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Low Intensity Natural Sounds and Pink Noise's Effect on Attention

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Abstract

Background noise and how it influences attention in humans is researched in various ways and forms. Usually it has been done by using music and silence to compare the effects on a primary cognitive task. Since music is an artificial sound created with the intention to draw attention to it, the present study sought to determine if background noise cause differences in reaction time whether it was artificial noise or natural noise (such as the sound of a stream of water compared to pink noise). The two background noises were compared through a visual oddball paradigm measuring reaction time on a sample (N = 30) whose mean age was 29 years (M = 29.70, SD = 7,82). The paired t-test confirmed the hypothesis. Therefore, this study concludes that pink noise creates longer reactions compared to natural sounds when presented as background noise.

Keywords: Cognitive, perceptual, primary task, pink noise, deviant, deci-seconds

Abstrakt

Bakgrundsljud och hur det influerar människors uppmärksamhet är undersökt i ett flertal olika former. Vanligtvis genom att använda musik och tystnad som variabler för att jämföra effekten på en primär kognitiv uppgift. Eftersom all musik skapas med intentionen att lyssnas på, dvs. att dra uppmärksamheten till sig, söker denna studie att undersöka huruvida bakgrundsljud ligger till grund för olika reaktionstid beroende på om ljudet är artificiellt eller naturligt (ljud från naturen som en strömmande bäck jämfört med rosa brus). Genom att använda ett visuellt oddball-paradigm på ett reaktionstids-test med de två bakomliggande ljuden på en population (N = 30) där snittåldern var 29 (M = 29.70, SD = 7,82). T-testet bekräftade hypotesen. Därför fastslår denna tes att rosa brus ger längre tid på reaktionstids-test än naturliga ljud när de presenteras som bakgrundsljud.

Nyckelord: Kognitiv, perceptuell, primär uppgift, rosa brus, avvikelse, deci-sekunder

Introduction

According to tests performed by Anderson and Fuller (2010) on students performing reading comprehension tests, music can be a distracting element regardless of the type of music the test subject is listening to when compared to performing the same reading comprehension test in complete silence. This study also showed that individuals who were used to listen to music whilst studying performed better at the primary task than those who were not used to listening to music while working. This suggests that training is required to not have attention drawn towards the incoming auditive stimuli which in the case of Anderson and Fuller was lyrical music. Research on individuals performing cognitively demanding primary tasks shows that silence is generally to be preferred for the best possible accuracy and test performance on the primary task (Avila, Furnham, & McCelland, 2011; Furnham & Strbac, 2002).

In 1977 O'Malley and Gallas performed a test in which test-participants were subjected to different frequencies of white noise and also complete silence whilst performing a cognitive primary task. In an attempt to figure out if silence or a specific frequency of white noise would result in the best test scores, they found that when performing a stroop-task test, the test subjects who were subjected to white noise of 85 db presented with better results than those presented with no noise, 75 db and 100 db white noise. This contradicts the test scores presented by Anderson and Fuller's reading comprehension task, where all lyrical music had a performance impact on test takers performance. The differences between the studies include: the type of sound presented, and the type of cognitive primary task. The studies of O'Malley and Gallas (1977) and Anderson and Fuller (2010) seem to contradict each other. Unless different sounds are decoded in the brain, similarly to visual stimulus, which is separated early and into categories like color, motion and shape (Altmann, et al 2007). Different pathways in the brain seem to be responsible for different types of sound decoding in the brain, specifically the dissociation between location processing and auditory patterns (Altmann et al. 2007). Thus, the question then arises how the interplay with attention connects to these findings. If different auditory information is decoded similarly to the visual system, what role does attention have in and how humans decode auditory signals? And if we want to test the different effects that different sounds have on attention across a population, what sounds would be prominent to use? And how does it relate to the role of attention and the filtering of information, is the attentive load distributed equally?

According to Laive (2010), attention is a resource to be distributed. Is that a theory that is compatible with Altmann's (2007)? It seems that liking or personal preference also hold significance in the experience of the sound (Cassidy & McDonald 1997). In studies where participants were subjected to music of their preference whilst playing a racing video game, participants showed fewer crashes and lower average lap time when listening to music they themselves chose. In comparison when listening to pre-selected music that test designers designated, where the overall performance was reduced (i.e., higher lap times and more crashes.) Similarly, other studies regarding video games and other cognitive functions have explored that training on a specific task can improve performance on that task significantly, even with as few as 10 hours of practice on that task (Boot et al, 2008). Information coming in through the senses are filtered through an early and a late selection process, referring to when the intake of information through the senses is filtered and sorted as relevant or not (Laive, 2010). The two theories were combined into a theory that solved the debate of the late vs early selection. The theory, called Laive's load theory, suggested that attention is a resource that is distributed depending on what tasks require it the most. This is related to the "cocktail party effect", which explains how in a room crowded with conversation a person can select what conversation to pay attention to (Bronkhorst, 2000). There are 2 types of attention, Top-down and Bottom-up attention. If the attention of the individual is task oriented and voluntary it is top-down (Originates in the experiences of the person). Bottom-up attention is based on the environment around the individual (Originates from the cues and clues you observe and react to in the environment), and the attentive cues all come from around them, they are undirected (Fritz, et al. 2007). Auditory attention is flexible and can switch between these two models when task specific tools are required. Attention is not a single system with a specific task, but instead a multitude of systems and integrating models that combine to a whole cognitive function. This is compatible with Laive's load theories (Laive, 2010) that combines the early and late selection theories, referring whether information is filtered out early or late in the process of perception.

Music has been used in many attentional studies. For example, Anderson and Fuller (2010) used vocal music to test reading comprehension in students. Furnham and Stbac (2002) compared music to other background noise. There are several theories about music and the cognitive system that are not empirically confirmed such as "The Mozart effect", which suggests that an individual could increase their intelligence simply by listening to Mozart scores (Jenkins, 2001) that circulate in social groups and pop culture in general. The one thing that can be said about music is that it is made to be listened to. Since any professional musician makes music with the intention of selling it, the best way to do this is to make music that people will want to listen to. Even music such as elevator music that is intentionally made to be present in the background of any environment is presented in, it will cover some other sound or noise that a person might interpret and feel uncomfortable. In the case of an elevator it could be stretching of the wires that hold the elevator or other metallic sounds amplified by the elevator shaft. Therefore, in essence all music is made to be listened to and thus it is not odd that listening to music, whilst performing a primary cognitive task that requires the attention of the test taker, might influence the test taker's ability to effectively complete that task. According to Altmann (2007), sounds can be decoded with different pathways in the brain depending on what the nature of the sound is. Are there sounds that our attentional system is more adept at handling than others? Is all sound equally taxing on our attention or will sounds of different nature have different effects on a primary task if you were to compare the two under similar conditions? When measuring the effect of white background noise on reaction time under a visual display terminal test, experiments found that white noise significantly increased reaction time when performing a reaction time task (Trimmel & Poelzl, 2007).

Most research that has to do with some form of music as background noise and its effect on cognitive functions has been made on children (Patston & Tippett, 2011). While studying the effect a disturbing element have on an individual there might be other factors that affect the result of the individuals results if they are in a developing phase in life. There is an argument to be made that children who achieve high result in tests might simply have developed further cognitively because they have a home environment with supporting caregivers who, support their emotional growth (Lynne, Feagans, Merriwether, 1991). This will vary heavily depending on individual. Adults have the added function of being trained in a craft or in a skill, which makes it easy to compare differences and see connections clearly. For example, Patston and Tippett's (2011) experiments on background music's effect on cognitive functions in musicians and non-musicians, they found that musicians had difficulty when performing a language comprehension task, but not a visuospatial task. The differences in skill that comes from practice changes the way that information is processed.

There are many studies that have taken parts of a natural soundscape and examined their restorative effects on humans. One of them done by Ratcliffe, Gatersleben and Sowden (2013) examined the restorative effects of birdsong on stress recovery as well as perceived attention restoration. They documented that the closer the individual's connection to nature was, the more successful the restorative effects of birdsong seemed to be. What constitutes as background noise? In urban development research papers, soundscape is discussed in detail. The soundscape is defined as the auditory environment, meaning all sounds that come as part of an environment, no matter if they are being payed attention to or not. In other words, the soundscape is determined by the physical environment around an individual (Porteous & Mastin, 1985). In urban development, the soundscape is considered when trying to create places of stress relief like a park in the middle of a city for instance. Some types of natural sounds have extensive research as to their effects on the individual as part of a soundscape (Porteous & Mastin, 1985). Sounds that are from nature, (i.e., water sounds, wind sounds, gentle voices,) are most preferred. Since the soundscape includes those that are not intentionally payed attention to, background noise is included in the term. The important distinction between background and foreground noise seems to be the consistency of the sound. A sound that drastically increases in volume or intensity will be more likely to draw attention to it (Noyce & Seukler, 2014). If background noise is to be investigated, it will have to be discrete enough to not draw attention to it, whilst prominent enough that a user will take notice clearly if the sound is pointed out to them. Halley (1996) stated that white noise is a kind of background static. In essence it is a random signal presented at fast intervals. This creates a kind of "static" noise that, when presented in conjunction with a primary task, can serve as a distractor designed to simulate random events in a surrounding environment. Pink noise is similar to white noise in the sense that it is designed to be background noise. But in comparison to white noise, which presents a true set of random notes out of an equal amounts of possible high and low pitched notes, pink noise has fewer high pitched notes than white noise (Metin et al., 2013). This is because the perceived loudness of these high pitched random notes is higher than the low pitched notes. Pink noise creates a less intensive loudness, and thus simulates a background low impact environment in a more pleasant way. Pink noise is also very similar to some natural sounds, as some use to better help them fall asleep and to similar result. When creating a white or pink noise, perceived loudness must be taken into consideration. As the higher pitched notes are more intense to humans, they have to be adapted to be equal to the perceived loudness of an un-converted file. That is to say, if you take a sound and convert it to white noise, the intensity of the converted noise must be lowered to match the perceived loudness of the original sound (Marks, 1980).

The question then becomes if there is a difference between the two. The natural sound recorded from an actual soundscape or the synthetically generated pink noise. In a study examining the way natural sounds are encoded (Theunissen & Elie, 2014), researchers claim that when observing the neural pathways of non-human primates, natural and synthetic sounds generate different neurological responses. If that is the case and if one were to compare a natural sound to a synthetic one, such as pink noise, there should be a difference in how they are perceived. Since pink noise is simply an assortment of notes played with low intervals at random it would be decoded differently.

An oddball task is a task in where an individual is asked to observe a pattern and look for a deviant. Once the deviant is observed, one would observe what happens when the deviant is recognized and how it creates a different response compared to the usual pattern the test person has been asked to look at. We know that oddball tasks are demanding of attention already (Noyce & Sekuler, 2014). Even though we will not be able to directly observe the changes in the different parts of the brain, it should still present a demanding enough task to be a tool for observation. The reason I have chosen not to use, for instance, the stroop task and other similar evaluation tools is that they are designed for a specific use to test specific brain functions and cognitive tools such as rule-definition. And while they are attentionally demanding they are not the best choice when an alternative designed for attention-studies is at hand.

The research question of this thesis is based on how sounds affect humans differently based on the nature of that sound. Looking at the research, it seems that natural sounds have some kind of calming or restoring effect on humans (Ratcliffe, Gaterslaben & Snowden, 2013) compared to synthesized or artificial sounds. This is especially interesting since synthesized pink noise is used to help some people fall asleep and is quite similar to sounds like rain. Is there a perceived difference between natural sounds and synthesized sounds that affect our reaction? The hypothesis of this thesis will be that natural sounds will make the reaction time of the oddball task shorter due to its properties that we as humans seem to respond to. The synthesized background noise should result in longer reaction times and thus be deemed more distracting at an equal level of intensity and perceived loudness. The easiest way to examine this would be to use brain imaging, for instance an fMRI to observe and directly examine the effect of the sound on the different parts of the brain. As such equipment is unavailable, instead observing the results of the sounds on a primary task, using attention and reaction time as a mediator will be an acceptable alternative.

Method

Participants

The participants for the current study were recruited randomly as they passed by the locale the test took place in. The sample of the test (*N* = 30) were between ages 18 and 45 where 17 were men and 13 were women. The original samples were 32; however, 2 subjects were excluded because of hardware malfunction in one case and inability to complete the task correctly due to non-disclosed visual impairment in the other case.

Ethics consideration

All participants were required to give informed consent to participate in the study. As part of this, all participants under the age of 18 will be excluded. Participants will be required to have normal or corrected-to-normal vision or auditory perception. No monetary reward will be offered to participants. Participants will receive information regarding the study in both oral and written form. They will have opportunity to ask questions regarding the study and their participation before the experiment commences. Participants will be required to fill out a forum with relevant information such as age and gender. The test is anonymous, and at any point during the procedure or after, the participant has the right to ask to have their data and participation be excluded from the experiment. Participation is anonymous and no individual’s data will be singled out and presented on its own. Instead all data will be collected and processed into tables and statistical analysis.

Instruments and materials

The test takers performed the test using a Lenovo Y50 laptop, whilst listening to two different background noises one at a time though a Marshall Major II headset. The sounds will be directly recorded and edited by the test leader to avoid copyright issues. The first sound will be a low intensity nature sound, a running stream. This sound will be put through a filter and made into pink noise so that the two sound files will have the same patterns of intensity, and thus be equally distracting. The participants listened to the sound files using a Sennheiser HD 201 headset in a quiet environment. The program running the oddball task is programmed for the specific task, with deviants appearing in 10 % of samples. Test takers were asked to continue with the test until the response time from observing the deviant to pressing the button is done.

Procedure

After the test takers had been given informed consent, they were be asked to fill out a form of information. The participants were asked to sit down in front of a terminal and receive headphones to put on. The test takers were seated at a table in a non-distracting environment with the laptop placed 10 cm from the tables edge, then be asked to make themselves comfortable before conducting the task. The test taker would then start the experiment whilst listening to the first of the two possible background noises. The natural noise was presented first in 50% of the tests, and the pink noise was presented first in 50%. Whilst listening, a random set of symbols appeared on the screen. The sets of symbols had 9 samples that follow the same pattern and one deviant who broke that pattern. Every time the participant identifies the deviant, they pushed a pre-determined button. Once the button was pressed, the program recorded the time taken from the deviant to appear and the input to come. After this had been done, the first test was concluded, and the participant was asked to do the same thing for the second sound. Once both sounds had been tested, the test was concluded.

A visual oddball paradigm consists of a sample of a set number of visual stimuli that changes every few seconds. A majority of the samples follow a set pattern, with one or more deviant from that pattern being introduced in a set percentage of the samples. The items from the samples are introduced one at a time and are displayed for a short time, before it disappears and is replaced with a new item from the sample list. The test takers objective is to identify each time one of the deviant items of the sample is shown (Cha, Choi, Jung, Kim, 2017).

Results

The means and standard deviations of the reaction time test on the two different sounds using a visual oddball paradigm are displayed in Table 1. The unit of time measured was deci-seconds (one deci-seconds is equal to one tenth of a second).

Table 1

	N	*M*	*SD*	*SE*
Natural time (deci)	30	70.57	12.10	2.2
Pink time (deci)	30	79.33	17.69	3.23

Figure 1

The results of the Natural background noise sound (*M* = 70.57, *SD* = 12.10) and the Pink noise background test (*M* = 79.69, *SD* = 17.34) reaction time task indicate that there is a significant difference in reaction time, $t = -2.74$, p <,01, d = -.05., when exposed to Pink background noise compared to Natural background noise.

Discussion

The hypothesis for this study was to determine whether natural sounds differed from pink noise when presented as background noise during a rection time test that stressed the attention of the test-taker. The theory being that natural sound would impact attention less, thus having a lesser observed reaction time compared to the artificial pink noise, as observed in previous research (Ratcliffe, Gaterslaben, Snowden, 2013). The population conducted the tests in a non-distracting environment to ensure that the intended distractors would be the primary sensory distractor during the primary task. The mean of the pink background noise sample presented as higher compared to the mean of the natural sound background noise.

The effects of the natural background noise distractor either did not tax the test-takers attention, or alternatively made the test-taker more relaxed and ready to act on the deviant cue. As natural sounds can have a positive effect on stress recovery and perceived attention-restoration, there is an argument to be made that it might be the latter of the two alternatives (Ratcliffe, Gaterslaben, & Snowden, 2013). However, as no empirical data can be gathered about that from the present test it is just speculation as to the cause of the effect. The more research about attention that comes to light, the more accurately the test can be modified to conduct research to find empirical support for either of these two options. Compared to phenomena such as the “Mozart effect”, this reaction time-based study shows that there is a significant difference. The long-term effects on either sound on attention is not tested within the parameters of this test, but rather, it observes the effects of the natural exposure of the population.

Studies that have compared the effect of background noise on a primary task to silence reported that silence generally produces highest test scores (Avila et al. 2010; Furnham & Strbac, 2002). If the result of the conducted experiment using the two background noises were different, assuming they are of equal intensity and perceived loudness, it would indicate that some characteristic of the sounds is the cause for difference. A significant difference was observed, thus something within the nature of the sounds seems to affect the encoding of the auditive input, based on what kind of sound it is. Altmann and colleagues (2007) observed that location is decoded faster than pattern changes in auditive stimuli when observing the neural pathways incoming sound take using, fMRI. Therefore, sounds are decoded at different speeds depending on the characteristics of the sound itself. Thus, comparing the characteristics of the sounds used in the reaction time experiment might be a starting point to figuring out why they yielded different results. As the natural sound is recognizable and something one can identify without having to analyze it, it might have a faster decoding process compared to the pink noise that was created to be a direct contrast to the natural sound. Even if the two sounds are similar in perceived loudness and intensity, they are different because it is likely the test taker has some kind of experience with natural sounds and not the pink noise. If this is the case, there is an argument to be made that the two sounds tax different kinds of attention. From the perspective of the top-down and bottom-up models of attention (Fritz, Mounya, Stephen & Shibab, 2007). The natural sound might be classified as top-down as the listener might have experience with that particular sound and does not need to analyze it in regard to its environment. Thus, the natural sound affects the attention lesser than a sound with no immediate environmental context, like the pink noise. The pink noise might require more resources to analyze, if it uses the bottom-up model of attention. This is because it is unknown or more abstract than the natural noise, making it more resource intensive. This would also be compatible with the theories regarding attention as a resource, where different tasks require different amounts of attention (Laive, 2010). This would explain why different tests might seem contradictive. For instance, Anderson and Fuller (2010) observed that silence was to be preferred to listening to music when preforming cognitive primary task, whereas O' Malley and Gallas (1977) reported that listening to white noise at a db of 85 yielded higher results in a primary task than silence would. If the nature of the sounds used in a test differs, they might utilize different pathways depending on the listeners experience of said sound.

Limitations and future directions

As the experiment-data supports the hypothesis, questions regarding the different variables of the test become interesting to consider. For instance, what would happen if the sample set were to be of an equal size for all participants instead of the deviant appearing randomly at 10% of the total sample set? Ideally, the test would benefit from a second round of tests, where one would compare the effects of the 2 ways to present the deviant (either randomly or after a set number of repetitions). Though the data was not included in the statistical analysis, the number of repetitions were recorded by the test taker and the average number of repetitions for the natural background noise were 12,74 whilst the average number of repetitions for the pink background noise were 15,74. So the longer average waiting time of the pink background noise might have affected the reaction time. The data from the study suggests that low intensity background noise could be beneficial to focusing attention on other tasks as well. If the natural sounds would be presented in a classroom during class, if there is a disturbing amount of background noise that is artificial (for instance the sound of machinery, the buzzing of computers or similar distractors) teachers could play low intensity natural sounds to mask the artificial distractors. The same could be applied on any environment where one distractor needs to be masked. The response to the natural sounds might differ with the individuals experience of nature, since personal preference is a significant factor when listening to sounds whilst performing a primary task (Cassidy & McDonald, 1997). If an individual has less experience with the natural sounds presented, they would most likely not respond as well to it, until they gather the necessary experience with the sound to benefit them as much as it potentially could. However, with as little as 10 hours of practice it is likely that one could observe significant effect on the primary task (Boot & Kramer, 2008).

Internal validity for this experiment was highly considered when designing the test. The test environment was secluded and without auditory or visual distractors that might take attention from the primary task towards something else. The only factor that might have affected the test takers was the room temperature, which was fairly low due to the size of the room and the fact that it was empty of other people. External validity for this study is somewhat less clear. As the data presents a clear answer to the question of reaction time, the conclusions that can be made from the data collected is more subjective. Ideally more and modified testing of a similar procedure would benefit the data. Thus, the conclusions drawn from the results of the experiments become speculations as to what other factors might have influenced the results. Influencers such as motivation, the test-taker being extraverted or introverted, the way recruitment was conducted (on the street with a short two-minute introduction of the task), the way the sample was presented etc. Even so, there is confidence in the gathered data's validity.

Unrelated to the gathered data, the test-takers commented on the effects of the different noises after having tested. Five individuals commented on the calming effects of the natural sounds comparing it to the stressful nature of the pink noise while trying to focus. Whereas 2 individuals who had lower reaction times on the pink noise test said that they were excited by the hectic nature of the pink noise and thus were more motivated to react quickly. There might be some individuals who were motivated by the competitive environment of the 2 samples, and thus were influenced by their own competitive nature. If it is the case that natural sounds stimulate the human attention in a focused way, there might be use for it in concentration aiding tools.

Summary

In summary, the results indicate that natural sounds have a less taxing effect on attention compared to artificial or synthetic sounds when presented in the background whilst performing a primary task. The implications of the findings in the current study open venues of research that could extend the subject further. Attention, sound and our performance on cognitive tasks are all linked. If the learnings of this thesis are adapted to a learning environment or an environment where close and focused concentration is key to productivity, it could benefit those who must operate within those soundscapes.

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