial, participant was instructed as follows:

"Please be attentive and look at the screen. You will see a list of 15 words displayed on the screen for 2 seconds each. After seeing the video, you will be given a break of some seconds. Then, you will be asked to recall the words you saw on the screen. Order of the words doesn't matter. After completion of each trial, you will be given a break of one minute."

III. RESULT

Baseline score (in absence of white noise) and I-scores (in presence of white noise) were analysed using descriptive statistics, independent sample t-test (for gender differences) and paired sample t-test (for group differences).

Table no 1:Shows sample characteristics of the participants.

GENDER	MEAN	N	Std. Deviation	Median	Minimum	Maximum	Range
MALE	11.98	50	.685	12.00	11	13	2
FEMALE	12.00	50	.728	12.00	11	13	2
TOTAL	11.99	100	.703	12.00	11	13	2

Table states the sample characteristics of the population. Total sample size is 53, out of which 26 are males and 27 are females. Mean age for females was found to be 11.70 years (standard deviation=0.669). Mean age for males was found to be 11.92 years (standard deviation=0.628). Mean age foe the total sample is 11.81 years (standard deviation=0.652). Median age for both the genders is 12.00 years. Minimum and maximum age is 11 years and 13 years respectively. Thus, age range is 2 years.

Table no 2:Shows gender difference in absence of white noise (Independent Sample t-test)

95% Confidence Interval of the differences							
	T	Df	Sig (2- tailed)	Mean Differences	Std Error Differences	Lower	Upper
Equal variances assumed	-1.552	98	.124	-0.540	0.34804	-1.23068	0.15068
Equal variances not assumed	-1.552	96.164	.124	-0.540	0.34804	-1.23084	0.15084

In accordance with the above table, if variances are assumed to be equal. t- score is found to be -1.552, degree of freedom is 98, Significance is 0.124. Mean difference between both the groups was -0.540. When variances are assumed to be not equal, t-score is -1.552, degree of freedom is 96.164 and significance is 0.540. Hence, there is a difference in the performance of males and females in standard lab conditions.

Table no 3: Shows group statistics in absence of white noise.

Gender	N	Mean	Std Deviation	Std. Error Mean
Male	50	5.66	1.61553	0.22847
Female	50	6.20	1.85653	0.26255

According to the above table, mean score in absence of white noise for males and females was 5.66 (SD:1.61553) and 6.20 (SD: 1.85653) respectively. This suggests that females performed better than males in absence of white noise.

Table no 4: Shows gender difference in presence of white noise (Independent Sample t-test)

						95% Confidence Interval of the differences	
	T	Df	Sig (2-tailed)	Mean Differences	Std.Error Differences	Lower	Upper
Equal variances assumed	-1.493	98	0.139	0.57333	0.38398	-1.33533	0.18866
Equal variances not assumed	-1.493	95.526	0.139	0.57333	0.38398	-1.33557	0.18891

In accordance with the above table, if variances are assumed to be equal. t- score is found to be -1.493, degree of freedom is 98, Significance is 0.139. Mean difference between boththegroupswas0.57333. Whenvariancesareassumedtobenotequal,t-scoreis-1.493, degree of freedom is 95.526 and significance is 0.139. Hence, there is a difference in the performance of males and females in presence of whitenoise.

Table no 5:Shows group statistics in presence of white noise.

Gender	N	Mean	Std Deviation	Std. Error Mean
Male	50	6.6800	1.75863	0.24871
Female	50	7.2533	2.06862	0.29255

According to the above table, mean score in presence of white noise for males and females was 6.68 (SD:1.75863) and 7.2533 (SD: 2.06862) respectively. This suggests that females performed better than males in presence of white noise.

Table no 6: Paired Samples Statistics

	Mean	N	Std. Deviation	Std. Error Mean
White noise (presence)	6.9667	100	1.93178	0.19318
White noise (absence)	5.9300	100	1.75253	0.17525

This table states that mean of the scores recorded presence of white noise is 6.9667 (SD=1.93178). Mean of the scores reded in absence of white noise is 5.9300 (SD= 1.75253). Total sample size is 100.

Table no 7:Shows paired sample correlations

	N	Correlation	Sig
White noise (presence) & white noise (absence)	100	0.880	0.000

There is a strong positive correlation between white noise and visual memory as the correlation is calculated to be 0.880.

Table no 8:Shows paired sample t-test

	95% Confidence Interval of thedifferences							
	Mean	Std. Deviation	Std. Error mean	Lower	Upper	t-score	df	Sig. (2-tailed)
White noise (presence) & white noise (absence)	1.03667	0.91856	0.09186	0.85440	1.21893	11.286	99	0.000

Mean is calculated to be 1.03667 (SD= 0.91856), t-score is found to be 11.286 and 2- tailed significance is 0.000. Degree of freedom is 99. Upper 95% confidence interval limit and lower 95% confidence interval limit is 0.85440 and 1.21893 respectively. Hence, there is a difference in the short-term memory in absence of white noise and in presence of white noise.

IV. DISCUSSION

The aim of the study was to find if white noise enhances visual memory of school children.Thisstudywasalsoaimedtofindoutifthereisagenderdifferenceinvisualshort-termmemoryinthestandardlabconditions.Thisstudyalsoexploresifthereisdifferencein performance of males and females when presented with white noise. If the differenceexists, then what is the nature and extent of the differences.The first hypothesis was that "there is a difference in visual short-term memory of males and females". The results showed that there is a gender difference in visual short-term memory. The existing literature lends support to the observed since the girls and boys have similar verbal ability in pre-school and elementary school but female superiority increases from age 11 and it is found in both high-level and low-level task[59]. A study done in 1986, demonstrated better verbal abilities than males[45]. It has been observed that females have a more detailed elaboration of information which leads to more specific representation. Event related potential analysis showed larger amplitudes for females than for males[44]. In another study conducted in 2003, 14 separate measures of short-term memory were used to investigate gender differences among children and adolescents using stratified sampling. The results revealed that females performed better than males on verbal tasks and males performed better than females on spatial tasks[57]. In same line a study conducted in Sweden showed that men performed better than women in visuospatial task and women performed better than man on tests of verbal fluency[49].Therefore, the present study concludes that females have a better memory for verbal stimuli as compared to males.

The secondhypothesiswas proposed that"thereisadifferenceinthevisualshort-termmemoryofmales and females". The results showed that there is a significant difference in the performance of both the genders in presence of white noise. There are some previous studies which also showed that semantic and episodic memory in presence of background noise, girls outperformed boys in the task[9].Girls outperform boys in a verbal memory task because they have better verbal memory skills, whereas, males have better spatial skills. To illustrate this, when navigating from one location to another in traffic and with various background environmental noises,

women rely on landmarks and verbal coding of the landmarks, while males prefer to use special perception strategies.

The thirdhypothesiswas that "thereisadifferenceintheperformanceinfreerecallmemorytask in absence of white noise and in presence of white noise". The results showed that participants performed better in presence of white noise ascomparedtoabsenceofwhitenoise regardless of gender.The resultcanbebetter explainedbythephenomenon of stochastic resonance. When an external noise is added to the weak stimulus, detectability oftheweakstimulusisenhanced[18,39]. When auditory noise enters the brain, it generates an activation in multisensory neurons in different regions of the brain, thus, modifying the original electrical activity of the brain [58].InCA1hippocampalcells,stochasticresonancecanenhance signal detection[90]. Sub threshold sensory signal can cause threshold crossingwhenoptimumlevelofnoiseisadded,thereby,enhancingsensitivityforweak signals [18,29,65,99,102].White noise leads to increase in relative gamma and beta power in thebrain,whichleadstoincreaseinlevelofthinking,attentionandsensoryprocessing[28].A f-MRI study demonstrated that stimulus driven phasic activity in SubstantiaNigra/ Ventral Tegmental Area and auditory cortex is selectively enhanced by white noise[63].It also induced strong connection between SubstantiaNigra/ Ventral Tegmental Area and Superior Temporal Sulcus and exhibits a strong positive correlation with memory improvement by white noise[71].Positiveeffectofwhitenoisedependsondopaminergicneuromodulationas wellasconnectivitybetweenmidbrainregionsandsuperiortemporalsulcus[71]. This suggests that white noise can also be used to facilitate learning when changes in mesolimbic system is related to memory deficits[71].White noise improves phasic dopamine release, thereby modulating activity within the superior temporal sulcus and leading to increased attention and memory formation[71].

It can also be suggested that phasic dopamine release and stimulus driven phasic activity in substantiaNigra/ Ventral Tegmental Area and auditory cortex is the reason for better recall memory in presence of white noise. However, the observed results should be confirmed by measuring the dopamine uptake directly by using PET scan. The findings of the research suggest that additional research could be done to investigate if white noise can be used as a non-pharmacological intervention for Attention Deficit Hyperactivity Disorder. Future studies can also account for physiological changes caused by white noise and if those changes play a role in determining the nature or extent of the effect. Studies can be done using various different tasks and not only just one task to explore the effect of white noise of different types of memory.

V. CONCLUSION

The present study reveals some interesting yet valuable insights about effectiveness of white noise on verbal memory tasks and also gender difference in memory of school going children in presence or absence of white noise. The present area is not fully explored and have enormous possibility for memory, executive functioning and various cognitive abilities. The results of the present study provide strong evidence of positive influence of white noise on verbal memory which opens the possibility of such kind of possible intervention to improve academic performance. The result of the present study should be used with precaution owing to limited sample size.

VI. CONFLICT OF INTEREST

The authors report no conflict of the interest in the present study.

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