The Effects of Color Noises on Attention

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Abstract. This study investigated the potential effects of two kinds of color noises (white and pink) on attention. Eighty-one healthy college students were recruited and divided into 3 groups (quiet, white noise, and pink noise). Twenty trials of attention tests without noise or in different noise contexts were used to measure participants' attention. The results showed that compared to the quiet group, the average reaction time of white noise was significantly shorter ($p < 0.05$). Pink noise showed neither improvement nor impairment in attention when compared to the white noise or the quiet context ($p > 0.05$). These findings indicated that white noise may promote attention. The results may change the stereotype that quiet environments are best for work. Future studies could use a within-group design to reduce bias due to participants' differences. Furthermore, the study of cognitive neuroscience can be conducted to investigate whether brown noise activates or intensifies the prefrontal cortex's activity.

Keywords: White noise · Pink Noise · Attention · Cognition

1 Introduction

Attention is the ability to focus information processing power on a few areas or events. Noise is thought of as a harmful factor towards attention in many studies. For example, traffic noise was proved to be harmful to people's attention [1]. An analysis of Polish children also showed that noise impaired attention [2]. What's more, some researchers argued that noises of different densities could lead to an increase in reaction time and the impairment of attention [3]. Noise above 85 dB has been furthermore shown to be detrimental to cognitive functions involving attention [4]. These studies indicate the potential adverse effects of background noise on the cognitive function of attention. However, different types of noises may lead to different results. There is now a way to classify noises by naming them and distinguishing them by color. The definition and differentiation of color noise are related to the spectrum. White noise refers to those with constant energy and density in different frequency bands [5]. Pink noise's energy level is the same in every octave, with the energy density decreasing by 3 dB per octave as the frequency increases [5, 6].

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White noise's effect on cognitive functions has been discussed. In terms of memory, a study on monkeys indicates that white noise in delayed response testing improves working memory [7]. A recent study also shows that white noise benefits working memory performance, helping to reduce the participants' guess rate of tasks [8]. However, Herweg and Bunzeck reported that the accuracy and reaction time of the working memory task were not influenced by white noise played during the memory encoding and maintenance period, while the noise played during the delay period impaired working memory [9]. What is more, when compared to music, white noise seemed to show no significant difference in its effects on working memory [10]. Recent research also discussed white noise's influence on other cognitive functions. In previous research by Söderlund et al., white noise could improve children's reading and memory performances [11]. According to the Moderate Brain Arousal model and stochastic resonance, white noise can help the original weak signal (e.g., visual or audio signal) to be more detectable, which explains why white noise can affect individuals' performance in study and memory tasks [12].

There is also controversy over the impact of white noise on attention. Penaloza et al. argued white noise negatively affects visual attention by measuring error rate and reaction time [13]. However, research on attention deficit hyperactivity disorder (ADHD) children show an improvement in attention with background white noise [14, 15]. In addition, Söderlund et al. found that inattentive participants' memory tasks performed better than those without white noise, while attentive participants' performed worse than those without noise exposure [16]. Moreover, Jafari et al. pointed out that white noise at 73 dB is beneficial for attention [17]. These controversies reflect that white noise, one of the color noises, remained to be studied for its effect on cognitive functions.

There are also some case studies done to investigate the influence of pink noise. However, these studies show a pattern of contradictory views on pink noise's effect on people's cognitive processes. Researchers explored short pink noise exposure's impact on memory. They found that participant's ability to perform memory tasks improved when exposed to pink noise at 91.5 dB with loud background noise [18]. However, Harmon et al. investigated how background noise influences participants' speech. They concluded that participants' attention toward speech and language was impaired when exposed to noise involving pink noise [19].

Northern Kentucky University did cognitive research to figure out how pink noise can affect students' cognitive performance, especially those related to reading tasks [20]. The experiment made 80 subjects exposed to three different contexts: pink noise, popular music, and non-noise, and asked them to read in silence simultaneously. Later, a cognitive test was given to evaluate their cognitive performance. The result shows that pink noise does not improve students' cognitive performance compared to the other two conditions. It offers a different outcome compared to the research done with white noise, which seems to be effective in improving cognitive performance.

For attention, similar to the experiment done to figure out the white noise effect on ADHD patients mentioned before, pink noise's influence on ADHD patients has also been investigated. Unlike the previous outcome that white noise can help reduce problem behaviors of ADHD children, the research shows that children with ADHD did not reduce impulsive behavior when being exposed to pink noise [21]. These contradictory results make the problem even more complex. Besides, the relationship between pink noise exposure and attention remains unclear.

To more thoroughly compare different color noises' effects on cognitive performance, Lu and Huang et al. utilized cognitive experiments to discover how the different color noises affect the working efficiency. Four aspects of work efficiency were tested, including continuous performance, psychomotor speed, working memory, and executive function in four noise environments (pink, red, white noise, and quiet environment). The impacts of color noises on the performances of participants were different in the four tests: in the psychomotor speed, executive function, and working memory tasks, the noticeable improvements could be found in color noises environments compared with the quiet context. However, in the continuous performance test, the apparent improvement could only be found in a pink noise environment [22]. This study shows that color noises could improve individuals' performance in certain aspects. Nevertheless, this study did not discuss different color noises' influence on attention.

Most of the existing studies focus on the effects of specific color noises on cognitive processing. Fewer attention-specific studies and fewer studies are comparing the effects of different color noises. What's more, current findings are contradictory. Therefore, the influence of different color noises on attention is worth investigating.

This study attempted to explore two colour noises (white and pink)'s effects on attention, using a non-noise condition as a control group. It was hypothesized that different noise exposures would affect performance on the attention task, as indexed by reaction time. Furthermore, the present study sought to explore which noise exposures would be most beneficial for the attention task.

2 Methods

2.1 Participants

This study recruited 81 participants (22 male, 59 female) with normal hearing and normal vision (corrected vision included) through an online questionnaire system. The size was determined before any data analysis. All participants were selected after they had filled in the registration questionnaire reporting no medical history of neurological disease. Before the formal experiment, all participants promised that they had gotten enough rest. The mean age of the participants was 20.83 years (SD = 1.88; range: 18–25). All of the participants were university students, who were given informed consent and were paid 15 yuan in return.

2.2 Materials

The attention experiment was programmed on Psychopy. Data from the experiments were stored in OFFICE Excel 2019 as a database and then transported in the IBM SPSS Statistics Version 24 to have analyzed. Participants completed the task on an individual laptop (Win 10) with a resolution of 2560 × 1440, 144 Hz. The visual stimulus was presented on the screen with a 60 Hz refresh rate in a quiet laboratory. The color noise was collected from the website: https://www.audiocheck.net/testtones. The audio noise

Fig. 1. Pentagons and a hexagon on the screen.

was delivered binaurally through the headphones connected to the computer. According to previous research, positive noise effects were obtained when the noise level was set to 80 dB [16]. Therefore, the noise level in this study was set to 80 dB.

2.3 Experimental Design

The independent variable was different kinds of sound environments: quiet (without noise), white, and pink noises. The dependent variable was the reaction time of participants in the attention experiment. Participants participated in the tests in the same standard cognitive laboratory with glass partitioned. According to the participants' appointment time, the experiment was conducted under conditions of non-noise, pink noise, and white noise exposure. All the participants were assigned randomly into three different groups with different types of sound environments. They were informed to wear the headphones during the experiment, and they didn't know the kind of sound scenario in advance. Before they started the experiment, a one-minute interval was set to ensure the participants adapted to the laboratory environment both physiologically and psychologically. After the interval, the participant was told after a while there would be clear instructions on the screen, just clicked according to the instructions. Then they were instructed to put on the headphone and began the experiment when they felt they were ready.

Every participant was required to take an attention experiment in a certain sound environment, the experiment contained 20 trials. Figure 1 shows an example from an experiment. In each trial, every participant could see several pentagons and a hexagon on the screen, participants were required to find and click the hexagon among the pentagons, and the position of the polygons changed randomly in each trial. Each participant had one chance to learn before the formal experiment began. The reaction time of participants was recorded. An inter-subject design was used in the experiment with one independent variable (i.e. sound condition).

2.4 Statistical Analysis of Data

The point of interest in this research was to measure the effectiveness of colour noise exposure. The performance of a sample of participants after the noise exposure was evaluated, and the average reaction time was used to represent the response performance of each group. The exploration of data's homogeneity and normality was conducted. The Krustal-Wallis test was used to analyse the difference among three color noise groups. Pairwise comparisons with adjusted values were adopted then to detect the potential significant difference between each two groups. The p-value was set as 0.05. All analyses were conducted with IBM SPSS Statistics Version 24 to determine whether there were potential statistically significant differences between the means of three groups. Data from the experiments were saved into a database, then the statistical program SPSS was used to analyse them.

3 Results

After data filtering, the study retained the data of all participants. The final sample comprised 81 university students, aged 18–25 years (M = 20.83, SD = 1.88; 22 males, 59 females).

The exploration of data's homogeneity and normality was conducted. A Krustal-Wallis test was conducted later to analyze the difference in participants' average reaction time in different noise groups. Consistent with the hypothesis that noise can affect attention, the results showed that different noise contexts significantly affect participants' reaction time in the tasks ($H(2) = 10.09$, $p = .006$).

Pairwise comparisons with adjusted p-values were used to compare the differences between every two groups. The white noise group's average reaction time (s) (M = 2.38, SD = .29) was significantly shorter than the quiet group (M = 2.68, SD = .33), $U = 20.30$, $p = .009$, $r = .43$. However, contrary to our hypothesis, no significant differences were found in the average reaction time (s) between the quiet group (M = 2.68, SD = .33) and the pink noise group (M = 2.56, SD = .42), or between the white noise group (M = 2.38, SD = .29) and the pink noise group (M = 2.56, SD = .42) (All $p > .05$).

What is more, a Mann-Whitney test was applied to examine the gender's potential effects. There was no significant effect of gender on general average reaction time ($p > .05$).

4 Discussion

The motivation of the experiment derived from researchers' concern towards all kinds of contradictory and controversial arguments proposed by many previous researchers. Conflicting outcomes about the effect of color noises' exposure on human cognitive performance have constantly been proposed. Some researchers said that color noises benefit human cognition, and some contend otherwise. Hence, the paper needed to make further investigation into the actual effectiveness of color noises and their relationship with human cognitive performance.

The experiment aimed to investigate the influence on human cognitive performance brought by exposure to different color noises. To be more specific, we chose the reaction time of visual attention tasks as the representative index of human cognitive performance. We hypothesized that exposure to color noises will improve participants' attention performance and reduce their reaction time. To verify the hypothesis, we designed an experiment that participants were randomized into the three stimuli: white noise, pink noise, and a non-noise condition, then tested participants' reaction time towards visual attention tasks under different conditions.

The results showed that when participants were exposed to white noise, their reaction time is significantly shorter than the non-noise group. However, contrary to our hypothesis, there were no significant differences in the average reaction time between the non-noise group and the pink noise group, or between the white noise group and the pink noise group. Though when they were exposed to pink noise, their reaction time was somewhat shorter than the non-noise group, the difference was not significant. Based on the result of the experiment, it was quite reasonable to infer that exposure to white noise will reduce human reaction time towards visual attention tasks and thus improve their cognitive performance. However, we failed to corroborate pink noise has the same function.

It's true that there were still some limitations of the experimental design. The experiment used a between-subject method, which means it would be hard to guarantee that the various reaction time was led by different color noises, but not the subjects themselves. For example, it's possible that one of the groups was extremely sensitive to visual attention tasks and could do a great job regardless of the potential positive or negative effects brought by the color noises, which compromised the validity of the experiment. To make improvements, the within-subject design seems to be more reliable: the same participants will be exposed to all kinds of stimuli, and their reaction time will be recorded and compared to infer the influence brought by the color noises. Furthermore, though no significant effect of gender on general average reaction time was discovered, the sex ratio of our participants was not ideal because the data were gathered from only one university. Future research could consider a bigger sample size with a more desirable sex ratio.

The experiment also points to potential future research directions for other researchers. For example, in the experiment, the reaction time of the group exposed to white noise is significantly shorter than that of the quiet, control group. Hence, it will be reasonable to infer whether the presence of white noise activates or intensifies the prefrontal cortex's activity, which is responsible for many higher-level cognition processes, including attention. An fMRI study could be introduced to verify the hypothesis and make more inferences about the connectivity between the auditory cortex and prefrontal cortex. In addition, we only explored the effects of pink noise and white noise on cognitive performance due to the constraints, and there are many more potential discoveries in the field of color noises such as blue noise, purple noise, and so on. Also, there will be some practical applications of the experiment. For example, in some circumstances that need great cognitive resources, introducing white noise seems to be beneficial because it can increase participants' cognitive performance and reduce their reaction time towards various stimuli. The stereotype that quiet places are best for working may become the past tense.

5 Conclusion

In summary, the reaction time of participants in the white noise environment was significantly shorter than the non-noise group in this study, which means that attention ability could be improved by the white noise environment. However, pink noise didn't show significant improvement in participants' performance of attention tasks in this study, this indicates that pink noise doesn't have a similar function to white noise in attention tasks. Therefore, it will be meaningful if attention ability can be improved by setting controlled levels of white noise as background sound. In addition, the effects of other color noises on humans' cognitive performance are also worth discovering.

References

1. Hygge, S., Boman, E., & Enmarker, I. (2003). The effects of road traffic noise and meaningful irrelevant speech on different memory systems. *Scandinavian Journal of Psychology, 44*(1), 13–21. https://doi.org/10.1111/1467-9450.00316
2. Skrzypek, M., Kowalska, M., Czech, E. M., Niewiadomska, E., & Zejda, J. E. (2017). Impact of road traffic noise on sleep disturbances and attention disorders amongst school children living in Upper Silesian industrial zone, Poland. *International Journal of Occupational Medicine and Environmental Health*, *30*(3), 511–520. https://doi.org/10.13075/ijomeh.1896.00823
3. Trimmel, M., & Poelzl, G. (2006). Impact of background noise on reaction time and brain DC potential changes of VDT-based spatial attention. *Ergonomics, 49*(2), 202–208. https://doi.org/10.1080/00140130500434986
4. Zeydabadi, A., Askari, J., Vakili, M., Mirmohammadi, S. J., Ghovveh, M. A., & Mehrparvar, A. H. (2018). The effect of industrial noise exposure on attention, reaction time, and memory. *International Archives of Occupational and Environmental Health, 92*(1), 111–116. https://doi.org/10.1007/s00420-018-1361-0
5. Thompson, M. (1989, December 27). Colored noise. Archive. https://web.archive.org/web/20030607151308/, http://mv.lycaeum.org/M2/noise_ahf.html
6. Wisniewski, J. S. (1996, October 7). The Colors of Noise. Archive. https://web.archive.org/web/20110430151608/, https://www.ptpart.co.uk/colors-of-noise
7. Carlson, S., Rema, P., Artchakov, D., & Linnankoski, I. (1997). Effects of music and white noise on working memory performance in monkeys. *NeuroReport, 8*(13), 2853–2856. https://doi.org/10.1097/00001756-199709080-00010
8. Han, S. Z., Zhu, R. Z., & Ku, Y. X. (2021). Background white noise and speech facilitate visual working memory. *European Journal of Neuroscience, 54*(7), 6487–6496. https://doi.org/10.1111/ejn.15455
9. Herweg, N. A. & Bunzech, N. (2015). Differential effects of white noise in cognitive and perceptual tasks. Frontiers in Psychology *6*.https://doi.org/10.3389/fpsyg.2015.01639
10. Borella, E., Carretti, B., Meneghetti, C., Carbone, E., Vincenzi, M., Madonna, J. C., Grassi, M., Fairfield, B., & Mammarella, N. (2017). Is working memory training in older adults sensitive to music? *Psychological Research Psychologische Forschung, 83*(6), 1107–1123. https://doi.org/10.1007/s00426-017-0961-8
11. Söderlund, G. B. W., Sikström, S., & Smart, A. (2007). Listen to the noise: Noise is beneficial for cognitive performance in ADHD. *Journal of Child Psychology and Psychiatry, and Allied Disciplines, 48*(8), 840–847. https://doi.org/10.1111/j.1469-7610.2007.01749.x
12. Hancock, R., Pugh, K. R., & Hoeft, F. (2017). Neural noise hypothesis of developmental dyslexia. *Trends in Cognitive Sciences, 21*(6), 434–448. https://doi.org/10.1016/j.tics.2017.03.008
13. Penaloza, Z. S., Izquierdo, J. M. A., & Requena, C. S. (1999). Is focused visual attention affected by noise? *Psicothema, 11*(1), 97–111.
14. Allen, R., & Pammer, K. (2018). The impact of concurrent noise on visual search in children with ADHD. *Journal of Attention Disorders, 22*(14), 1344–1353. https://doi.org/10.1177/1087054715605913

15. Söderlund, G. B. W., Bjork, C., & Gustafsson, P. (2016). Comparing auditory noise treatment with stimulant medication on cognitive task performance in children with attention deficit hyperactivity disorder: Results from a pilot study. *Frontiers in Psychology, 7*, 1331. https://doi.org/10.3389/fpsyg.2016.01331
16. Söderlund, G. B. W., Sikström, S., Loftesnes, J. M., & Sonuga-Barke, E. J. (2010). The effects of background white noise on memory performance in inattentive school children. *Behavioral and Brain Functions, 6*, 55. https://doi.org/10.1186/1744-9081-6-55
17. Jafari, M. J., Saremi, M., Khosrowabadi, R., Khodakarim, S., Azhdari, M. R., & Ghasemi, M. (2019). A novel effect of white noise on auditory and visual attention using biomedical signals on petrochemical control room operators. *Pakistan Journal of Medical & Health Sciences, 13*(3), 939–944.
18. Skarlatos, D., & Georgiou, A. (2001). Memorization of young people under loud pink noise of short duration. *Perceptual and Motor Skills, 92*(1), 89–94. https://doi.org/10.2466/PMS.92.1.89-94
19. Harmon, T. G., Dromey, C., Nelson, B., & Chapman, K. (2021). Effects of background noise on speech and language in young adults. *Journal of Speech and Hearing Research, 64*(4), 1104–1116. https://doi.org/10.1044/2020_JSLHR-20-00376
20. Chitwood, M. R. (1970, January 1). Cognitive performance and sounds: The effects of lyrical music and pink noise on performance. NKU Digital Repository Home. Retrieved March 24, 2022. https://doi.org/10.1111/ejn.15455
21. Metin, B., Roeyers, H., Wiersema, J. R., van der Meere, J. J., Gasthuys, R., & Sonuga-Barke, E. (2016). Environmental stimulation does not reduce impulsive choice in ADHD: A "pink noise" study. *Journal of Attention Disorders, 20*(1), 63–70. https://doi.org/10.1177/1087054713479667
22. Lu, S. Y., Huang, Y. H., & Lin, K. Y. (2020). Spectral content (color) of noise exposure affects work efficiency. *Noise & Health, 22*(104), 19–27. https://doi.org/10.4103/nah.NAH_61_18