Brainwave Entrainment to Improve Problem-solving skills in People with the Neurodevelopmental Disorder ADHD

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Abstract

The purpose of this study is to examine whether brainwave entrainment has an effect on problem-solving skills in people with an attention-deficit/hyperactivity disorder (ADHD). A predominant symptom of ADHD is inattention. ADHD is associated with symptoms such as difficulty sustaining attention during tasks, easily distracted, and seeming to avoid tasks that require sustained mental effort. The first-line treatment for ADHD is through the use of psychostimulant drugs, but some may experience negative side-effects. Therefore, there is a need for an alternative treatment that is less invasive. The present study hypothesizes that brainwave entrainment will put participants in a productive brainwave frequency that will allow them to perform better at problem-solving tasks. Binaural beats with a gamma-frequency (50HZ) were used to acquire brainwave entrainment. Four healthy subjects with ADHD participated in a single-subject ABA reversal research design study (three phases). In the first phase, participants listen to rain noise with no binaural beats for 5-minutes, then given 5-more-minutes to complete a puzzle (while still listening). In phase two, participants listened to rain noise with binaural beats for 5-minutes, then given 5-more-minutes to complete the puzzle. Lastly, in phase three, the first phase was repeated. The results suggest that brainwave entrainment had a moderate effect on the participant's problem-solving skills. Moreover, two participants performed very well while under brainwave entrainment, the other two showed some effect, but not significant enough. A future direction for this study is to control for daily mood, adding a fourth phase (ABAB), and a larger sample size.

Keywords: brainwave entrainment, problem-solving skills, attention-deficit/hyperactivity disorder (ADHD), neurodevelopmental disorders, inattention, psychostimulants, binaural beats, gamma frequency

Introduction

The purpose of this study is to examine whether brainwave entrainment has an effect on problem-solving skills in people with an attention-deficit/hyperactivity disorder (ADHD). ADHD is a commonly diagnosed mental disorder of the neurodevelopmental type. According to the Diagnostic and Statistical Manual of Mental Disorders – 5th edition (2013) (DSM-5) ADHD is a mental disorder that has three subtypes: inattentive, hyperactive-impulsive, or a combination of the two. In this present study, we focused on the inattentive subtype of ADHD. The DSM-5 describes ADHD (inattentive subtype) with characteristics such as lack of attention, regularly does not follow through on instructions, gets distracted very easily, and commonly forgets normal daily activities (Pettersson, Söderström, Edlund-Söderström, & Nilsson, 2017). In addition, the DSM-5TM has three further components that must be met in order to be diagnosed with ADHD. These components are: inattention that is interfering with normal functioning or development, and these symptoms must be observed in two or more settings, and lastly, they must be directly impacting their social, academic, or their occupational functioning (Al-Moghamsi & Aljohani, 2018).

A predominant symptom of the inattentive subtype of ADHD is inattention. Some common behavior that is associated with this type of ADHD is difficulty sustaining attention during tasks and easily being distracted by extraneous stimuli in their environment. Most people with ADHD avoid tasks that require sustained mental effort and have problems completing problem-solving tasks such a homework, studying for an exam, or other problem-solving tasks that require full attention. Moreover, ADHD affects vital settings of their life (social, school, work, etc.) (Wiersema & Godefroid, 2018). A research study by Pila-Nemutandani & Meyer (2016) gathered a total of 90 children, half of them with ADHD, and provided a problem-solving task. Those with ADHD showed poor performance in the problem-solving task. The conclusion of the study noted that participants with ADHD had poor organizational and planning skills that explained their lack of problem-solving skills. Another reason the researcher believes people with ADHD lack problem-solving is because of their difficulties with executive functioning and complex reasoning (Elisa &

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Parris, 2015). One way that a researcher described ADHD, in regards to completing a specific task is by comparing them to a sleepy driver: ADHD is like driving while you're very sleepy and roll down the windows in hopes to get some fresh air and wake up, only to still be sleepy and unable to wake yourself up (Trejis, 2000). ADHD impacts the execute functions of a person's brain, including problem-solving skills, which is considered an executive function. (Pila-Nemutandani, & Meyer, 2016).

People with ADHD are notoriously known for "not paying attention" and being easily distracted while completing problem-solving tasks, this can lead them to poor problem-solving skills and low academic performance. A study that illustrates how students with ADHD are more susceptible to certain tasks than people without it was conducted by Weyandt, Oster, Gudmundsdottir, DuPaul, and Anastopoulos (2017), in which researcher recruited 436 first-year college students with ADHD and had them both perform working memory and performance tasks. Weyandt et al. (2017) concluded that students with ADHD had more academic difficulties compared to students that did not have ADHD in continuous problem performance tasks. Students with ADHD that were taking psychostimulants had a slight improvement over those that were not under medication; however, the improvement was not on all neuropsychological tasks (Weyandt, Oster, Gudmundsdottir, DuPaul, & Anastopoulos, 2017)

Although ADHD is vastly diagnosed in most children and adolescents, it also affects a great number of the adult population (Gould, Porter, Lyneham, & Hudson, 2018). About sixty-percent of adults continue to experience ADHD symptoms after childhood (Elisa & Parris 2015). ADHD has an epidemiological prevalence of about 5%, which makes it one of the most diagnosed mental disorders (Banaschewski et al., 2017). The most common first-line treatment for ADHD is through a psychostimulant intervention plan. Psychostimulants, such as Ritalin and Adderall, are among the most prescribed drugs that have shown to be effective in treating ADHD symptoms. Psychostimulants such as Ritalin and Adderall can be safe to use, but only when used as prescribed. Unfortunately, many of these prescription drugs are abused and even given or sold, by the patient, to other people that do not have ADHD (Prescription Stimulants, 2011). In contrast, in some cases, they have short term positive effects and/or severe side effects (Meppelink, de Bruin, & Bögels, 2016). Despite the great possibility of adverse side effects, most people diagnosed with ADHD are routinely prescribed psychostimulant drugs to ameliorate their symptoms. Taking psychostimulants can substantially increase their mortality rate – mortality rates are high for people taking psychostimulant medications for ADHD (Quinn, et.al., 2017).

Even though psychostimulant medication treatments are effective in treating the main symptoms of ADHD, these benefits might come at a high cost (Pettersson et al., 2017). On the one hand, most people taking these drugs have reported positive improvements, such as better; school/work performance, social interactions with peers, and control of their ADHD symptoms (Lynn, 2007). On the other hand, some have reported that the medication only ameliorated some of the symptoms but experienced severe unwanted negative side-effects. For instance, a well-known negative side-effect produced from taking psychostimulant drugs is a "zombie-like" feeling and/or adverse interaction with alcohol or other drugs, resulting in serious toxic side-effects (Barkla, McArdle, & Newbury-Birch, 2015). Other side effects include feeling constantly fatigued, not being able to sleep through the night, tremors, and depression. Despite this concerning information, according to Health Canada, psychostimulants like Ritalin have seen a dramatic 537 percent increase of use for people with ADHD (Trejis, 2000). Not only may they have negative side effects, but they are highly addictive. Ritalin, for example, is prescribed to millions of people with ADHD. Ritalin, like other prescription stimulants, makes most people feel energized and alert, just as what cocaine and methamphetamine (meth) does to people. The effects are similar because they are both (cocaine and Ritalin) in the same class of drugs. Ritalin (prescribed stimulant) has similar effects on the brain as cocaine does (see Figure 1). In figure 1, you are able to observe how cocaine (brain scan on top) lights up in similar areas as the brain scan below when people took methylphenidate (Ritalin), (Prescription Stimulants, 2011).

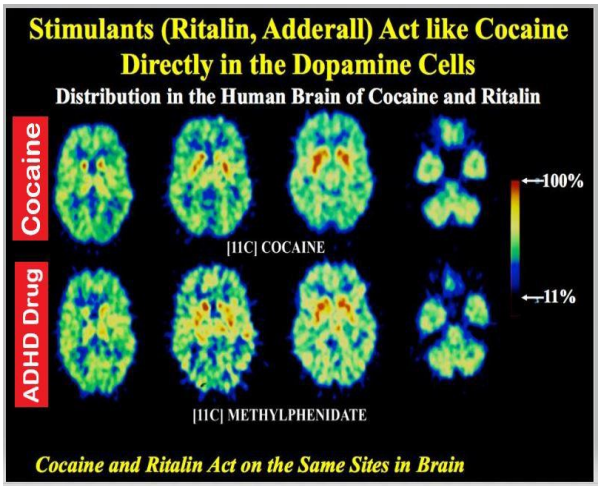

Figure 1. *Brain scans: showing effects of cocaine on brain (upper brain scan) and effects of methylphenidate (Ritalin) on brain (lower scan)* (after Volkow, et al. (BNL))

Other serious negative side-effects reported have been premature deaths and serious cardiovascular problems (Lynn, 2007). These negative side-effects may encourage people with ADHD to discontinue their prescribed medication treatment and instead suffer from their symptoms. If ADHD symptoms are left untreated, it may lead to low academic grades (children & adolescents), and problems at the workplace (adults) (Banaschewski, et. al., 2017).

Further research into alternative treatments is important. A possible alternative to ADHD medication is brainwave entrainment. Brainwave entrainment is a method that stimulates the brain into entering a desired specific brainwave frequency and state of mind (see Figure 2). Even though brainwave entrainment has been used since the late 1800s, many researchers are unaware of it (Huang & Charyton, 2008). Brainwave entrainment can be acquired through different methods, however, in the present study, we acquired brainwave entrainment with the use of binaural beats. Binaural beats are auditory sound waves, normally not consciously noticeable to the person hearing them, but easily captured by the brain. Binaural beats play a significant role in increasing neural synchronization (Colzato, Steenbergen, & Sellaro, 2017). See figure 2, for a visual description of how binaural beats are used to acquire brainwave entrainment. Binaural beats are administered through a set of headphones, two different frequencies are sent to each ear (150Hz left ear & 100Hz right ear), the difference between those two frequencies is then processed by the brain as a new frequency. The brain then tunes into this new frequency and in a way "takes-over," at that point, the subject has entered into the desired mind state (one of the 5-types of brainwaves) thus, brainwave entrainment has been acquired (Wahbeh, Calabrese, Zwickey, & Zajdel, 2007).

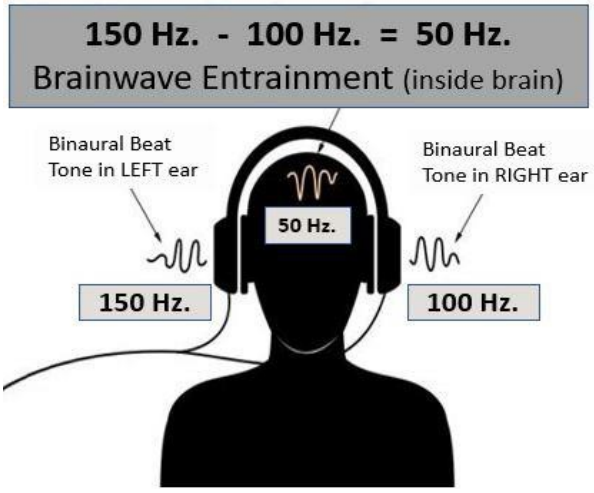

Figure 2. *How brainwave entrainment is acquired through the use of binaural beats*
(after httpts://wakeup-world.com)

Past research has discovered that people with ADHD use theta brainwaves substantially more than those that do not have ADHD. As seen in Figure 3, "theta" brainwaves are associated with sleeping, which may lead people to feel drowsy resulting in feeling uninterested in completing any type of tasks (Trejis, 2000). A study into brainwaves by the Mission Psychological Consultants (1996) revealed that a treatment called Neurofeedback, where a person with ADHD learned how to manipulate certain brainwaves and control a computer game without the use of a keyboard or joystick, only by changing his brainwaves (measured with electrodes attached to the scalp), was successful at significantly reducing their inattentive behavior symptom (Trejis, 2000). This study is a good example of how brainwave patterns have a significant impact on people with ADHD.

When the brain goes into a specific wave pattern that has a specific targeted effect, like the gamma-frequency (high brain activity), it in a way "takes over" the brain. This will influence your brainwaves into a desired mind state: super focused mindset (gamma), normal alert consciousness (beta), relaxed (alpha), light sleep (theta), or deep sleep (delta) (Colzato, Steenbergen, & Sellaro, 2017). Figure 3 describes the various different brainwave frequencies and their effects once under brainwave entrainment. The gamma-frequency is the highest frequency in human brainwaves and can be achieved at 30Hz and above. This frequency has been used for centuries to get super focused and go into deep spiritual trances. The gamma-frequency is known to evoke peak brain performance, this high brain activity works very well while performing problem-solving tasks. At the other side of the brainwave's spectrum is delta waves (1-3Hz), which are considered the lowest brainwaves to humans and good for deep sleep (Colzato, Steenbergen, & Sellaro, 2017).

Another study used to show the impact that binaural beats (brainwave entrainment) have on people with ADHD is a study by Nacim et al. (2008). Nacim et. al. (2008) recruited two groups of children: one group of children with ADHD, and the other group without ADHD. The researchers had the children take an IQ posttest while exposing them to musical binaural beats that resulted in brainwave entrainment. After analyzing the results of the IQ posttests, researchers discovered that both groups showed an improvement in their IQ performance while under brainwave entrainment. In Nacim et al. (2008) study, brainwave entrainment has shown promising results in treating some of the symptoms of ADHD. This is yet another great empirical study in which it demonstrates that brainwave entrainment can be of potential benefit to students with ADHD who are currently academically struggling.

Figure 3. *A description of the 5-types of brainwaves*
(after http://www.practicingmindfulness.com)

Another study, used in a slightly different way, used binaural beats (theta-frequency at 6Hz) to treat chronic pain in people (Zampi, Fore, Jerome, & Durham, 2015). A study by Zampi et al. (2015), recruited 36 subjects with different types of chronic pain and had them listen to theta binaural beats, while researchers measured any changes in the severity of pain the subjects perceived to be in. The results indicated that there was a large main effect for reducing the subject's perceived pain severity with the use of binaural beats (Zampi et al., 2015). Although the participants did not have ADHD, brainwave entrainment showed to be effective.

Each of these research studies demonstrates that brainwave entrainment is potentially effective at treating different symptoms in people with and without ADHD. Furthermore, these studies provide empirical evidence that people with ADHD lack problem-solving skills and show that brainwave entrainment can potentially be a treatment plan for such subjects.

Research Question/Significance

The present research aims to discover if brainwave entrainment has an effect on problem-solving skills in people with ADHD. Brainwave entrainment can either be used as an addition to an existing psychostimulant treatment or as a stand-alone alternative thus providing ADHD subjects with treatment options. Brainwave entrainment may possibly be used at times when the extra focus is needed to successfully complete a difficult problem-solving task. For instance, while studying for an exam, doing homework, or performing any other problem-solving activity that is known to be particularly challenging to the individual. We are asking the question, "can brainwave entrainment improve problem-solving skills in people with ADHD?" We are hypothesizing that brainwave entrainment with a gamma-frequency of 50Hz. will improve problem-solving skills in people with ADHD. Positive findings of this research can provide a non-invasive treatment plan option for people with ADHD. In any case, if this study produces significant results, it may improve the overall quality of life of the individual.

Methods

Participants

A total of four participants with ADHD, two males and two females in the age range of 14-62 years old were recruited from Stanislaus County, a county with a medium sized population located in Northern California.

Design

A single-subject ABA reversal research design was used. The problem-solving task was generated using a one-hundred-piece puzzle task. Three different puzzles, of similar difficulty, were used for each phase. Brainwave entrainment was acquired with the use of binaural beats masked by rain noise, listened through a set of over-the-ear headphones. The independent variable was manipulated by the addition or removal of gamma-frequency (50Hz) binaural beats. The study consisted of three phases – no treatment (A), treatment (B), and no treatment (A). The dependent variable was the completion of the problem-solving task (puzzle), measured by the number of puzzle pieces the participant was able to connect in a five-minute time period.

Materials

Materials used in the study included: three one-hundred-piece puzzles (similar illustration & difficulty), a smartphone with a binaural beats app (Pure Binaural Beats), a timer, and over-the-ear headphones.

Procedure

Participants were administered a consent form, allowed time to read it, and asked to sign it. Once participants indicated consent, they were given instructions on how to proceed through the study and given a copy of the consent form for their records. Participants that continued with the study were requested to complete all three phases of the study. All four participants were tested individually. In the first

phase, the participant listened to rain noise for five minutes, without binaural beats. While listening to rain noise, participants were instructed to connect as many puzzle pieces as possible for an additional five minutes (see Figure 4). The number of puzzle pieces was recorded, but not told to the participant. In the second phase, the participant repeated the procedure as in Phase one, with the exception that this time the rain noise had binaural beats with a gamma-frequency of 50Hz., resulting in brainwave entrainment. In the last phase, the procedure was reversed to the same procedure as in phase one. In each of the three phases, the participant completed a different puzzle to avoid error through learned knowledge. At the end of the last session, participants were handed a debriefing form.

Figure 4. *Visual model of a session*
(taken by author)

Results

The results suggest that brainwave entrainment had a moderate effect on the participant's problem-solving skills. Moreover, two participants performed very well while under brainwave entrainment and showed significant results (see Figures 5, 6, 7, & 8). However, the other two participants showed very minimal effect, but not significant enough.

Discussion

The aim of this study was to investigate if brainwave entrainment could help people with ADHD perform better during problem-solving tasks. Further analysis of the results indicated that the participants that obtained positive results from brainwave entrainment reported feeling more focused. Although data suggests that there was an increase in the participant's problem-solving skills while exposed to brainwave entrainment, since it was only significant in fifty-percent of the subjects, it is not significant enough to reach a conclusion that brainwave entrainment was the direct cause. All four participants claimed to be able to hear the binaural beats through the rain noise. To address that, an auditory inspection was performed by people without ADHD in which it was determined that the binaural beats sound was not able to be heard through the rain noise. It may be possible that people with ADHD are more susceptible to these audible waves and can hear the faint sound of the binaural beats. This is interesting because it shows some of the great differences that people with ADHD experience. A future direction that this study can possibly take is to be able to control for daily mood, add an extra treatment phase, and obtain a larger sample. The findings of the effects of brainwave entrainment on people with ADHD may be particularly of interest to clinicians that have patients with ADHD who have experienced severe negative side-effect to psychostimulants.

Future work

There are many potential works that could develop out of this study. For instance, it is possible to include subjects that do not have ADHD to the research study and analyze their effects on such brainwaves. In regards to the subjects with ADHD, the use of brainwave entrainment should be administered to both: subjects that are taking psychostimulants, and those that are not, and compare the results. Our study used a single subject ABA reversal design in order to use the same subject as their own control. However, follow-up studies should potentially use a single subject ABAB reversal design (extra treatment phase) to have more data and use a larger sample size. Additionally, there is the possibility of exploring other potential methods to acquire brainwave entrainment, including other frequencies. This would expand the current limits of only one frequency (gamma) and possibly discover benefits that the other brainwaves can offer. Each of these potential future studies would expand the capabilities and thus provide greater value and stronger research.

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Data Charts

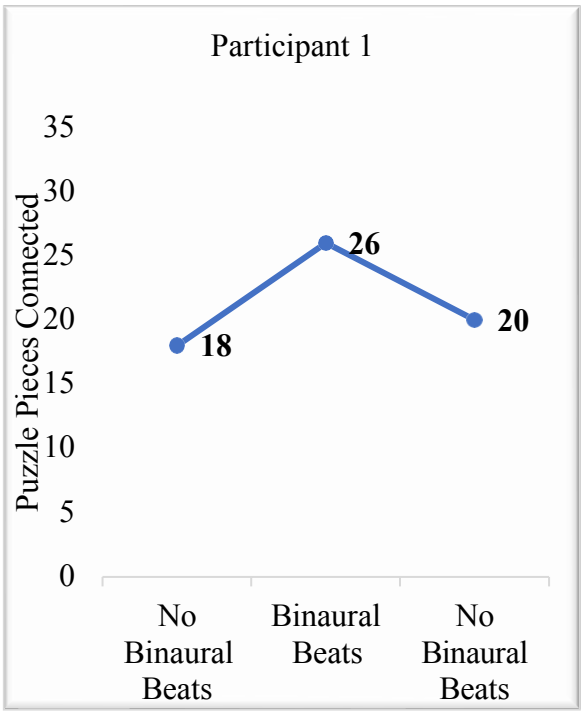

Figure 5. *Data chart of older female participant*

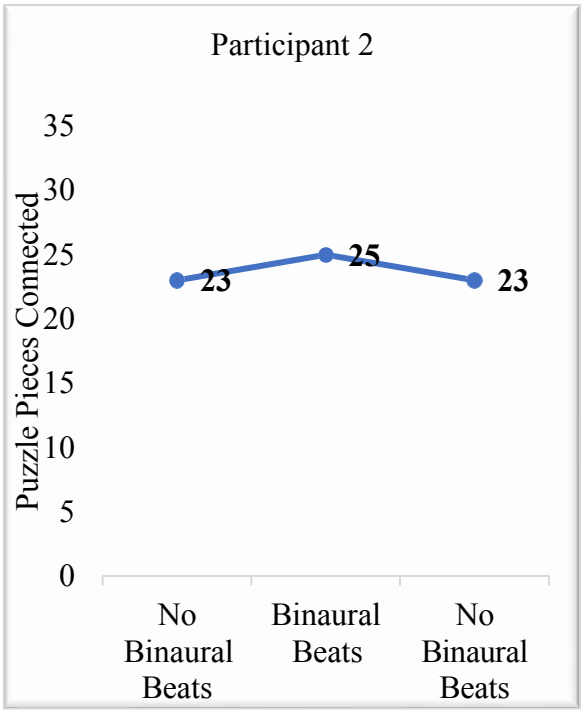

Figure 6. *Data chart of older male participant*

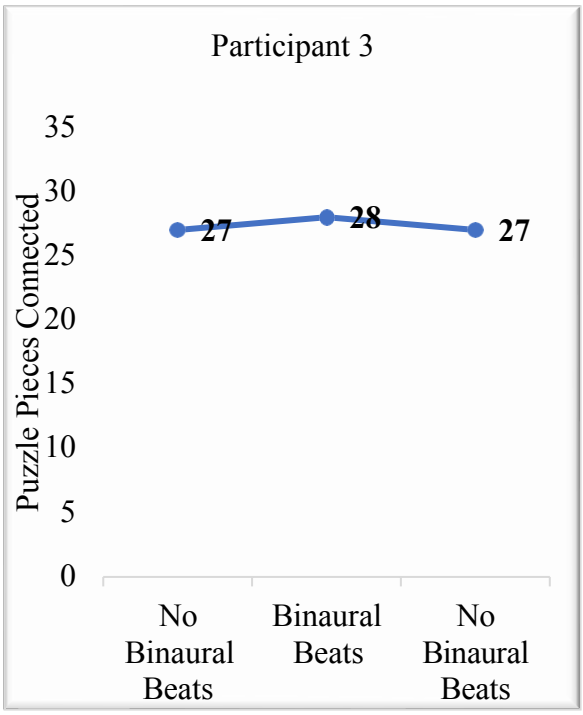

Figure 7. *Data chart of younger female participant*

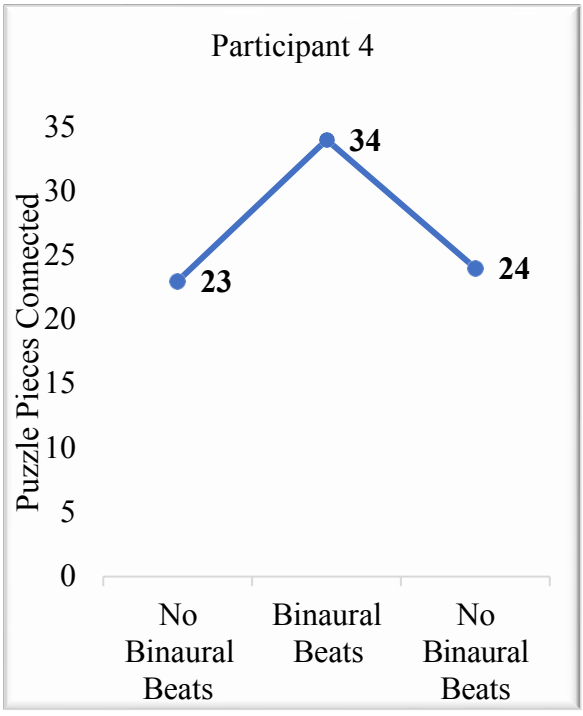

Figure 8. *Data chart of younger male participant*

References

Al-Moghamsi, E., & Aljohani, A. (2018). Elementary school teachers' knowledge of attention deficit/hyperactivity disorder. *Journal of Family Medicine & Primary Care*, *7*(5), 907–915. https://doi-org.libproxy.csustan.edu/10.4103/jfmpc.jfmpc_183_18

American Psychiatric Association. (2013). Attention deficit/hyperactivity disorder. In *Diagnostic and statistical manual of mental disorders* (5th ed.). https://doi.org/10.1176/appi.books.9780890425596

Banaschewski, T., Becker, K., Döpfner, M., Holtmann, M., Rösler, M., & Romanos, M. (2017). Attention-deficit/hyperactivity disorder. *Deutsches Ärzteblatt International*, *114*(9), 149-158.

Barkla, X. M., McArdle, P. A., & Newbury-Birch, D. (2015). Are there any potentially dangerous pharmacological effects of combining ADHD medication with alcohol and drugs of abuse? A systematic review of the literature. *BMC Psychiatry*, *15*

Colzato, L. S., Steenbergen, L., & Sellaro, R. (2017). The effect of gamma-enhancing binaural beats on the control of feature bindings. *Experimental Brain Research*, *235*(7), 2125-2131. doi:10.1007/s00221-017-4957-9

Elisa, R. N., & Parris, B. A. (2015). The relationship between core symptoms of ADHD and the Cognitive Reflection Test in a non-clinical sample. *Cognitive Neuropsychiatry*, *20*(5), 416–423. https://doi-org.libproxy.csustan.edu/10.1080/13546805.2015.1068687

Gould, K. L., Porter, M., Lyneham, H. J., & Hudson, J. L. (2018). Cognitive-behavioral therapy for children with anxiety and comorbid attention-deficit/hyperactivity disorder. *Journal of the American Academy of Child & Adolescent Psychiatry, 57*(7), 481-490. http://dx.doi.org/10.1016/j.jaac.2018.03.021

Huang, Tina L., & Charyton, Christine. (2008). A comprehensive review of the psychological effects of brainwave entrainment (Clinical report). Alternative Therapies in Health and Medicine, 14(5), 38-50.

Lynn, Shari J. (2007). ADHD medication: Risks and warnings. *American Journal of Nursing*, *107*(6), 36. doi: 10.1097/01.NAJ.0000271845.22968.cf

Meppelink, R., de Bruin, E. I., & Bögels, S. M. (2016). Meditation or Medication? Mindfulness training versus medication in the treatment of childhood ADHD: A randomized controlled trial. *BMC Psychiatry*, *16*

Nacim, B., Kleine, Sheldon, Nocita, Andrew, & Reed, Linda. (2008). Study on the Efficacy of IMusic© on Intelligence among Children with ADHD, *ProQuest Dissertations and Theses.*

Pettersson, R., Söderström, S., Edlund-Söderström, K., & Nilsson, K.W. (2017). Internet-based cognitive behavioral therapy for adults with ADHD in outpatient psychiatric care: A randomized trial. *Journal of Attention Disorders, 21*(6), 508-521. http://dx.doi.org/10.1177/1087054714539998

Pila-Nemutandani, R. G., & Meyer, A. (2016). Behaviour planning and problem solving deficiencies in children with symptoms of attention deficit hyperactivity disorder from the Balobedu culture, Limpopo province, South Africa. *Journal of Child & Adolescent Mental Health*, *28*(2), 109–121. https://doi-org.libproxy.csustan.edu/10.2989/17280583.2016.1200582

Prescription Stimulants. (2011). *Science World*, *67*(11), 20. Retrieved from http://search.ebscohost.com.libproxy.csustan.edu/login.aspx?direct=true&db=mih&AN=59373812&site=ehost-live&scope=site

Quinn, P. D., Chang, Z., Hur, K., Gibbons, R. D., Lahey, B. B., Rickert, M. E., & ... D'Onofrio, B. M. (2017). ADHD medication and substance-related problems. *The American Journal Of Psychiatry*, *174*(9),877-885. doi:10.1176/appi.ajp.2017.16060686

Treijs, D. (2000). A brainwave fix for ADD. *Report / Newsmagazine (Alberta Edition)*, *27*(13), 56. Retrieved from http://search.ebscohost.com.libproxy.csustan.edu/login.aspx?direct=true&db=aph&AN=3714466&site=ehost-live&scope=site

Wahbeh, H., Calabrese, C., Zwickey, H., & Zajdel, D. (2007). Binaural beat technology in humans: A pilot study to assess neuropsychologic, physiologic, and electroencephalographic effects. *The Journal Of Alternative And Complementary Medicine*, *13*(2), 199-206. doi:10.1089/acm.2006.6201

Wiersema, J. R., & Godefroid, E. (2018). Interoceptive awareness in attention deficit hyperactivity disorder. *PLoS ONE*, *13*(10), 1–13. https://doi org.libproxy.csustan.edu/10.1371/journal.pone.0205221

Weyandt, L. L., Oster, D. R., Gudmundsdottir, B. G., DuPaul, G. J., & Anastopoulos, A. D. (2017). Neuropsychological functioning in college students with and without ADHD. *Neuropsychology*, *31*(2), 160-172. doi:10.1037/neu0000326

Zampi, D., Fore, C. Jerome, & Durham, Thomas. (2015). *Efficacy of Theta-Binaural Beats for the Treatment of Chronic Pain*, ProQuest Dissertations and Theses.