Adv Syst Sci Appl 2017; **4**; 14-21
Published online at http://ijassa.ipu.ru/ojs/ijassa/article/view/482

Selective Attention Compensates Detrimental Effect of Auditory Noise on Performance in Posner Experiment

Borzou Alipourfard[1], Kamyar Arbabifard[2], Fatemeh Bakouie[3*], Somayeh Sadat Hashemi Kamangar[3], Shahriar Gharibzadeh[4]

[1] *Department of Bioengineering University of Texas at Arlington, Arlington, United States*

[2] *Department of Computer Engineering, Amirkabir University of Technology, Tehran, Iran*

[3] *Institute for Cognitive and Brain Sciences, Shahid Beheshti University, Tehran, Iran*

[4] *Department of Biomedical Engineering, Amirkabir University of Technology, Tehran, Iran*

Abstract: Environmental noise has a degrading effect on individual's capacity to pay attention. In this paper, we revealed that the individual's impaired performance under noise can be counterpoised by recollecting and recalling his attention. We studied the effect of auditory white noise on individual's performance in Posner experiment; and examined if actively reorienting the individual's attention to stimuli would mitigate the effects of auditory noise. Our subjects, ten undergraduate students, participated in the classical Posner experiment, while auditory white noise was being played for them through earphone. We varied the intensity of the auditory noise and studied subject's performance in three conditions: neutral, valid cued, and invalid cued trials. Our results showed that the presence of auditory noise degraded subject's performance in neutral trials. However, subject's performance was not affected by auditory noise in valid cued trials.

Keywords: Auditory white noise, Attention, Posner experiment.

1. INTRODUCTION

Most people prefer a quiet place for work; they commonly believe that in the presence of environmental noise, their performance is negatively impacted; and they have had experiences that seem to prove this point. Thus, studying why environmental noise may affect performance on a task and how we can mitigate its effects is not only of theoretical importance, but is also of practical application and importance.

There have been many studies concerned with various effects of auditory noise. Some have considered the effects of noise in residential areas. For instance, auditory noise, such as road traffic, has been proved to have an unhealthy effect on residents sleeping patterns or children learning capabilities [1]. There are also studies concerning the detrimental effects of noise in working environments and the physiological and psychological consequences of long exposure to noise on workers [2]. At the physiological level, noise has been seen to cause increased heart rate and blood pressure [3]. Furthermore, the neural correlation of the effects of background noise have been reported as increased direct-coupled potential, as induced decrease in brain alpha wave, or as increased dopamine turn over in PFC [4,5].

In experimental settings, the immediate effects that auditory noise may have on an individual's performance have been examined. In most of these studies, subject's performance under noise condition was compared with those recorded in standard condition; and impacts of noise, at a psychological and behavioral level, have been described in terms of an overload framework, arousal model, Inverted-U Hypothesis and Stochastic Resonance [6-10]. Interestingly, the effects of noise on performance have been seen to be consistent with that of performance under induced arousal [8, 9]. That is, under the effect of noise, a subject's

* Corresponding author: f_bakouie@sbu.ac.ir

performance in low priority task components is degraded while his performance in high priority task components is unaffected; and the subject also shows increased selectivity in utilizing cues [6-9]. Although most studies have observed that noise induces arousal, it is to mention that not all the studies have observed such effect: there has been cases in which noise has induced simply a vegetative stress state, or has even improved a subject's accuracy and sensitivity to stimuli [10, 11].

In this paper, we aimed to study why environmental noise may affect an individual's performance on a task and how we can decrease this effect. To find an answer for the proposed question, we noticed that many of the previous studies have attributed changes in subject's performance (under noise) to changes in attentional mechanisms (such as narrowing of attention) [7]. An intuitive thinking suggests that this conjecture is consistent with our personal experience: most of us find it more difficult to focus in a noisy environment. If such a hypothesis is true and that noise disrupts subject's attentional mechanisms then we expect that with the aid of some other mechanism that captures, recalls and reorients individual's attention, the impaired performance under noise can be recovered. A suitable experimental setting to determine if recollecting an individual's attention would mitigate the effects of auditory noise on his performance is Posner experiment. In Posner task, the experimenter is able to orient and manipulate subject's attention with the aid of visual cues of his own design. In such an experimental setting, we can study if reorienting an individual's attention, with the aid of Posner cues, compensates the detrimental effect of noise on his performance. But before that, we first have to show that noise does have a detrimental effect on a subject's performance in Posner experiment.

Posner experiment was one of the early demonstrations of selective attention. In a visual detection task, Posner, prior to the onset of the detection stimuli (a black dot), used a cue (an arrow) to indicate the stimuli location to subjects [12]. Posner showed that orienting subject's attention to stimuli location (pre-cueing) decreased subject's response time, facilitating his perceptual processing. Furthermore, Posner task has since provided a strong framework for many computational models of attention [13].

Dosher and Lu studied a subject's performance in Posner experiment, when the detection stimulus (visual stimulus, a dot) was embedded in different levels of background visual noise. Through this paradigm they showed that visual noise had a detrimental effect on a subject's performance and orienting subject's attention to stimuli location mitigated this detrimental effect; hence they discovered a new attentional mechanism, which they called external noise exclusion. It is to point out that in such an experimental setting we would expect the noise to be harmful to a subject's performance as it affects the visual information he requires to complete the task. On the other hand, it seems that auditory noise does not affect any sensory information an individual requires to complete the Posner task. Now we are encountered with two questions:

1) Does the auditory noise affect subject's performance in Posner experiment detrimentally?

2) Does recalling and reorienting individual's attention mitigate the detrimental effect of auditory noise on subject's performance in Posner experiment?

In this study we design an experiment to answer these two questions that leads the two novelties in comparison with Dosher and Lu study, i.e. I) The presence of auditory noise degraded subject's performance; II) Orienting of attention disrupts the detrimental effect of auditory noise on subject.

It should be mentioned that in the study of Dosher and Lu, both the stimulus and noise are visual; while in this study, we designed an experiment with visual stimulus and auditory noise. In this study, our subjects participated in the classical Posner experimental setting while different levels of auditory white noise were played through an Apple Earpods earphone. We varied the intensity of the noise and studied subject's performance in three conditions; namely: neutral, valid cued and invalid cued trials. Through this methodology, we examined interactions between auditory noise and oriented attention, and we sought to learn whether actively reorienting the individual's attention to stimuli location would mitigate the effects of auditory noise or not. With the intuitive thinking we mentioned before, we expected to observe an antagonistic interaction between noise and oriented attention in subject's performance.

2. METHODS

Ten undergraduate students, all male, aged between 19 and 22, and with no observable medical conditions that could affect their performance in the task, participated voluntarily in this experiment. The subjects each sat on a chair placed in front of a LCD monitor and at a distance that each found to be comfortable. Each subject was instructed to fix his gaze at the center of the fourteen-inch monitor, which had a white background. We asked each subject to press a key as quickly as possible upon detecting the stimulus. The detection stimulus, a black dot, occurred at either the left or the right of the fixation point. The detection stimulus was offset with respect to the fixation point; the offset was set at 600 pixels.

Our experiment consisted of 5 blocks of trials for five different levels of auditory noise intensity (specifically, no noise, 70 dB, 85 dB, 100 dB, 115 dB). White noises of different intensities were generated using MatlabR2010a; the noise intensity levels were measured by an HM-303-6 voltage meter. In the study of Arnsten & Goldman-Rakic, it is mentioned that the background noise intensity is 60-70 dB; the loud noise intensity is more than 95 dB and the noise intensities more than 115 dB is annoying. As we wanted to cover all the noise intensities, from background noise to loud and annoying one, we chose the intensity levels of 70 dB, 85 dB, 100 dB, 115 dB. The generated noise was then fed to an Apple Earpods earphone to produce the desired level of auditory noise intensity for each block of trials. To prevent noise intensity adjustments from affecting the subject's decisional criteria, the order in which these blocks took place in the experiment was designed to be random.

Each block of trial then consisted of ten cued trials and ten neutral trials. So, the total number of collected dataset for each subject is $5\times10\times2=100$. At the beginning of each trial, subjects were presented with either a plus sign (neutral trials) or an arrow pointing to the right or left (cued trials). As shown in Fig. 1, if the plus sign was presented for the trial, then the detection stimuli occurred with equal probability to the left or right of the fixation point. For the cued trials, the detection stimuli occurred at the indicated location with the probability of 0.8 (valid trials) and occurred at the opposite side with the probability of 0.2 (invalid trials). Detection stimuli occurred 400 ms after the onset of either the plus sign or the arrow. The time between trials was set at three seconds. The subject's performance was measured in each trial as indicated by his response time. The described framework was developed virtually in Java environment.

Before the official experiment commenced, subjects were instructed on the paradigms and methods of the experiment; and each subject was allowed to practice the experiment for as many times as he desired, until he found himself comfortable with the process. Finally, in the actual testing process, care was taken to provide each subject with a comfortable and a stress-free environment. All subjects were tested during the period between 14:00 and 18:00.

3. RESULTS

The results of our experiment are shown in Fig. 2. The upper plots show the statistical distribution of subjects' Response Time (RT). In the lower plots of this figure, the average response time is shown as a function of noise intensity. The leftmost plots in this figure show the results for neutral trials; the middle plots are for the valid cued trials and the rightmost plots show the response time for invalid cued trials. Data is plotted using logarithmic scale for noise intensity (X axis) and linear scale for response time (Y axis). To check the accuracy of the collected data, we measured the difference in the average response time when the stimuli occurred at the left of the fixation point and when it occurred at its right; in an accurate data set, we would expect this difference to be very close to zero. In our experiment, this difference accumulated to only 2 ms.

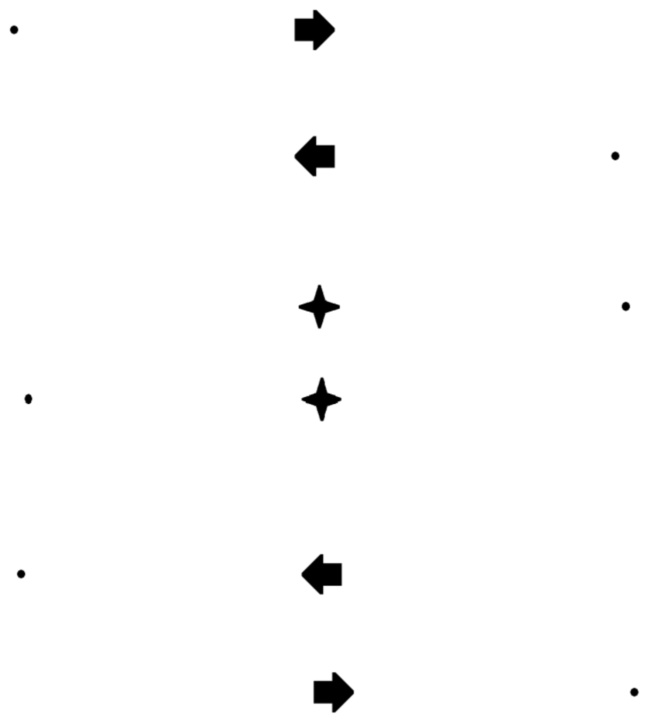

Fig. 1. Organization of Posner Task. If the plus sign was presented for the trial, then the detection stimuli occurred with equal probability to the left or right of the fixation point. For the cued trials, the detection stimuli occurred at the indicated location with probability of 0.8 and occurred at the opposite side with the probability of 0.2.

A preliminary examination of the data in Fig.2 shows that valid cue facilitates performance in all noise conditions while invalid cue does not facilitate performance. This observation is more prominent at higher noise intensities: in 115 dB intensity condition, invalid cueing degrades performance while accurate cueing improves performance.

As the data in Fig. 2 shows, effects of noise on performance in neutral trials and valid cued trials are unalike. On the one hand, for neutral trials, the response time is an increasing function of noise intensity; in neutral trials, as the leftmost plots in Fig. 2 show, the response time increases from 721 ms at no noise condition to 738 ms at noise intensity of 115 dB. F-test was conducted by R3.1.1 software to compare subject's response time in these conditions. There was a significant effect of noise on subject's response time, $F(1,9) = 5.64$, $MSE = 1896$, $p < 0.05$.

On the other hand, for the valid cued trials, as shown in the middle plot of Fig. 2, the response time is seemingly independent of noise intensity, exhibiting a total variation of only 9ms. Interestingly, in valid cued trials, by conducting F-test to compare subject's response time in no noise condition and 115dB noise condition, we see that there was no significant effect of noise on subject's response time, $F(1,9) = 0.33$, $MSE = 2938$ ns.

As demonstrated in the right most plot of Fig. 2, the response time for invalid cued trials is also an increasing function of noise intensity. Specifically, in these instances, the increase in response time is greater as compared with neutral trials. The ample increase in subject's response time in the 115dB noise condition shows that the degrading effect that noise may have on subject's performance can be as detrimental as the effect of removing valid cues: in the no-noise condition, we see that valid cueing improves performance by 34.2 ms and 115 dB noise condition increases subject's response time by 29.8 ms.

In addition, the detailed data of Fig. 2 is presented in Table 1. In this table, we have provided the exact values of means and SDs (std) of cued and neutral trials. On average, the difference between the means of cued and neutral trials as calculated from the table below is 48.50 ms.

To further expand upon our hypothesis, we calculated differences in subject's RT in neutral and valid cued trials and plotted them against noise intensity. The result is presented in Fig. 3.

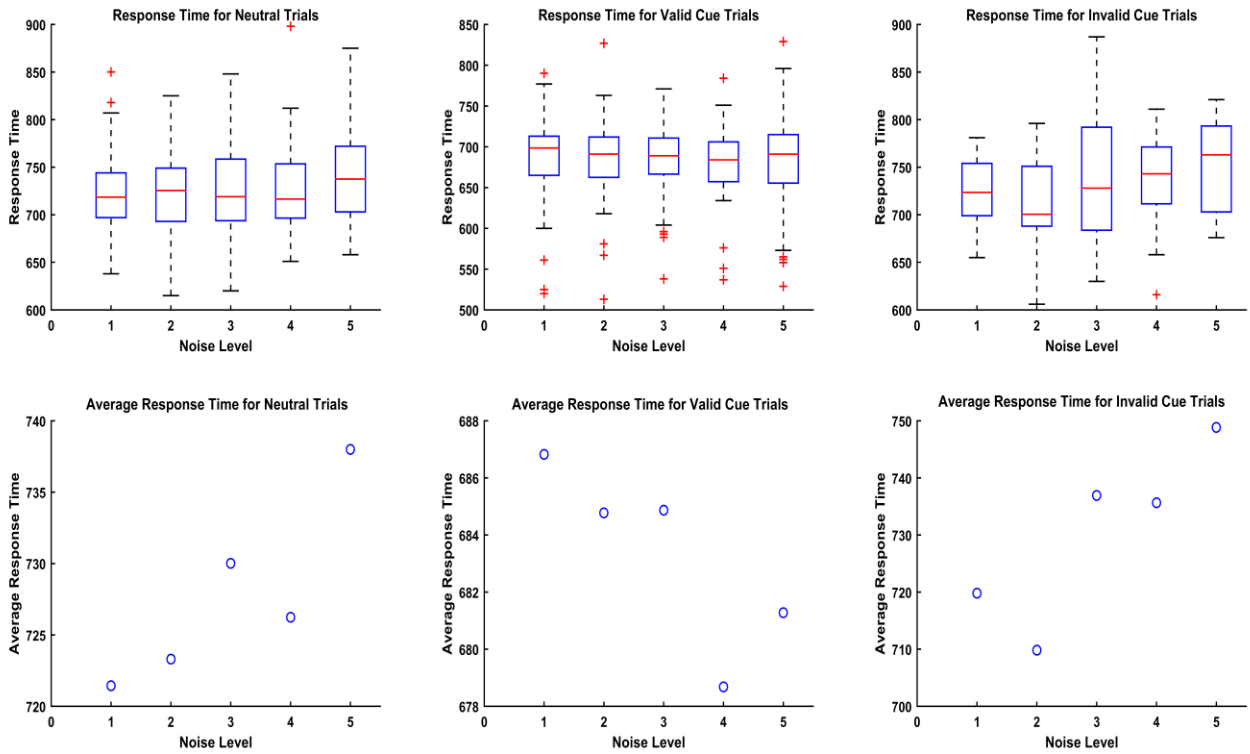

Fig.2 Recorded response time is plotted against noise intensity level. Statistical distributions of the collected RTs are shown in the upper plots of this figure. The average RT is plotted in the lower figure. Plotted data in the leftmost figures corresponds to the data collected in the neutral trials, while the middle figures and the rightmost figures show the results for the valid cued trials and invalid cued trials respectively. The data is plotted using logarithmic scale for noise intensity (X axis) and linear scale for response time (Y axis)

Table 1. the exact values of means and SDs (std) of cued and neutral trials

Noise Level	1	2	3	4	5
Mean RT in Cued Trials (std)	686.82(51.4)	684.77(48.8)	684.86(45.5)	678.68(44.6)	681.28(56.7)
Mean RT in Neutral Trials (std)	721.83(39.5)	724.05(46.5)	734.79(50.5)	734.66(49.8)	743.60(51.4)

We then built a simple linear regression model (least square regression) using R3.1.1 software to study the relation between noise and differences in subjects' performance in valid cued and neutral trails. The value of R2 was calculated to be 0.0177. The results are shown in Table 2. Note the significant p-value for the noise level coefficient. The "Intercept" of the calculated linear model shows that cueing, on average, facilitates performance by 31.09 ms.

Table 2 The coefficient for the regression model.

Coefficients	Estimate	Std. Error	t- value	Pr(>|t|)
Intercept	31.09	6.32	4.898	1.56e-06
Noise Level	6.68	2.56	2.606	0.009

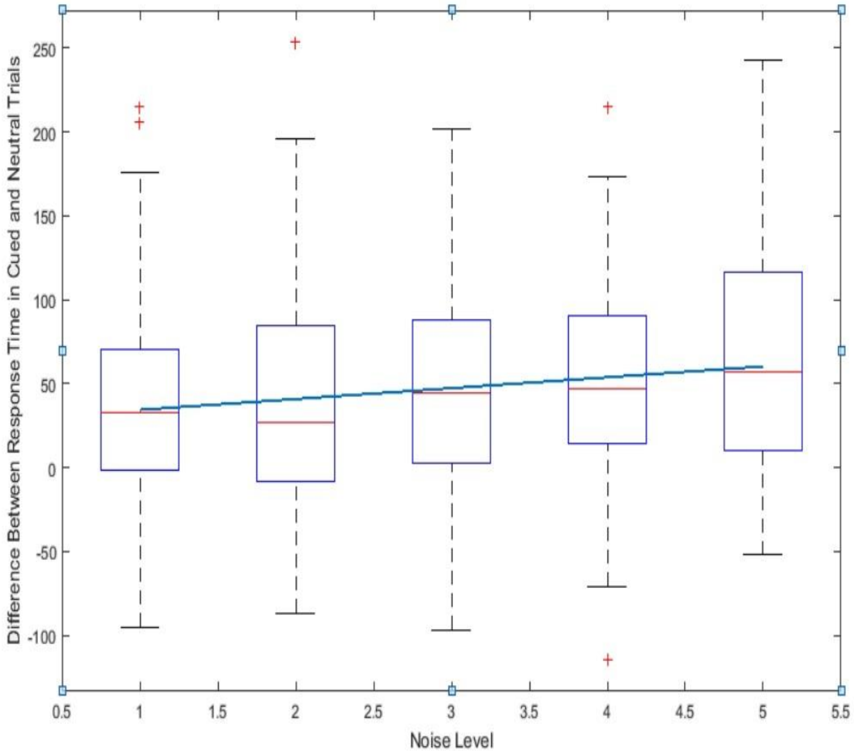

Fig.3 The difference in subject's RT between valid cued and neutral trials as function of noise intensity. The blue line is a least square linear regression model that shows the dependency of the aforementioned data on the intensity level of the auditory noise

4. DISCUSSION

In this study, our goal was to examine whether the underlying mechanisms by which environmental noise impacts performance, were related to human attentional mechanisms; we examined if the individual's impaired performance under noise could be counterpoised by recollecting and recalling his attention. Our subjects participated in the classical Posner experiment, with the addition that different levels of auditory white noise were played through an Apple EarPods earphone. We varied the intensity of the noise, studied the changes in subject's response time, and examined interactions between environmental noise and oriented attention. We found that the presence of noise was degrading to subjects' performances in neutral trials. However, subjects' performances were not affected by noise in valid cued trials.

We have specifically compared our design with that of the Dosher & Lu 2000 [13]. In order to better capture our experimental setting, we examined a similar experimental setting proposed by Dosher and Lu. They studied a subject's performance in Posner experiment, when the detection stimulus (visual stimulus, a dot) was embedded in different levels of background visual noise. Through this paradigm they showed that visual noise had a detrimental effect on a subject's performance and that orienting subject's attention to stimuli location mitigated this detrimental effect. Hence, they discovered a new attentional mechanism, which they called external noise exclusion. It is to point out that in such an experimental setting we would expect the noise to be harmful to a subject's performance as it affects the visual information he requires to complete the task. On the other hand, in our experimental setting, auditory noise does not affect any sensory information an individual requires to complete the visual Posner task. Hence, we would not expect it to be harmful to his performance. However, presence of noise has been shown to have a degrading effect. The main question that remains is that why noise may affect a subject's performance.

In neutral trials, our results show that noise impacts a subject's performance negatively; this degrading effect of noise has also been seen in previous researches [8, 9]. On the other hand, for the valid cued trials we found that a subject’s response time was independent of noise intensity. This suggests that orienting attention to the stimuli location somehow counteracted the detrimental effects of noise. Interestingly, we see that this interaction is present at all noise levels. And irrespective of the intensity, orienting the subject’s attention fully counteracts the effect of noise. This persistent antagonistic relation not only suggests that these two events are counteracting each other at some cognitive level [2], but is also an evidence to our main hypothesis since recalling subject’s attention fully negated the detrimental effect that noise had had on his performance. To further expand upon our hypothesis, we calculated differences in subject’s RT in neutral and valid cued trials and plotted them against noise intensity (see Figure.3).

The “Noise Level” coefficient can be interpreted as the average increase in a subject’s RT per noise level in neutral trials that was compensated by cueing in valid cued trials. If there was no interaction between noise and oriented attention on a cognitive level, we would expect the “Noise Level” coefficient to be zero and for cueing to decrease response time on average by 31.09 ms regardless of noise intensity (see Table 1). However, our results suggest a very strong interaction ($Pr(>|t|)=0.009$) between noise and oriented attention. This result is a strong evidence for the cognitive level presence of auditory noise that is fully nullified when orienting attention.

Another interesting aspect of the collected data set is concerning a subjects’ performance in invalid cued trials; however, we want to note that the results here are more qualitative than quantitative, since the small collected data for the invalid cued trials does not allow for a statistical inference. Our results show that the presence of noise was the most hurtful to a subject’s performance in these trials (see Fig. 2). In cued trials, we then have a task component in which performance is continuously worsened when increasing noise intensity (invalid cued trials) and a task component that is not affected by the presence of noise (valid cued trials). Previous studies recognized that under noise conditions, a subject’s performance is continuously degraded in low priority task components, while the performance in high priority task components is not affected [8, 9]. In other words, the amount of noise effect on subject’s performance depends on the priority of the task; if the task has high priority, negative noise effect on subject’s attention would be less [8, 9]. Taking into consideration the results of such studies, we may conclude that in our experiment, valid cueing attracts attention of the subject and make a priority for the task. Subjects’ performance in valid cued trials represents their performance in the high priority component of the task, and in invalid cued trials represents their performance in the low priority task component. Hence, we hypothesize that, pre-cueing had a prioritizing effect on subject’s surrounding sensory events. Therefore, visual events on the cued side became his sensory events with high priority, while the visual events on the opposite side were given a lower priority. This prioritizing effect favors the hypothesis that pre-cueing orients subjects' attention and the decrease in his response time in valid cued trials is a result of the orientation of attention rather than a change in response criteria.

5. CONCLUSION

In this paper we used Posner task to study why environmental noise may affect an individual’s performance on a task. We studied the accuracy of the common belief that the presence of noise makes it more difficult to focus and to pay attention; and examined if recollecting and recalling an individual’s attention would counterpoise his impaired performance under noise. Our results supported our main hypothesis. They showed that orienting a subject’s attention to stimuli location mostly negated the detrimental effect that noise had on his performance. Our study suggests that, it would be possible to decrease the negative effect of environmental noise even if its modality differs from the stimuli's. This would certainly raise the efficiency of individuals and helps them work well and accurately in noisy workplaces.

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.

[2] Broadbent, D. E. (1971). *Decision and stress*. London, UK: Academic Press.

[3] Hsu, S.-M., Ko, W.-J., Liao, W.-C., Huang, S.-J., Chen, R. J., Li, C.-Y., & Hwang, S.-L. (2010). Associations of exposure to noise with physiological and psychological outcomes among post-cardiac surgery patients in ICUs. *Clinics*, 65(10), 985-989.

[4] Arnsten, A. F., & Goldman-Rakic, P. S. (1998). Noise stress impairs prefrontal cortical cognitive function in monkeys: evidence for a hyperdopaminergic mechanism. *Archives of General Psychiatry*, 55(4), 362-368.

[5] Briggs, F., Mangun, G. R., & Usrey, W. M. (2013). Attention enhances synaptic efficacy and the signal-to-noise ratio in neural circuits. *Nature*, 499, 476–480.

[6] Bell, P. A. (1978). Effects of noise and heat stress on primary and subsidiary task performance. *Human Factors: The Journal of the Human Factors and Ergonomics Society*, 20(6), 749-752.

[7] Woodhead, M. M. (1966). An effect of noise on the distribution of attention. *Journal of Applied Psychology*, 50(4), 296.

[8] O'Malley, J. J., & Gallas, J. (1977). Noise and attention span. *Perceptual and motor skills*, 44(3), 919-922.

[9] Hygge, S., & Knez, I. (2001). Effects of noise, heat and indoor lighting on cognitive performance and self-reported affect. *Journal of Environmental Psychology*, 21(3), 291-299.

[10] Manjarrez, E., Mendez, I., Martinez, L., Flores, A., & Mirasso, C. R. (2007). Effects of auditory noise on the psychophysical detection of visual signals: Cross-modal stochastic resonance. *Neuroscience letters*, 415(3), 231-236.

[11] Hasenfratz, M., Michel, C., Nil, R., & Bättig, K. (1989). Can smoking increase attention in rapid information processing during noise? Electrocortical, physiological and behavioral effects. *Psychopharmacology*, 98(1), 75-80.

[12] Posner, M. I. (1980). Orienting of attention. *Quarterly Journal of Experimental Psychology*, 32(1), 3-25.

[13] Dosher, B. A., & Lu, Z.-L. (2000). Noise exclusion in spatial attention. *Psychological Science*, 11(2), 139-146.

