Analysis of Research on the Effects of Auditory Stimulation on Anxiety and Stress in Clinical and General Populations

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Analysis of Research on the Effects of Auditory Stimulation on Anxiety and Stress in Clinical and General Populations

submitted to
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by
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Abstract

The use of auditory stimulation may be a useful method in treating clinical anxiety disorders, as well as aiding in coping with daily stress among general populations. The understanding of how certain forms of auditory stimulation can increase anxiety and stress is also critical so clinicians and the general population can approach decreasing anxiety and stress in the most effective way possible. The following paper will provide a literature review on studies published after the year 2000, analyzing the various impacts of different types of auditory stimulation, including impacts of music-therapy, music and noise at different frequencies, binaural beat stimulation, fear conditioning from negative auditory stimuli, and soothing nature sounds. The review will assess various findings on how these types of auditory stimulation impact clinical anxiety levels, as well as overall anxiety and stress levels in the general population. These observations can influence how clinicians approach treatment methods, and they may help to create a more holistic approach to treatment with added consideration of environmental factors and managing anxiety exacerbated by these stressors. Ultimately, this review aims to provide additional approaches to managing symptoms of anxiety and decreasing stress levels in a more accessible way.
# Contents

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction</td>
<td>4</td>
</tr>
<tr>
<td>Positive effects of music therapy among clinical populations</td>
<td>5</td>
</tr>
<tr>
<td>Impacts of negative noise stimulation among clinical populations</td>
<td>8</td>
</tr>
<tr>
<td>Effects of Binaural Beat Stimulation at different frequencies among</td>
<td>10</td>
</tr>
<tr>
<td>general populations</td>
<td></td>
</tr>
<tr>
<td>Fear conditioning as a result of negative sounds among general</td>
<td>13</td>
</tr>
<tr>
<td>populations</td>
<td></td>
</tr>
<tr>
<td>Impacts of low frequency noise among general populations</td>
<td>16</td>
</tr>
<tr>
<td>Positive effects of music therapy among general populations</td>
<td>17</td>
</tr>
<tr>
<td>Positive effects of nature sounds among general populations</td>
<td>19</td>
</tr>
<tr>
<td>Conclusion</td>
<td>20</td>
</tr>
<tr>
<td>References</td>
<td>22</td>
</tr>
</tbody>
</table>
Introduction

The following literature review will analyze various research findings on the effects of different forms of auditory stimulation on stress and anxiety levels among clinical anxiety patients and general populations. Auditory stimulation as it relates to stress and anxiety will include the following analyses: Positive effects of music therapy among clinical populations, impacts of negative noise stimulation among clinical populations, effects of Binaural Beat Stimulation at different frequencies among general populations, fear conditioning as a result of negative sounds among general populations, impacts of low frequency noise among general populations, positive effects of music therapy among general populations, and positive effects of nature sounds among general populations.

The PsycINFO database was used to locate the articles included in this review. Search terms included “auditory stimulation and anxiety”, “auditory sensitivity and anxiety”, “binaural beats and anxiety”, “music and anxiety”, and “noise and clinical anxiety”. Criteria for articles was narrowed down to peer-reviewed academic articles and articles published after the year 2000. Exclusion criteria included studies published before the year 2000 and those irrelevant to auditory stimulation and anxiety or stress. Articles who obtained research by purposefully killing rodents to obtain evidence were also excluded. Additionally, exclusion criteria extended to those that focused more on auditory sensitivity, rather than auditory stimulation’s impacts, as this tended to produce research on clinical autism populations, rather than on populations with anxiety and stress.

The general findings of this review included that music therapy, especially classical music such as Mozart, yielded reduction in anxiety levels among both clinical and general populations. Binaural beat stimulation was also found to help decrease anxiety levels in the
general population. A study analyzing BBs (Binaural Beats) in the gamma range produced no significant effects, indicating the frequency of BBs is important to anxiety reductions. Listening to nature-based sounds was also found to help produce soothing feelings and lower anxiety levels among general populations. A study analyzing fear conditioning from negative noises found that auditory fear conditioning leads to disengagement with negative auditory stimuli, causing higher anxiety levels when exposed to negative noise among general and clinical populations. Environmental factors were found to play a huge role in this, such as residential areas. Ultimately, it was challenging to find much research on each type of auditory stimulation, especially regarding clinical populations and binaural beat stimulation, so inclusion criteria had to be expanded to include studies that used rodent subjects as well.

**Positive effects of music therapy among clinical populations**

Several studies have indicated that music therapy has positive effects among clinical anxiety populations in reducing overall anxiety levels. This is especially true when combined with auditory beat stimulation (ABS) in the theta frequency range, as a study that analyzed the impacts of sound-based anxiety treatments for patients taking anxiolytics (anti-anxiety medication). The study found that music therapy was more effective in reducing somatic anxiety than pink noise, which was used as a control group, due to its frequency (1/f energy distribution) being similar to silence but controlling for the placebo effect that silence alone can have. The results also revealed that the most effective condition in reducing cognitive state anxiety was music combined with ABS. This significant effect in the combined music and ABS condition was observed more significantly in participants with moderate anxiety. In high anxiety participants, combined music and ABS was more significant in decreasing their anxiety levels than the ABS-alone condition, when compared to those with moderate anxiety, likely indicating
that ABS in the theta frequency may actually increase negative affects in those with high anxiety, due to the irritation the hum of ABS can have on those with higher noise-sensitivity. Combining ABS with music may help to mask the hum from ABS alone, which could be more beneficial for those with high anxiety. The researchers suggested this finding indicates the need for music treatments in high anxiety participants more frequently and for longer durations than needed for moderate anxiety participants (Mallik, 2003).

The positive effects of music therapy in reducing anxiety in clinical anxiety patients was also supported by a study analyzing impacts of multimodal music therapy (MMT) for children with anxiety disorders. Rather than simply listening to music, as in the previous therapy, this method of treatment involved regular therapeutic treatments combined with playing instruments to help children with emotional expression and communication. The results of this study also indicated improvements in anxiety levels for participants, supporting the effectiveness of music therapy in clinical anxiety patients, especially when actively playing music during therapeutic sessions for children. However, the control group, which received treatment as usual, also saw improvements in anxiety, suggesting that music therapy is most effective for clinical anxiety patients when combined with regular therapeutic sessions. The researchers concluded that this method of anxiety treatment could be especially beneficial for children and those who struggle with verbal forms of therapeutic treatment (Goldbeck, 2012).

While research on the effectiveness of music therapy in clinical anxiety patients is limited, several studies have examined these trends in rodents, which can be used as a helpful foundation on which to build for therapeutic interventions in human clinical populations. For instance, one literature review suggested that examining these interventions in rodents can help researchers better examine the underlying biological, pathophysiological mechanisms that are
more challenging to observe in human participants. This review analyzed studies of music interventions on rodents and the impacts on brain structure and neuro-chemistry, behavior, immunology, and physiology. The overall results of these studies indicated that music interventions significantly increased BDNF (Brain-Derived Neurotrophic Factor) levels, which helps increase cognition, memory, and learning. Studies also revealed increases in spatial and auditory learning abilities, improvements in immunity responses, and decreases in anxiety behaviors. Blood pressure and parasympathetic nerve activity were also improved following music interventions, especially in interventions that involved playing classical music (Kühlmann, 2018).

Another study analyzing the impacts of music at different frequencies on spontaneously hypertensive rats (SHR) found significant effects in decreasing systolic blood pressure, specifically when exposed to high-frequency and full-frequency music. Researchers of this study placed male rats in a cage and played Mozart’s Adagio from Divertimento No. 7, K. 205, on repeat for 10 consecutive hours. Once the hypotensive effect was confirmed after being initially exposed to full-frequency music (unfiltered), the rats were separated into three different groups in which they listened to music at different frequencies. The authors of the study concluded that music in the high-frequency range (4k-16k Hz) was significantly greater when compared to lower frequencies in reducing blood-pressure levels. They interpreted these results to mean that dopamine synthesis is stimulated by high-frequency music, which, in turn, may help in regulating several different brain functions (Akiyama, 2010). These results corroborate Kühlmann’s (2018) argument that classical music can improve many biological functions, including reducing blood pressure. Akiyama’s study helps to provide more details into the
importance of the frequency range of music to achieve the most effective results, providing a foundation for potential music therapy treatments in humans with clinical anxiety.

Furthermore, a study that sought to analyze the impacts of background noise on lab animals’ stress levels and overall well-being, found that enrichment programs, such as music therapy treatments, can help to decrease anxiety and stress-related behaviors. While this study particularly observed how background noise negatively impacts rats in a laboratory setting, it can still be beneficial to consider how background noise, such as the radio or the television, can negatively impacts anxiety levels in clinical patients. Consistent with Akiyama’s and Kühlmann’s findings, this study also found that Mozart’s piano sonatas had anxiety-reducing effects on the rats, helping to reverse the anxiety-inducing effects of background noise (Escribano, 2013). These results can be used for future research to analyze similar effects of high-frequency music, especially Mozart’s piano sonatas, in helping human clinical anxiety patients reduce their symptoms or aid in coping with their symptoms as an additional treatment approach.

**Impacts of negative noise stimulation among clinical populations**

In addition to the positive effects auditory stimulation can have on anxiety in clinical populations, such as in music therapy, it is equally important to understand the negative impacts different types of noise stimulation can have on this group to better understand effective treatments and how to manage clinical anxiety. One study analyzed the effects of noise annoyance, which was composed of separate analyses of road traffic, railways, aircraft noise, neighborhood indoor and outdoor noise, and industrial noise, on Depression and Generalized Anxiety Disorder (GAD). As predicted the results found the higher the degree of overall noise annoyance, the more anxiety and depression increased, especially when noise annoyance went
from moderate to extreme. These results were observed to be most significant when the noise came from aircraft, suggesting the significance of where someone lives on their anxiety levels (Beutel, 2016). This study was conducted with participants of at least 35 years of age, providing valuable insight into how noise annoyance might become a larger contributor to increased anxiety levels as age increases. More research on younger populations is needed to support this hypothesis; however, this study’s results can contribute to clinicians’ understandings of the major negative impacts environmental noise exposure can have on patients with anxiety, leading to a more holistic approach to treatment.

One literature review analyzed multiple studies on the connections between GAD and electromyographic (EMG) recordings when participants were introduced to loud noises. The results revealed GAD patients took a significantly longer time for their EMGs and blood pressure to return to their baseline after the exposure to a loud noise, when compared with a non-clinical control group and a group of patients with schizophrenia. The author suggests that this is likely because GAD patients prolong their vagal blockades, which are unpleasant symptoms that occur when the vagal is stimulated by triggers like stress or pain, because of the sudden uncontrollable surges in worry and overuse of some rostral neural pathways (responsible for the body’s internal states and its regulation of those states) they experience (Malmo, 2002). This research suggests loud noises have a particularly negative effect on the anxiety levels of patients with GAD and the time it takes these patients to return to their baseline states. When considering the results in Beutel’s study, these findings indicate exacerbation of anxiety clinical patients experience when living in areas of high noise pollution. When clinicians consider treatment methods for GAD patients, considering the environmental factors that contribute to their difficulties in managing their anxiety levels is crucial. As Escribano’s study indicated, music therapies may help as an
ANALYSIS OF RESEARCH ON THE EFFECTS OF AUDITORY STIMULATION ON ANXIETY AND STRESS IN CLINICAL AND GENERAL POPULATIONS

additional enrichment intervention in helping patients manage their anxiety if they are exposed to lots of noise pollution in their daily lives.

A study that challenged the argument that a city’s urbanization level (the mean number of addresses per kilometer squared within a 1 kilometer radius) was a main factor in the presence and severity of depressive and anxiety disorders, supported these findings and revealed that a neighborhood’s socioeconomic, physical, and social characteristics were more significantly associated with the prevalence of these disorders. The study found environmental stressors like neighborhood violence, low social cohesion and support among neighbors, and overcrowding have significant psychological impacts, for clinical populations. The results also indicated that those with anxiety or depression tend to live in lower socioeconomic status neighborhoods, with higher amounts of air pollution, traffic noise, and water, as well as lower social neighborhood cohesion. The authors of this study concluded that these findings suggest a high level of association between neighborhood characteristics and anxiety and depression, both in regards to clinical diagnoses and the general presence of negative moods and stress (Generaal, 2018). As the previous studies revealed, environmental factors, such as neighborhood characteristics, are significant influences on the anxiety levels of clinical patients. This further suggests the need for a more holistic approach to developing treatment programs for clinical anxiety, to include sound-based interventions like music therapy, especially for individuals consistently surrounded by negative auditory stimuli.

Effects of Binaural Beat Stimulation at different frequencies among general populations

Understanding the impacts of various forms of auditory simulation on non-clinical populations is also critical for both clinicians and the general public. Many individuals face significant barriers in obtaining clinical diagnoses, while others may suffer from chronic stress
without meeting the criteria for a clinical diagnosis. Understanding the impacts of noise pollution, as well as potential sound-based therapies, can help individuals learn how to manage their general stress levels and provide a less-expensive way to manage daily anxiety levels of those unable to obtain comprehensive clinical treatment. The impacts of binaural beat stimulation (BBS) has been recently studied in relation to its impacts on anxiety levels. One such study observed its effects on women’s anxiety levels before undergoing an elective cesarean section. The researchers divided participants into three groups, one of which was exposed to binaural music for 12 minutes before the surgery. The results revealed greater changes in anxiety levels among the binaural music group when compared to the normal music and control groups. The authors of the study suggested these findings may provide a more time- and cost-effective way of reducing preoperative anxiety levels, suggesting that while music is effective in reducing stress, binaural beat stimulation has more significant impacts in reducing stress in the general population (Parodi, 2020).

A literature review analyzing several studies’ findings on the impacts of auditory beat stimulation (ABS) on cognition, mood, and anxiety, found that ABS was most significant in reducing anxiety levels when conducted with binaural beat frequencies and that certain frequency ranges are more effective than others. For instance, participants who received binaural beat stimulation in the delta frequency range for 30 minutes each day for 60 days showed significantly decreased levels of overall state and trait anxiety (Chaieb, 2015). These results emphasize the importance of considering the use of binaural beats over monaural beats in reducing general anxiety levels, as well as what frequency range will be most effective. As this literature review observed, binaural beats in the delta frequency range have been shown to
decrease both state and trait anxiety levels, which is insightful into what the most effective sound-based therapies will be.

Another study provided additional insights into impacts of various BB frequencies on anxiety levels, with a specific analysis on BBs in the gamma frequency range (40 Hz). This study revealed no significant improvements in anxiety or attention levels with BBs in the gamma frequency range, suggesting the importance of considering which frequency ranges to utilize when attempting BBS as a sound-based therapy (Leistiko, 2023). While it is possible that confounding variables may have impacted these results, as the study was conducted remotely during COVID-19, it provides a foundation on which future research can build in analyzing which BB frequency ranges are most effective in reducing general anxiety levels.

Yet another study analyzed the effects of binaural ABS in the theta frequency range (6 Hz) on cognitive fluency and fear induction. The results of the study revealed a significant increase in participants’ feelings of fear when compared with the control group, suggesting that BBs in the theta frequency can cause mild states of fear, despite it improving other negative moods like anger and depression. The authors of this study predicted this is likely because theta rhythms are heavily associated with the amygdala and its processing of fear, and long-term potentiation, which is the persistent increase in synaptic strength that typically follows the high-frequency stimulation of a synapse, has been observed during auditory fear conditioning in the synapses between the primary auditory cortex and the amygdala (Pluck, 2019). These results emphasize the importance of considering the frequency range of BBs when utilizing sound-based treatments. While BBs in the theta frequency may be helpful in achieving other goals, such as in anger-management interventions or in helping to treat depression, it can have the opposite effect on individuals with high anxiety.
Another study observed impacts of ABS on the EEG (electroencephalogram) recordings of epilepsy patients before undergoing surgery. The researchers exposed patients to various frequencies of both monaural and binaural beats, which included frequencies in the theta (5 Hz), alpha (10 Hz), low gamma (40 Hz), and high gamma (80 Hz) ranges. EEG recordings specifically observed changes in the mediotemporal, temporo-lateral, anterior temporo-basal, posterior temporo-basal, and surface areas of the temporal lobe. These areas help to manage emotions, process sensory information, store and retrieve memories, and understand language. Located within the temporal lobe is the amygdala, which is responsible for experiencing and processing emotions, as well as an individual’s fight-or-flight response, which is heavily associated with the level of anxiety an individual experiences. The results of this study found that significant decreases were found in EEG power and synchronization when exposed to binaural 80-Hz stimulation (the high-gamma frequency range), but no significant changes were observed when exposed to monaural 80-Hz stimulation (Becher, 2015). These findings suggest that the most significant reductions in anxiety can result from high frequency BBs, such as frequencies in the 80 Hz range. Consistent with the results of Akiyama et. al.’s study on clinical rat populations, sound-therapy interventions are most useful when high-frequencies are used, both for music therapy and BBS.

**Fear conditioning as a result of negative sounds among general populations**

One study analyzed the ways in which negative sounds can condition fear into individuals with high trait anxiety, so they have a negative attentional bias towards negative stimuli in natural sounds. The study categorized negative sounds as those of a woman screaming, thunder, humming sounds, and a tiger roaring; neutral sounds were categorized as those of water sounds, whistling, grasshoppers singing, and cows mooing. The participants were presented with
ANALYSIS OF RESEARCH ON THE EFFECTS OF AUDITORY STIMULATION ON ANXIETY AND STRESS IN CLINICAL AND GENERAL POPULATIONS

auditory aversive cues, followed by target stimuli. If the target stimulus matched the side of the cue, the cue was categorized as valid. If, for example, the target stimulus was neutral and the cue was negative, the cue was categorized as invalid. The differences of reaction times between targets primed by negative cues and neutral cues revealed attentional bias, while the differences of reaction times between negative-cued and neutral-cued invalid trials displayed the presence of disengagement biases. When compared with individuals with low trait anxiety, high trait anxiety participants had slower reaction times after being exposed to negative cues than when exposed to neutral cues in invalid trials, indicating their ability to disengage from negative cues was impaired. The results also revealed that disengagement bias increased as trait anxiety increased, reflecting the challenge those with high levels of trait anxiety have in disengaging from negative sounds within natural settings. The authors of this study suggested that treatment for individuals with high trait anxiety may be more beneficial when focused more on teaching patients how to disengage from negative sound stimuli, rather than engage with neutral stimuli (Wang, 2019). This suggests that sound-based therapies, such as the use of high-frequency BBS, may be helpful in providing a space for these individuals to disengage from the negative noise stimuli surrounding them, while simultaneously actively helping to decrease anxiety levels with BBs or music therapy.

Another study analyzed how deviant auditory stimuli, along with maternal trait anxiety, can impact neonatal brain responses and their probabilities of developing an anxiety or other psychiatric disorder later in life. This study recruited pregnant women within their second or third trimester and, after childbirth, measured the brain activity of their neonates using fMRIs. The researchers played white noise before beginning the tests, which started with exposure to background scanner noise, and transitioned to exposure to 24 “oddball” auditory stimuli, with the
test ending after the last oddball noise for the majority of infants, and ending after an additional session of listening to background scanner noise for the other eight infants. The results showed a robust response to the deviant auditory stimuli in the brains of the neonates, suggesting that exposure to negative noise stimuli near birth can impact neonatal neural pathways, increasing the risk of developing anxiety and other psychiatric illnesses later in life. Additionally, when mothers were shown to have higher trait anxiety, their infants tended to have higher amounts of neural responses in those parts of the brain responsible for deviant stimuli responses, which has been shown in previous studies to be correlated with higher levels of attention to threat or errors in the environment. This reveals strong connections between being exposed to high levels of anxiety and deviant auditory stimuli as a neonate, and an increased likelihood of developing anxiety disorders later in life (Sylvester, 2021). In addition to using this information for potential anxiety treatments and stress-reducing interventions, it can also be implemented into prenatal care programs. The results of this study support previous studies’ findings on the negative impacts environmental stressors like noise pollution can have on stress levels, especially for individuals with high levels of anxiety. It further emphasizes the importance of sound-based therapies for pregnant women in helping them manage and reduce overall anxiety levels, as well as providing more positive auditory stimulation for neonates, especially if often surrounded by deviant auditory stimulation.

In another study, researchers analyzed fear conditioning of multiple sensory modalities to observe how taking in fear-inducing information with one sensory modality creates similar associations with that stimulus in other senses, also known as crossmodal generalization. The results of the study found feelings of fear acquired from a visual stimulus creates associations with auditory stimuli that match the visual stimuli. It was also more difficult for participants to
break the fear associations made from auditory stimuli that connected with congruent visual stimuli. The authors of this study concluded these findings support the idea of considering use of crossmodal generalization in conditioning or eliminating fears (Gerdes, 2020). This implies the significance of using multiple modalities, the most significant being the use of auditory stimuli, in eliminating fears. This is valuable information for clinicians looking to conduct exposure therapy or anxiety treatments for patients. It is also important for the general population to understand how certain stimuli in their environments can prime fear associations in other sensory modalities, so they can better understand themselves and how to reduce anxiety levels caused by environmental stressors.

A literature review analyzing the interactions and connections of neurons between limbic and auditory systems helped to explain the biological aspects of why auditory stimulation can impact anxiety levels. The review found that sound stimulation can affect the functioning of regions in the limbic system, such as the hippocampus and the amygdala, which are associated with the body’s internal states and emotional processing. The review looked at both the impacts of noise and tinnitus, which is perceived phantom sound, on these regions of the brain, and it found that in addition to impairing memory and cognitive functioning, they can also result in increased anxiety and emotional stress (Kraus, 2012). Understanding the neuronal pathways of auditory stimulation can help to advance knowledge of how to treat anxiety and chronic stress, especially for individuals who are persistently surrounded by auditory stressors in their daily environments.

**Impacts of low frequency noise among general populations**

One study analyzed the effects of exposure to moderate levels of low-frequency noise, such as the noise of an air conditioner or ventilator, while performing mentally challenging work,
on levels of reported stress, annoyance, and cortisol secretions. The researchers of this study also analyzed the influence participants’ levels of noise sensitivity had on their cortisol response, in relation to the task. Results of the study found that participants who had higher sensitivity levels to noise in general and to low-frequency noise had the highest rates of impaired performance under exposure of low-frequency noise. Additionally, when the most demanding tasks were performed under low-frequency noise, researchers observed increased levels of cortisol and longer response times among participants (Waye, 2002). These results support the idea that frequency of noise matters when considering sound-therapy for reducing anxiety and stress levels, even for noise outside the category of BBS. These results are consistent with the findings of the study done by Akiyama et. al. (2010), which found that high-frequency noise was most beneficial in reducing anxiety levels. These results are also similar to those in the study done by Pluck et. al. (2019), in which BBs in the theta frequency was shown to induce fear in participants. Theta frequencies are within a low-frequency range, consistent with these study’s findings that low frequency noise in general can have adverse effects and increase cortisol levels and performance impairment. Ultimately, this is important to understand so people are aware of how the environment surrounding them may impact their psychological well-being, and so people consider the necessity of choosing higher-frequency noises for sound-therapy treatments in reducing anxiety and stress levels.

**Positive effects of music therapy among general populations**

In addition to understanding how certain types of auditory stimulation can negatively impact individuals’ psychological well-being and increase their anxiety levels, it is also important to understand how other types of auditory stimulation can improve anxiety levels and stress, especially for those who lack resources to completely change their environments or obtain
comprehensive treatments for chronic stress. One method these individuals can use to cope with daily stress and anxiety is the use of music-therapy. One study analyzed the impacts of the use of music therapy on women before undergoing gynecological surgery. The researchers divided participants into three groups: treatment as usual (control), music with headphones, and headphones without music. After recording pre- and post-operative anxiety, researchers observed improvements in anxiety for all groups post-operation; however, significantly lower anxiety levels were seen in the music with headphones group, while the lowest rate of change in anxiety levels was seen in the control group. The headphones group also displayed the greatest change in anxiety levels postoperative, possibly due to this group having higher preoperative anxiety levels (Johnson, 2012). While the study failed to control for the amount of time participants had to listen to music, it still provides valuable insight into potential treatments that can be implemented within surgical procedures to help reduce patients’ preoperative anxiety levels. It also supports the concept of using music-therapy as a treatment for chronic stress and anxiety.

Another study analyzing the use of music-therapy for military veterans found similar results. The study revealed that the participants often turned to music as a way to regulate their emotions, likely because it provides a safe way for them to express and experience distressed emotions. Veterans also tended to use music as a way to disengage from negative emotions or states of mind, or as a way to vent out suppressed emotions. The results indicated that veterans who listened to music to cope with distressing emotions tended to have overall better self-reported health (Zoteyeva, 2016). This supports the use of music therapy as a way to not only decrease anxiety levels, but also to improve overall states of well-being, which can also indirectly improve anxiety levels. Additionally, this study provides insight into why the use of music-therapy as a sound-based treatment can specifically be more helpful for certain people,
such as for those who tend to suppress emotions and need the outlet music provides to express
and experience them.

**Positive effects of nature sounds among general populations**

In addition to music-therapy, the use of nature sounds as a sound-based therapy can be
beneficial in reducing anxiety and stress. One study analyzed how nature-based sounds could be
used to improve stress, anxiety, and agitation in patients under mechanical ventilator support.
The results found that patients who received the nature-based sound treatment had significantly
improved anxiety and agitation levels, as well as lower levels of systolic and diastolic blood
pressure. These findings are especially significant because it provides a potential method for
managing dangerous physiological reactions that result from high anxiety levels in these patients
undergoing ventilator support (Saadatmand, 2013). These results support the use of auditory
stimulation, specifically soothing sounds from nature, in reducing anxiety and stress in the
general population. Clinicians can utilize this knowledge to help treat chronic stress in
individuals or to reduce anxiety levels while under physiological care, such as prior to surgery or
when undergoing ventilator support.

Similarly, another study found that using soothing nature images in conjunction with
soothing nature sounds can help to improve anxiety levels and overall states of well-being.
Participants were sorted into either the image-only, sound-only, or combined group, and their
depressive mood states, positive and negative affects, and serenity affects were measured. The
results found that all groups experienced decreased levels of depressive mood states and positive
and negative affects, as well as overall increases in serenity affects. Participants with higher
anxiety and depressive baselines experienced greater improvements overall, suggesting the major
benefits use of this method as a sound-based treatment for anxiety in the general population can
have (Witten, 2022). These results are also consistent with the findings in the study done by Gerdes et. al., indicating crossmodal generalization as having the most significant impacts on anxiety levels. This study, however, focused more on the positive impacts of using multiple sensory modalities to decrease anxiety levels. This is an important insight because it suggests that ABS will be most effective as a treatment method to improve anxiety and stress when combined with soothing images.

**Conclusion**

Overall, the current literature suggests some types of auditory stimulation can increase anxiety and stress levels, while other types can serve as alternative forms of treatment to aid in reducing anxiety and stress levels. Noises that have become associated with negative outcomes, such as loud crashing noises, individuals will be more prone to experiencing increased anxiety levels upon hearing such noises, due to a fear conditioning effect. Additionally, socioeconomic factors play a major role in this, as living in environments with more noise pollution, such as living next to a freeway, can result in individuals being predisposed to higher baselines of anxiety. However, auditory stimulation can also be used as an alternative treatment method, especially for those with limited resources who may not have the ability to access more formal types of treatment. For instance, music therapy, especially higher frequency music like Mozart’s compositions, can be used to decrease overall anxiety levels in individuals. Similar effects can be observed when listening to nature-based sounds. Binaural beat stimulation has also become a recent subject of research. Studies have indicated that BBs in the theta frequency range seem to decrease overall anxiety levels in individuals and can also serve as a form of auditory-based therapy. Some research, such as a study analyzing BBs in the gamma frequency range, have shown no significant impact on anxiety levels, indicating that the frequency of BBs is important
in treatment. Furthermore, when comparing studies analyzing clinical anxiety populations versus general populations, similar effects have been depicted, indicating that auditory-based therapy can help clinical patients in managing their symptoms, as well as general populations in reducing overall feelings of stress. The same is observed in negative auditory stimulation: general populations are just as susceptible to fear conditioning as clinical anxiety patients; however, the impacts of fear conditioning on clinical anxiety patients is more commonly more significant and longer-lasting.

Future research could study more on the different types of frequencies of binaural beat stimulation, and how those might adversely affect anxiety levels. While the majority of studies indicated positive effects from binaural beats in the theta frequency range, other research has shown BBs in different frequencies may have no effect, such as those in the gamma range. This indicates that additional research is needed to better understand the differences in various frequencies on anxiety levels. Additional research is also needed for clinical anxiety patients, in particular. While there is a generous amount of literature on anxiety levels of the general population and auditory stimulation, more is needed on clinical anxiety patients to propose alternative modes of treatment in managing symptoms. There are many barriers individuals with psychological illnesses face, including access to treatment resources. Further research into types of treatment these individuals may be better able to access can have significant outcomes.
ANALYSIS OF RESEARCH ON THE EFFECTS OF AUDITORY STIMULATION ON ANXIETY AND STRESS IN CLINICAL AND GENERAL POPULATIONS

References


ANALYSIS OF RESEARCH ON THE EFFECTS OF AUDITORY STIMULATION ON ANXIETY AND STRESS IN CLINICAL AND GENERAL POPULATIONS


