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Meta-Analysis of the Efficacy of Neurofeedback

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Abstract

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MS, Walden University 2013

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Dissertation Submitted in Partial Fulfillment

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Abstract

Decreases in overall well-being and daily functioning result from unpleasant and uncomfortable symptoms associated with physical health and mental health disorders. Neurofeedback training, rooted in the theory of operant conditioning, presents the possibility of increasing brain wave regulation, decreasing symptoms experienced from abnormal brain wave activity, and increasing overall well-being and daily functioning. The efficacy of neurofeedback for physical and mental health outcomes is unclear, contributing to confusion about the treatment and any potential benefits. In order to assess the efficacy of neurofeedback in the alleviation of physical health and mental health symptoms, a systematic review and meta-analysis of neurofeedback using a random effects model to generate the effect sizes was conducted on 21 studies with 22 comparisons that used neurofeedback to treat patients. The results showed that neurofeedback can be effective for physical and mental health outcomes, including for autism with an effect size of 0.29, tinnitus with an effect size of 0.77, schizophrenia with an effect size of 0.76, depression with an effect size of 0.28, insomnia with an effect size of 0.52, obesity with an effect size of 0.40, intellectual disability with an effect size of 0.73, and pain with an effect size of 0.30. Well-being and daily functioning for those with physical and mental health disorders can be improved. These findings have implications for clinical practice to help patients in treatment for physical and mental health problems, and also for social change by providing evidence for alternative health care options.

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Chapter 1: Introduction to the Study

Introduction

This meta-analysis addressed the overall efficacy of neurofeedback for physical health and mental health outcomes. Physical and mental health are significant to safety and peace as much as they are to positive social existence (World Health Organization, 2018). Neurofeedback has roots dating back to the 1950s, with evolution in techniques, software, and hardware still occurring today, leaving inconsistencies about the details of the treatment and its overall efficacy (Thompson & Thompson, 2016). In psychology education, it is important to critically evaluate evidence across a diverse body of research on a given topic. For aspiring educators, it is important to master knowledge to be shared through the active construction of that knowledge, making it easily transferred to learners through non-passive educational applications (Horn, Kamata, & Midwestern Higher Education Compact, 2014). Thus, in addition to demonstrating mastery of meta-analysis research protocols, this systematic review and meta-analysis of the efficacy of neurofeedback has pedagogic value for understanding the body of evidence on neurofeedback for physical health and mental health outcomes.

Background

Pharmacological and non-pharmacological treatment options are available for a variety of physical and mental health conditions, and there are numerous reasons why one option might be chosen over the other. For example, Cipriani et al. (2018) cited a lack of adequate resources as a reason why pharmacology is used more frequently than other psychological interventions for depression. Dehghani-Arani, Rostami, and Nadali (2013) stated that substance abuse is frequently treated both pharmacologically and behaviorally, but even with significant resources being dedicated to improving treatment outcomes, seven out of 10 treatment recipients relapse. Van Doren et al. (2018) indicated that pharmacology and psychological intervention are the most effective for the short-term treatment of attention deficits, with neurofeedback cited as effective for long term treatment of attention deficits with lasting effects beyond the point when neurofeedback treatment stops. According to Cipriani et al. (2018) psychiatric disorders account for almost 23% of global disorders, and according to Batson, Merson, and Dzau (2017), global health is in need of a challenge to old practices and ways of thinking to encourage and embrace change and innovation to save lives and improve health outcomes. Neurofeedback offers an innovative approach to physical and mental health, yet it remains controversial as to whether or not it is efficacious.

Abnormal brain behavior is a cited cause for psychological abnormalities and functioning, and with some links to abnormal physical health such as pain, epilepsy, and so forth (Marzbani, Marateb, & Mansourian, 2016). Neurofeedback according to Alkoby, Abu-Rmileh, Shriki, and Todder (2017) and Marzbani et al. (2016) lacks conclusive evidence of its efficacy, but is commonly used to treat attention deficits, anxiety, depression, epilepsy, eating disorders, emotional disorders, insomnia, substance abuse, substance dependence, other addictions, schizophrenia, stroke, tinnitus, learning disabilities, dyslexia, dyscalculia, autism, pain, and so forth. Reduction or amelioration of these physical and mental health disorders and symptoms are likely to improve the daily functioning of the individual. However, Alkoby et al. (2017) and Thibault and Raz

(2017) cautioned that simply because neurofeedback is used to treat such a wide range of conditions, it does not mean that neurofeedback is effective in treating those conditions or symptoms. Thibault and Raz (2017) reported that placebo is a likely cause of neurofeedback success, and Alkoby et al. (2017) reported that many treated with neurofeedback do not benefit from the treatment, adding that it is difficult to predict which individuals will benefit from treatment and who will not. To date, no researcher has conducted a meta-analysis on the use of neurofeedback for physical and mental health outcomes, leaving the efficacy debate to the specific symptom or disorder being treated rather than with a larger consideration of how neurofeedback may improve physical and mental health. Adaptive approaches to global health, including mental health, could save or improve lives by millions (Batson et al., 2017).

The value in conducting meta-analytic research for an aspiring educator rests in the educator's need to understand and apply his or her ability to interpret meta-analytic research to understand a body of research as well as to teach others to understand a body of research to make their instruction increasingly effective (Ouyang & Stanley, 2014; Horn, et al., 2014; Blank, 2013). For example, Horn et al. (2014) reported that in the collegiate landscape, mastery learning far exceeds the traditional lecture in student success, noting that the traditional lecture method relies on the antiquated ideal that students passively learn. Blank (2013) outlined the transformation of professional educator development (educator learning) to student success as a process including active engagement in learning activities that require participation, learning and outcome goals, and learning about how students learn which translate to educator knowledge and skills influencing educator instruction and student success simultaneously. Knowledge is constructed through learning and learning occurs through knowledge construction, which requires an educator to be flexible in acquiring and dispensing knowledge to increase both the quality and effectiveness of instruction (Ouyang & Stanley, 2014). Active participation in learning, such as conducting meta-analytic research, presents an opportunity for mastery learning which requires demonstrating proof of learning through experience, application, and integration (Horn et al., 2014). Thus, my systematic review and meta-analysis of the efficacy of neurofeedback for physical and mental health outcomes (a) has pedagogic value as an example of meta-analysis as a tool for understanding a body of evidence for mastery learning and future instruction, and (b) contributes to current body of knowledge on neurofeedback's efficacy for physical and mental health outcomes.

Problem Statement

Neurofeedback, also known as electroencephalograph (EEG) biofeedback, is a clinical treatment modality involving the use of operant conditioning to train brain waves. Wigton and Krigbaum (2015) described neurofeedback as a process that uses scalp sensors, an amplifier, and computer software to train specific brain wave frequencies noted from the EEG that are not working in the target range. Neurofeedback, as a clinical treatment modality and in a specific context, can be used in conjunction with most clinical treatments such as psychotherapy, psychology, nursing, chiropractic care, medical care, and so forth. According to Cleary (2011), psychological disorders that are characterized by specific patterns of brain activity are visible via an EEG. These abnormal brain waves can then be trained via neurofeedback to help regulate the brain waves towards normal, which simultaneously treats the symptoms that are associated with psychological disorders (Cleary, 2011). Symptoms of psychological disorders have the potential to be unpleasant and uncomfortable, contributing to an overall decrease in physical and mental health (daily functioning).

As with other clinical treatment modalities, adverse or iatrogenic effects are possible with neurofeedback (Hammond & Kirk, 2015). Specific reasons why neurofeedback might present such adverse or iatrogenic effects include an increase in unqualified professionals providing treatment, a lack of emphasis on standards of practice within the field, providers not seeking competency and continuing education trainings, and licensed healthcare providers who choose not to obtain a neurofeedback certification (Hammond & Kirk, 2015). Perhaps the adverse effects result from variability in the neurofeedback treatment. There is a lack of clarity about the efficacy of neurofeedback or how strong the evidence for efficacy is across studies with varying designs and quality (Alkoby et al., 2017). In psychology education it is important to consider a body of research on a topic and not just single studies of treatment effectiveness, and also to assess the contextual factors across studies, such as populations, study design, and endpoints that contribute to varying results. This is important to consumers of research in psychology and psychology education. I undertook this study on the premise that a meta-analysis of the existing research on neurofeedback could provide new insight into its efficacy for physical and mental health outcomes as well as provide an update for the field regarding the existing research.

As scientists studying the mind and behavior, psychology practitioners and teachers use systematic scientific methods to observe, describe, predict, change, teach, explain, analyze, or draw conclusions about people and data (King, 2016). For example, in psychology education, it is important that the educator is able to critically evaluate evidence across a diverse body of research on a given topic. Meta-analysis can be an important tool for the synthesis of this evidence. Psychologists examine available evidence to make determinations about the strength of data to provide answers to questions related to human existence (King, 2016). Improving physical and mental health, as measured by reductions in psychological diagnoses or experienced psychological symptomology, or simply by improved feelings of wellness, is of central importance to humans, psychologists and teachers included.

In my search for currently available meta-analyses and systematic reviews of neurofeedback and biofeedback, I found six studies: Tan et al. (2009) focused on neurofeedback specifically for epilepsy and seizures, Schoenberg and David (2014) bundled neurofeedback and biofeedback without meta-analysis, Luctkar-Flude and Groll (2015) focused on neurofeedback for fatigue and cognition, Rogala et al. (2016) focused on neurofeedback training, Mirifar, Beckman, and Ehrlenspiel (2017) focused on neurofeedback for optimizing athletic performance, and Renton, Tibbles, and Topolovec-Vranic (2017) focused on neurofeedback for cognitive rehabilitation following a stroke. Due to the lack of data on neurofeedback for physical and mental health outcomes, opportunities for health and mental health efficiency and improvement might be missed.

Purpose

Neurofeedback is a specialty treatment (or therapy) that has roots dating back to the 1950s, with evolution in techniques, software, and hardware still occurring today, leaving inconsistencies about the details of the treatment (Thompson & Thompson, 2016). For example, neurofeedback treatment approaches like live z-score and low resolution electromagnetic tomography (LORETA) neurofeedback are more recent advances in treatment approaches, treatment technology, and treatment applications, and are often compared to older treatment approaches like conventional neurofeedback, traditional neurofeedback, standard neurofeedback, or regular neurofeedback (Collura 2016; Koberda, Moses, Koberda, & Koberda, 2012; Thatcher, 2013; Thompson & Thompson, 2016; Wigton, 2013; Wigton & Krigbaum, 2015). When reviewing the literature, a clear understanding of what each term entails is necessary to understand the efficacy of the treatment for physical and mental health conditions because more recent treatment approaches, technology, and applications have utility across a broader scope of symptoms whereas the older approaches are specific to certain conditions such as attention deficits (Wigton, 2013; Wigton & Krigbaum 2015). A focus solely on the efficacy of neurofeedback for attention deficits (Arns, Heinrich, & Strehl, 2014) does not cover the vastness of physical and mental health.

In this meta-analysis, I sought to evaluate and synthesize evidence on the efficacy of neurofeedback by pooling results of studies examining its efficacy for physical and mental health outcomes. Specifically, I pooled the related independent studies of the use of neurofeedback for health and mental health conditions to critically evaluate the evidence for efficacy as it exists collectively. Card (2011) argued that rather than a need for continued research to propel a knowledge area forward, a more significant need rests in the unification of existing research that organizes and summarizes the collection of what we know. In this meta-analysis, I addressed a gap in the literature by analyzing the results of qualifying published research (peer reviewed, editor reviewed, open access, and so forth) and unpublished research (conference material, working papers, case studies, and so forth) on neurofeedback to understand the overall efficacy of neurofeedback for physical and mental health outcomes (Card, 2011; Huffcutt, 2004).

Defining the dependent and independent variables of this quantitative meta-analysis was significant in developing the research question and hypothesis. According to Trochim (2006) the independent variable is manipulated (treatment) and the dependent variable is affected by the independent variable (outcomes). In this study, neurofeedback was the treatment (independent variable) I reviewed for efficacy in physical and mental health outcomes (dependent variable).

Research Question

RQ: What are the effects of neurofeedback on physical and mental health outcomes across published and unpublished studies?

H_0: Neurofeedback will not have a significant effect on physical and mental health outcomes as determined by meta-analysis of published and unpublished studies.

H_a: Neurofeedback will have a significant effect on physical and mental health outcomes as determined by meta-analysis of published and unpublished studies.

Theoretical Framework

Skinner's (1938) theory of operant conditioning served as the theoretical base for this meta-analysis. Skinner contended that the reinforcement of a behavior is likely to create an increase in the likelihood of that behavior repeating. An operant, as described by Kobayashi, Schultz, and Sakagami (2010), is any behavior that impacts the environment and creates an outcome. Operant conditioning uses reinforcement following a desired behavior to increase the likelihood that the behavior will repeat in the future and punishment following an undesired behavior to decrease the likelihood that the behavior will repeat in the future (King, 2016). The significance of operant conditioning to physical health and mental health is in the interaction of all living beings with their environment. As environments change, the outcomes of the same behaviors will change, creating a need for changing behaviors which requires the brain to assess and modify behavioral interactions as necessary (Kobayashi et al., 2010).

The process of neurofeedback training requires regulation of brain wave activity by following the principles of operant conditioning. Gunkelman and Johnstone (2005) described brain wave activity (brain electrical patterns) as a form of behavior. Changing brain wave activity through the principles of operant conditioning is less like taking medication with the effects wearing off as each dose wears off and more like learning to ride a bicycle where your skills can become rusty when not used, though likely never gone entirely. This connects to the neural plasticity of the brain, meaning that the brain is malleable or amenable to change, with this ability to change (or grow) lasting a lifetime (Gunkelman & Johnstone, 2005). As learning occurs, the dendritic connections and structure of the brain are microscopically changed. In the case of neurofeedback, the EEG of the learner is used by the clinician to learn which brain waves are in excess and which in deficit. The clinician then creates a training plan for the learner to work on over a number of sessions to reduce excessive brain waves and increase those in deficit. The learner is rewarded via audio and visual feedback as they learn to use their brain waves normally.

Nature of the Study

In this quantitative meta-analysis, I used statistical techniques applied to a systematic review combining results from each included research study (see Moher, Liberati, Tetzlaff, Altman, & Prisma Group, 2009). This meta-analysis of studies of the efficacy of neurofeedback for physical and mental health serves as a single source of synthesized information researchers can reference without the need to locate multiple articles (Gates & March, 2016). A quality meta-analysis follows a systematic process such as the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA)—guidelines I followed in this meta-analysis (see Haidich, 2010). PRISMA guidelines include a 27-item checklist for information to be included in the meta-analysis and a four-phase flow diagram of the information to be included (Moher et al., 2009).

I identified available relevant published and unpublished research studies and selected them for inclusion in this meta-analysis. The evaluation and then statistical synthesis of each independent research study pooled together in this meta-analysis can strengthen the outcomes of the existing data potentially resting results from conflictual studies (Card, 2011; Gates & March, 2016; Haidich, 2010; Huffcutt, 2004).

The quantitative meta-analysis method was appropriate for this research because it presented the opportunity to review the current literature, organize the outcomes of varying studies, and integrate them into a single study that increases transparency in the field regarding the efficacy of neurofeedback treatment. According to Haidich (2010), the conclusions from a meta-analysis include increasing the clinical understanding of the effects of the treatment and a consolidation of the outcomes from multiple studies. The availability of clearer evidence regarding the efficacy of neurofeedback can potentially increase treatment effectiveness and decrease negative outcomes in addition to providing direction for areas of future research. Increased understanding of the efficacy of neurofeedback across a number of published and unpublished research studies that focus on diverse physical and mental health outcomes can shed light on treatment effectiveness and which treatment approaches work for which populations and health conditions. This knowledge can inform treatment efficacy and serve as a pedagogical tool for evaluating the body of evidence for the efficacy of neurofeedback. Such an increase in effectiveness and decrease in negative outcomes presents the opportunity for improved physical and mental health outcomes.

Definitions

Effect size: Strength of the relationship between variables; quantifies the difference between variables. A unit of analysis in meta-analysis (Cumming, Fidler, Kalinowski, & Lai, 2012).

Health: Core requirement for safety and peace; a state of physical, emotional, and social well-being (World Health Organization, 2018).

Mental health: A state of well-being; the ability to handle normal life stress, work, and contribute to society (World Health Organization, 2014).

Meta-analysis: A quantitative approach to the evaluation and synthesis of research that pools the statistical data of each individual research study to determine the overall effect size (Card, 2011).

Neurofeedback: Use of brain wave activity to teach the brain new patterns of behavior which can aid in self-regulation, relaxation, efficiency, and so forth; a non-pharmacological treatment for physical and mental health (International Society for Neurofeedback & Research, 2017).

Physical health: A state of well-being; the proper functioning of all internal and external body parts (World Health Organization, 2014).

Assumptions

In meta-analyses, researchers synthesize and quantify results of multiple independent research studies. In this study, I assumed that meta-analysis is a valid method for synthesizing the results of multiple studies in a similar body of research. For example, Gates and March (2016) noted that the initial approach to systematic reviews and meta-analyses is qualitative as research is located and evaluated for inclusion. Even with established guidelines for study selection, inclusion, and exclusion, human judgement is a component of the process and impacts the assumption that researchers with a sound methodological approach will reach the same conclusions when analyzing the same data. I also assumed that meta-analytic research retains the original qualities of each study, allowing me to re-analyze and synthesize the data of the original phenomenon (neurofeedback) accurately (see Crocetti, 2016). Finally, I assumed that the measures used in the original studies were valid and reliable.

Scope and Delimitations

The scope of the study included examining neurofeedback literature, published or unpublished, which included data that could be computed for effect size or data that could be reviewed to inform my interpretation of effect size calculations. Because meta-analytic research involves synthesis and statistical computation of existing research, the results of the meta-analysis can only be as reliable and valid as the data from the original studies (Crocetti, 2016). I excluded studies not published in English, studies that were older than 10 years, and previous meta-analyses or systematic reviews.

Limitations

Internal validity and reliability in meta-analytic research relies on the validity and reliability of each of the studies selected for inclusion in the meta-analysis. Inclusion of studies that are of poor quality or that do not provide data appropriate to answering the research question threaten the internal validity of a meta-analysis (Creswell, 2014). Research is an imperfect process, and human and systematic errors occur even when effort is made to reduce them. The external validity of a meta-analysis can be threatened by the predetermined inclusion and exclusion criteria if it is not specific enough to identify studies that are useful to answering the research question. Inaccurate data extraction of each study included in a meta-analysis presents a potential threat to the reliability of the meta-analysis.

To assess the methodological rigor of studies for inclusion in a meta-analysis, researchers use predetermined criteria based on the methodological domains of participation bias, attrition bias, outcome measurement, and data analysis and reporting. The participation bias domain includes assessing for the population of interest, ensuring that its key characteristics are adequately described for and inclusion, and ensuring that exclusion criteria are described. The attrition bias domain includes assessing for length of time sufficient for follow-up outcomes to occur (three months) and reporting missing participant data. The outcome measurement domain includes assessing for an objective outcome definition and providing that definition in advance of intervention. The data analysis and reporting domain includes assessing for alpha error and/or beta error specifications and including frequencies for most important data (outcomes and so forth).

Significance

The results of this meta-analysis may inform interventions to improve physical and mental health outcomes by identifying the efficacy of neurofeedback across populations and health conditions. A broad range of individuals suffer from diminished physical and mental health. As the World Health Organization (2018) has noted, physical and mental health are more than the absence of disease, they are fundamental to safety and peace. Thus this study of efficacious treatment options for physical and mental health conditions may contribute to the increased well-being of those with these conditions.

Future psychology educators experienced in meta-analytic research fulfill a mastery learning component of the active construction of knowledge. This experience can help decrease passive learning and increase the quality and effectiveness of future instruction and learning (Horn et al., 2014; Ouyang & Stanley, 2014). Effective instruction relies on the instructors’ ability to accurately and flexibly acquire, use, and share knowledge in meaningful ways that meets the needs of the learners (Ouyang & Stanley, 2014). Increasing the quality of instruction and learning success for students offers a unique opportunity for positive social change.

Summary

Neurofeedback has roots dating back to the 1950s, with evolution in techniques, software, and hardware still occurring today, leaving inconsistencies about the details of the treatment and its overall efficacy (Thompson & Thompson, 2016). In this meta-analysis, I evaluated and synthesized the evidence regarding the efficacy of neurofeedback for physical and mental health outcomes. In psychology education, it is important to be able to critically evaluate evidence across a diverse body of research on a given topic. Meta-analysis can be an important tool for the synthesis of this evidence. Thus, this systematic review and meta-analysis of the efficacy of neurofeedback has pedagogic value in understanding the body of evidence on neurofeedback for health and mental health outcomes and then communicating that understanding to others working and studying in the field.

Chapter 2: Literature Review

Introduction

In this meta-analysis, I addressed the lack of consistency and specificity in previous studies about the efficacy of neurofeedback for physical and mental health outcomes. There has been a diversity of findings and conflicting results on efficacy of neurofeedback across different physical and mental health outcomes. I thus determined that it was important to synthesize the evidence across these studies to evaluate the strength of the evidence for the effectiveness of neurofeedback and to delineate some of the boundaries for the observed effectiveness reported in published and unpublished studies. One or two studies with positive results can be misleading. Meta-analysis, a systematic review with statistical synthesis, is the gold standard in valid and reliable evaluation of the strength of the evidence in the literature across a number of studies (Crocetti, 2016; Cumming, 2013). The purpose of this meta-analysis was to evaluate and synthesize the evidence for the efficacy of neurofeedback for physical and mental health outcomes by conducting a systematic review with meta-analysis of published and unpublished studies on the topic.

Clinical drug trials that use placebos or double-blind conditions are often the standard approach for determining efficacy of treatments to physical and mental health outcomes (Thompson & Thompson, 2016). Unfortunately, such approaches are not effective for determining the efficacy of neurofeedback because the established conditions violate the basic principles by which neurofeedback operationalizes brain and behavior change (Thompson & Thompson, 2016). For example, the inclusion of a placebo condition in a clinical drug trial does not administer active medication to the individual, but a placebo condition in neurofeedback still involves training conditions with erroneous feedback (active medication) that, based on the principles of operant conditioning, can still result in learning (even if not desired or goal directed; King, 2016; Thibault & Raz, 2017). A pharmacological placebo is a pill that lacks the active medication found in the non-placebo pill. More specifically, a placebo in pharmacology is a pill that looks and feels like the real deal, but has no clinical function (Wang, Zhao, & Hao, 2017). Since placebo (or sham) neurofeedback would have a clinical (treatment) function, in this meta-analysis I included study designs such as observational and interventional designs (cohort studies, randomized clinical trials with or without placebo conditions, and so forth) that are not specific to controlled conditions. I did this so as to include the varying studies and approaches across the field that might increase my understanding of the intervention's efficacy across diverse physical and mental health outcomes.

Literature Search Strategy

I began the literature review by searching electronic databases including Medline, CINAHL, PsycARTICLES, PsycINFO, SocINDEX, ScienceDirect, IEEE Xplore Digital Library, PubMed, and Cochrane Register of Controlled Trials. To address publication bias, I also searched Clinicaltrails.gov for unpublished studies, in progress studies, reports, presentations, conference abstracts, and dissertations. The Office of Human Research Protections (OHRP), National Institutes of Health (NIH), and the Food and Drug Administration (FDA) web sites were searched for clinical study data. I searched for keywords including *EEG biofeedback*, *neurofeedback, fMRI,* and meta-analysis using Boolean operators. I found relevant articles in a variety of journals including *Journal of Neurotherapy, Journal of Mental Health Counseling*, *Biofeedback*, *Neuroscience*, *Applied Pyschophysiology & Biofeedback*, *American Psychologist*, *Experimental Brain Research*, *International Journal of Psychophysiology*, *BRAIN: A Journal of Neurology*, and *Proceedings of the IEEE*.

Overview of the Literature Review

Theoretical Base for Neurofeedback

Skinner’s (1938) theory of operant conditioning holds that humans learn through positive and negative consequences following a given behavior. According to Skinner, the reinforcement of a behavior is likely to create an increase in the likelihood of that behavior repeating and the punishment of a behavior is likely to create a decrease in the likelihood of that behavior repeating. Operant conditioning is the driving force behind neurofeedback, which is designed to reward healthy brain waves and increase the likelihood that they will repeat.

Kobayashi et al. (2010) described an operant as any behavior that impacts the environment and creates an outcome. The logic being that the operant can be changed through conditioning (i.e., operant conditioning). The process of operant conditioning uses reinforcement following a desired behavior to increase the likelihood that the behavior will repeat in the future, or punishment following an undesired behavior to decrease the likelihood that the behavior will repeat in the future (King, 2016). The timing of the reinforcement or punishment of the behavior is imperative for learning and the desired behavior change to occur (Skinner, 1938). Operant conditioning is significant to physical health and mental health due to the interaction of all living beings with their environment. As environments change, the outcomes of the same behaviors will change, creating a need for changing behaviors, which requires the brain to assess and modify behavioral interactions as necessary (Kobayashi et al., 2010).

The process of neurofeedback training involves regulation of brain wave activity following the principles of operant conditioning. Gunkelman and Johnstone (2005) described brain wave activity (brain electrical patterns) as a form of behavior. Changing brain wave activity through the learning principles of operant conditioning is less like taking medication with the effects wearing off as each dose wears off, and more like learning to ride a bicycle where your skills can become rusty when not used, though likely never gone entirely. The ability to change brain wave activity connects to the neural plasticity of the brain, meaning that the brain is malleable or amenable to change, with this ability to change (or grow) lasting a lifetime (Gunkelman & Johnstone, 2005; Thompson & Thompson, 2016). As learning occurs, the dendritic connections and structure of the brain are microscopically changed. In the case of neurofeedback, the clinician uses the EEG of the learner to learn which brain waves are in excess and which in deficit and creates a training plan for the learner to work on over a number of sessions to reduce excessive brain waves and increase those in deficit. The learner is rewarded via audio and visual feedback as they learn to use their brain waves normally.

Neurofeedback

Neurofeedback, also known as EEG biofeedback, is a clinical treatment modality focused on the use of operant conditioning to train brain waves. Wigton and Krigbaum (2015) described neurofeedback as a process that uses scalp sensors, an amplifier, and computer software to train specific brain wave frequencies that are not working in the target range, as noted on the EEG. Neurofeedback, as a clinical treatment modality and in a specific context, can be used in conjunction with most clinical treatments such as psychotherapy, psychology, nursing, chiropractic care, medical care, and so forth. Individuals typically do not observe their own brain wave activity, but with neurofeedback, individuals are given the opportunity to view and hear their brain wave activity through the feedback provided during the training (Collura, 2016).

Psychiatrists, psychologists, mental health counselors, and other professionals who diagnose and treat symptomology related to the functioning and well-being of the brain are surprisingly unlikely to examine the organ associated with the conditions they are treating. For example, the Council for Accreditation of Counseling and Related Education Programs (CACREP, 2016), has standards requiring that counselors learn, understand, and experience neurobiological mechanisms as they relate to mental health to aid in the integration of neuroscience to counseling practice. Neurobiological mechanisms include the relationships in an individual of the biological, neurological, and physiological connections that directly impact development, behavior, and functioning (CACREP, 2016). Mental health practitioners should understand neuroscience because the brain is composed of structurally and functionally connected areas, and practitioners can use observations of brain activity to distinguish healthy functioning from psychological and neurological disorders. (Murphy & Bassett, 2017; Sitaram et al., 2016). Identification of healthy brain functioning and the ability to differentiate it from unhealthy brain functioning increases the rate at which mental health professionals can identify symptomology and behavior as it correlates with healthy (or unhealthy) brain functioning and by extension healthy (or unhealthy) levels of daily functioning (Murphy & Bassett, 2017; Sitaram et al., 2016).

Historically, a neuroscientific connection to mental health and behavior might be overlooked, but recently the scientific community has highlighted connections between the neuroplasticity of the brain and the role that psychotherapeutic counseling has on changing brain functioning (Ivey, Ivey, & Zalaquett, 2014). Functional changes of the brain can also result from the purposeful attempt at changing brain functioning with neurofeedback training. During neurofeedback training, the learner acquires the ability to self-regulate by decreasing or increasing brain wave functioning (as identified by the practitioner) towards normal as determined by a normative database (Alkoby et al., 2017; Chapin, 2016; Cleary, 2011; Collura, 2016; Gunkelman & Johnstone, 2005; Thompson & Thompson, 2016; Wigton, 2013). As learners train with neurofeedback, they are presented with visual and/or auditory feedback that, based on the principles of operant conditioning, are meant to increase or decrease specific brain functioning. The learners acquire the ability to regulate brain waves and thus the ability to self-regulate and/or change how they interact with their environment (Alkoby et al., 2017; Chapin, 2016;

Cleary, 2011; Collura, 2016; Gunkelman & Johnstone, 2005; Thompson & Thompson, 2016; Wigton, 2013).

QEEG or Brain Mapping

Quantitative EEG (QEEG), sometimes referred to as brain mapping, is an extension of EEG where the EEG is analyzed, compared to a normative database, then converted to a map of the brain that can assist in the clinical understanding of the current functioning of the brain (Demos, 2005). The comparison of the EEG to the normative database is a process completed by computer software and involves specific algorithms and statistical analysis. Software can vary from manufacturer to manufacturer, but typical analyses include power, coherence, phase, amplitude, and frequency (Soutar & Longo, 2011). The QEEG is not intended for use as a diagnostic tool; rather, clinicians use it to (a) understand the current functioning of the brain including dysregulation, dysfunction or impaired function, and connectivity of and between various neural networks in the brain; and (b) confirm hypotheses regarding brain function in relation to symptoms or existing diagnoses (Soutar & Longo, 2011; Thatcher, 2016). While a QEEG is not required for neurofeedback, it is the preferred method of obtaining a clinical assessment of the brain and it aids in protocol selection prior to neurofeedback (ISNR, 2017; Soutar & Longo, 2011).

Recent technological advances have decreased some of the barriers present in gathering QEEG data and comparing the data to normative databases (Thompson & Thompson, 2016; Wigton and Krigbaum, 2015). A normative database includes data collected from a selected population of individuals that met the inclusion criteria of the creators of the database. QEEG data is compared to the normative database clinicians use to help increase their understanding of the clinical picture of the brain they are reviewing. Multiple databases are available for comparison. For example, the NeuroGuide normative database includes 678 subjects ranging in age from 2 to 82 that met certain clinical standards based on inclusion/exclusion criteria (without a history of neurological or behavioral disorders, performed at grade level, completed neuropsychological testing, and so forth.) and utilizes 2 year means with 6 months overlap of subjects (Thatcher, 2016).

Clinicians' use of the QEEG to better understand the patients' current levels of brain functioning will also increase their understanding of the individuals as they exist in their daily environments and how that compares to normal or healthy. Using the QEEG as part of the assessment process to then match findings to historical functioning, current functioning, and desired functioning is part of the documented gold standards for the field of neurofeedback that will potentially help to improve physical and mental health outcomes (Thompson & Thompson, 2016; Wigton and Krigbaum, 2015). The alternative option of not using a QEEG as a part of the neurofeedback training offers a potential hindrance to the trainee and the overall efficacy of the approach for physical and mental health outcomes.

Brain Waves and Frequency

Brain waves are measured as the electrical activity of neurons within the brain (Demos, 2005). The electrical activity of the neurons can be collected through EEG, which uses clinical equipment comprised of scalp sensors, an amplifier, and computer system to monitor, record, and transform the electrical activity to brain wave frequency data (Demos, 2005; Soutar & Longo, 2011). Each frequency is associated with specific behavioral characteristics. For example, the following frequencies and their relation to behavior, Delta is commonly 1 to 4 Hz representing sleep, repair, problem solving, and so forth; Theta is commonly 4 to 8 Hz representing creativity, insight, and so forth; Alpha is commonly 8 to 12 Hz representing alertness, peacefulness, readiness, meditation, and so forth; and Beta is commonly 13-21 Hz representing thinking, focusing, sustained attention, and so forth (Demos, 2005). Understanding brain activity and its connections to physical and mental health is critical for selecting training protocols that will increase functioning by brainwave regulation and simultaneously increasing physical and mental health (Sherlin et al., 2011; Thompson & Thompson, 2016). A lack of understanding of brain functioning and activity increases the potential for ineffective training and iatrogenic harm (Hammond & Kirk, 2015).

Brodmann Areas

The 47 Brodmann areas named after their founder Korbinian Brodmann in 1909 divide the cerebral cortex of the brain into 47 distinct regions that increase the clinical understanding of brain location and functioning (Soutar & Longo, 2011). The premise of the 47 Brodmann areas is based on the original idea that structure is a determining factor of function (Thatcher, 2016). The Brodmann areas aid in a visual representation of symptomology when using a QEEG brain map to view current brain functioning. For example, some of the Brodmann areas connect to function as follows: areas 1, 3, 4, and 6 are associated with sensory and motor functions; areas 5, 7, and 19 are associated with perseverance, self-awareness, orientation, agnosia, and apraxia; and areas 8, 9, and 46 are associated with verbal, spatial, and object short-term memory retrieval, facial recognition, planning, problem solving, vigilance, and some attentional characteristics (Soutar & Longo, 2011).

Inverse solutions estimate the structure (source/location) of activity from the EEG recorded at the surface of the scalp (Thatcher, 2016). The recording at the scalp is based on the specific electrode placement guided by the international 10/20 system that follows documented measurements beginning at four specific locations on the skull and follows a percentage (10% or 20%) to reach the next electrode placement destination (Thatcher, 2016). Talarich Atlas coordinates were used by the Human Brain Project to duplicate the coordinates used by Brodmann for each of the Brodmann areas and, when coupled with the use of the inverse solutions, these locations became easily identified in correspondence to electrode placements on the scalp surface when following the international 10/20 placement system (Thatcher, 2016).

Excluding fMRI

Functional magnetic resonance imaging (fMRI) focuses on changes in blood flow in the brain to measure activity of the brain which is different than measuring the electrical activity of the brain through sensors on the scalp. Cerebral blood flow and neuronal activation are coupled, thus allowing for images of brain functioning to be created similarly to the brain maps created by QEEG (Choi, 2013). The equipment necessary for fMRI and fMRI neurofeedback is costly in comparison to that for QEEG and EEG neurofeedback, and currently fMRI neurofeedback is not a readily available treatment for patients (Thibault & Raz, 2017). The use of fMRI neurofeedback is utilized in research settings where participants learn regulation of hemodynamics specifically in the brain. Treatment benefits of fMRI that compare or supplant those of EEG neurofeedback have yet to be established, and when added to the higher cost and reduced access to the fMRI equipment, fMRI neurofeedback is not included in this meta-analysis (Thibault & Raz, 2017). While fMRI neurofeedback has equal potential to affect physical and mental health outcomes, the reduced access and increased cost would present significant barriers for common access to the treatment.

History of Neurofeedback Use in Clinical Contexts

Practice Standards

The Biofeedback Certification International Alliance (BCIA) (2016) professional standards and ethical principles of biofeedback and neurofeedback include a standard of practice for all practitioners with the stated intent to uphold the highest standard of the profession while being diligent in protecting the best welfare of all clients. The Association for Applied Psychophysiology and Biofeedback (AAPB) (2008) publishes standards for performing biofeedback, which includes EEG biofeedback (neurofeedback) within the standards. Like BCIA, AAPB (2008) highlights the intentions of the standards of practice to protect clients through ethical practice and adherence to laws of the practitioners licensing body.

Practitioners of neurofeedback are not required to have a credential in the practice of neurofeedback, but are likely required to have a license to practice in their respective field in their home state to be a healthcare provider (AAPB 2008; BCIA, 2016). Such a reliance on individual providers to find a benefit in seeking out additional certifications beyond what is required presents a valid concern for unethical practices, and unethical practices increase the likelihood for harm as well as poor outcomes (Hammond & Kirk, 2008). The professional standards and ethical principles of the BCIA (2016) create an opportunity for the development of increased regulation, consistency, and efficacy in the field of neurofeedback through established practice standards that may positively affect health and mental health outcomes.

Practice standards in treatment approaches are suggested to begin with a thorough assessment of the individual including a QEEG that is matched to historical functioning, current functioning, and desired future functioning (Hammond & Kirk, 2008; Thompson & Thompson, 2016; Wigton and Krigbaum, 2015). Practitioners must also follow the ethical and practice standards for the area in which they have licensure. Technology advances have increased accuracy and access in neurofeedback, but it is important to note that organizations including BCIA (2016), AAPB (2008), and ISNR (2017) do not endorse any specific product(s) (software or hardware) and rather focus on maintaining ethics, standards, and knowledge within the field.

Strengths

A primary strength of neurofeedback rests in the fact that it is not introducing a chemical into the body and is an opportunity for the individual to learn to regulate his or her brain waves from the monitoring and feedback of the brain itself (Koberda et al., 2012). Like learning to ride a bicycle, neurofeedback is an opportunity for long term change. A headache could be a side effect of neurofeedback, but such a side effect that is a direct result of neurofeedback training can be reversed trained by the implementation of the opposite training protocol and thus eliminating the negative effect (Arns, et al., 2014). This type of brain regulation results from the internal change of brain functioning which is not reliant on the ingestion of a chemical that must be repeated when the effects of the chemical wear off. Without the addition of new chemicals in the body, treatment tolerance increases and potential withdrawal symptoms decrease (Arns, et al., 2014). Such strengths can be appealing especially when desiring a holistic or natural approach to functioning that will last and prompts the necessary investigation of the relevant current studies to increase our understanding of the efficacy of neurofeedback for physical and mental health outcomes.

Criticism

Side effects commonly occur with treatment interventions, even those that are determined to be reliably effective. A major criticism of neurofeedback treatment is the lack of reported negative effects resulting from treatment (Thibault & Raz, 2017). Possibly, Hammond and Kirk (2008) correctly suggested that adverse or iatrogenic effects of neurofeedback are connected to a lack of adherence to practice standards. This could explain the lack of reported negative effects considering researchers are more likely to avoid criticism when publish if they follow practice standards (Haidich, 2010).

Another major criticism of neurofeedback treatment is the documented financial interest of many of the researchers because they make a profit by either practicing neurofeedback in a clinical context selling neurofeedback equipment and software (Thibault & Raz, 2017). While financial interest is not entirely uncommon in clinical or pharmaceutical research, author or researcher bias can also impact outcomes towards their preference (Thibault & Raz, 2017). For example, many of the board members of the International Society for Neurofeedback Research (ISNR) and the Association for Applied Psychophysiology and Biofeedback (AAPB), the two major organizations related to neurofeedback, maintain financial interest in neurofeedback in some capacity (Thibault & Raz, 2017). On the other hand, such financial investment could signify deep interest in the field based on research and outcomes that indicate efficacy and positive change.

Side Effects and Placebo

The most simplistic consideration for the placebo effect is that all treatments can have a placebo effect (Demos, 2005). The risk of the placebo effect driving positive results exists especially when considering that research participants are likely to want and expect a treatment to work (Thibault & Raz, 2017). The placebo effect has the potential to mask less than effective treatments as participants likely want their symptomology to improve and as such, their hope and desire for improvement could be enough to convince them change has occurred. Research in the benefits of neurofeedback treatment over placebo or sham treatment effects have yet to make a compelling enough case for neurofeedback to become a recognized clinical standard of care (Thibault & Raz, 2017).

The overestimation of treatment effects in relation to mental health treatment is noted by Cuijpers and Cristea (2016) to be common. Evidence does exist that purports benefits of neurofeedback, but not with enough specificity to separate positive treatment effect from placebo effect (Thibault & Raz, 2017). It is helpful to have clarification that neurofeedback treatment outcomes are not likely to be overestimated given it is not yet a clinical standard of care and perhaps a meta-analysis of the independent studies can increase available documentation on the efficacy of the treatment for physical and mental health outcomes.

Neurotransmitters (chemical brain activity) have been documented to be altered through placebo treatment/effect, making a case for the level of difficulty that could be involved in separating the effectiveness of neurofeedback treatment from placebo (Thibault & Raz, 2017). A final noteworthy consideration is the idea of a placebo network that works with the hippocampus which may result in improvements to memory and validate that the placebo effect might be beneficial to brain plasticity and improvement (Thompson & Thompson, 2016).

Iatrogenic Harm

Iatrogenic harm is harm that results from the interaction of the individual with the medical community either from the treatment or from the clinician. Without neurofeedback being accepted as a clinical standard of care, the risk of iatrogenic harm increases with the administration of neurofeedback treatment as the clinician is opting to not follow the clinical standard of care (Thibault & Raz, 2017). Another consideration that can be made by clinicians is that treatments need to be tried to determine clinical utility and to prove effectiveness prior to becoming a standard of care, which does not necessarily indicate that iatrogenic harm will result from the use of neurofeedback treatment. Cuijpers and Cristea (2016) warn that in determining clinical effectiveness of new treatments, even with clinical trials, it is still possible (even likely) that researchers and clinicians can manipulate the circumstances to obtain favorable results while retaining the failsafe of only publishing favorable outcomes. Thompson and Thompson (2016) argued that neurofeedback is not a drug and cannot be researched in the same way as a drug with clinical trials that use blinding or placebo. A placebo in neurofeedback does not exist as a sugar pill exists for pharmacology; a placebo in neurofeedback administers neurofeedback where the learner would view feedback from a brain other than their own, during which time they could operantly learn to dysregulate their brain functioning (King, 2016; Thibault & Raz, 2017; Thompson & Thompson, 2016). This is neither safe nor conducive to determining the efficacy of the treatment.

Specific considerations about why neurofeedback might present adverse or iatrogenic effects were presented by Hammond and Kirk (2008) and include an increase in unqualified professionals providing treatment, a lack of emphasis on standards of practice within the field, providers not seeking competency and continuing education trainings, and licensed healthcare providers who choose not to obtain a neurofeedback certification. Thompson and Thompson (2016) argued that researchers unfamiliar with the underpinnings of how brain change through brain wave regulation occurs are in a position to incorrectly dismiss independent research studies that do not include blinding or placebo conditions and in doing so overlook a significant portion of the clinical research on the treatment that could increase the overall understanding of the efficacy of the treatment.

Neurofeedback in Physical and Mental Health

Physical and mental health influence one another and affect the overall well-being of the individual. A goal of the brain and body is homeostasis, stability or regularity within the system and its functioning, which can increase the predictability and consistency of the individual within their environment (Thompson & Thompson, 2016). As environments change (home, work, school, and so forth), similar behaviors elicit differing outcomes that create a need to change behaviors, requiring the brain to assess and modify how the individual should interact with the environment to achieve homeostasis (Kobayashi et al., 2010). If the body symbolizes physical health and the brain symbolizes mental health, it is the interaction and cooperation of both that results in overall well-being (homeostasis). Neurofeedback works to achieve brain wave regulation, which is likely to be a state of homeostasis for the brain. Achieving stability and regularity in the functioning of the brain is likely to have a positive impact on the functioning of the body, thus resulting in increased overall health and well-being.

Neurofeedback offers the opportunity for the brain to learn to function with less instability and dysregulation. According to Thompson and Thompson (2016), research has documented increased gray and white matter volume in the brain as a result of neurofeedback training. Once learning has occurred (like learning to ride a bicycle), it is no longer necessary to continue with the treatment. An example presented by Thompson and Thompson (2016) for offering neurofeedback as a business model is that repeat business is not likely because once learning has occurred, the need for the treatment no longer exists. The potential for neurofeedback to positively affect physical and mental health indicates a need to understand the overall efficacy of the treatment for physical and mental outcomes.

Neurofeedback Procedures

International 10/20 System of Electrode Placement

The international 10/20 system of electrode placement dictates the specific location of the scalp to place the electrode to be used in the recording of EEG data (Thatcher, 2016). The 10/20 references the percentage, 10% or 20%, of distance between scalp locations of the electrodes (typically 19) used for recording brain activity beneath the scalp (Marzbani et al., 2016). Two electrodes are used for a ground and reference electrode. This standard system of measurement creates consistency in acquired data from brain activity by ensuring that electrodes are placed in specific positions on the scalp and correspond to the specific cerebral location beneath the scalp.

Training by Channel

Neurofeedback training can be done utilizing a single channel and commonly uses 19 channels placed on the scalp using the international 10/20 system (Thompson & Thompson, 2016). Each channel is placed on the scalp with an electrode and is connected to an amplifier that records and transmits the EEG data to a computer. An increase in the number of channels used in training increases the number of potential areas of the brain that can be trained simultaneously. This increase also signifies an increase in the number of potential protocols that can be selected for training. One possible advantage to the use of 19 channels is that it can reduce the overall number of sessions required for learning to occur, and with fewer required sessions the likelihood of early termination reduces (Wigton, 2013).

QEEG Guided

Neurofeedback that is guided by a QEEG requires that a QEEG be completed prior to the neurofeedback training. The clinician doing the neurofeedback training does not need to be the clinician completing the QEEG. The clinician conducting the neurofeedback training must create protocols for training from the information acquired from the QEEG, client symptomology, clinical assessment, and so forth. The training is completed over a number of sessions and then another QEEG is requested to determine current treatment effectiveness and directions for continued training (Wigton, 2013).

Live Z-Score

Live *z* score neurofeedback begins with a QEEG prior to each training session to allow for the data of the brain at that time to be compared to the normative database and then to allow for protocol selection of neurofeedback training (Wigton & Krigbaum, 2015). The primary goal of all live *z* score neurofeedback training sessions is to train towards normalization of the QEEG ($z = 0$) in a way that is tailored for each client at each session (Wigton & Krigbaum, 2015). Clinicians can select the number of channels (1-19), or more specifically, which channels to include in training protocols based on the information from the current QEEG. Using 19 channel *z* score neurofeedback offers the potential opportunity to decrease the total number of neurofeedback sessions required and to decrease the frequency of the number of neurofeedback sessions necessary weekly while simultaneously increasing QEEG normalization and improving symptomology (Wigton & Krigbaum, 2015).

LORETA

Low resolution electromagnetic tomography (LORETA) neurofeedback is a type of neurofeedback that uses all 19 channels to record and monitor brain wave activity creating a 3-dimensional correspondence of the brain with the Brodmann areas and a reference magnetic resonance image (MRI) (Thatcher, 2016). Hubs, modules, and networks with the brain and Brodmann areas including phase, coherence, and symptoms are considered for neurofeedback training when utilizing LORETA neurofeedback. When using LORETA neurofeedback, specific brain networks can be targeted, such as the attention network, addiction network, default mode network, and so forth, which are connected to the Brodmann areas affecting connectivity between areas of the brain, and can be trained simultaneously (Thompson & Thompson, 2016).

Prior Meta-Analyses and Systematic Reviews

Neurofeedback has been researched in varying populations with differing physical symptomology (physical health) and psychological diagnoses (mental health) in single studies. While each individual study is useful to the field and for physical and mental health outcomes, a collective view of the outcomes of those studies can provide a clearer picture of the state of the art and its overall combined efficacy for physical and mental health outcomes. I located and examined a total of six meta-analyses and systematic reviews of biofeedback and neurofeedback to determine the need for this meta-analysis.

Of the six studies, Tan et al., (2009) focused on neurofeedback specifically used in the treatment of epilepsy and seizures. Even with positive outcomes for neurofeedback reported, the meta-analysis by Tan et al., (2009) is not current and has a limited focus for considering the overall efficacy of neurofeedback for physical and mental health outcomes. Schoenberg and David (2014) systematically reviewed sixty-three articles of both biofeedback and EEG biofeedback for psychiatric disorders. This review is current, within the last five years, but includes biofeedback modalities like electromyograph (EMG) biofeedback, heart rate variability (HRV) biofeedback, heart rate (HR) biofeedback, electrodermal (EDA) biofeedback, and thermal biofeedback, as well as EEG biofeedback (neurofeedback) for specific psychological diagnoses. The remaining four studies focused on fatigue and cognition (Luctkar-Flude and Groll, 2015), what to do and what not to do for neurofeedback training (Rogala et al., 2016), on neurofeedback for optimizing athletic performance (Mirifar et al., 2017), and on neurofeedback for cognitive rehabilitation following a stroke (Renton et al., 2017). These reviews offer information that is useful for physical and mental health outcomes in each specific area reviewed but fail to offer an overall understanding of the efficacy of neurofeedback for physical and mental health outcomes.

Excluding ADHD

The American Academy of Pediatrics (2013) lists biofeedback as a level 1 intervention for attention and hyperactivity behaviors. A level 1 intervention, according to the American Academy of Pediatrics (2013), is a best support intervention that is supported by at least two randomized trials supporting the efficacy of the treatment as superior to placebo or alternative treatments and demonstrates adequate statistical power with significant pre to post study change. In an evaluative review of ADHD treatment by neurofeedback, Arns et al. (2014) found clinical effectiveness in the use of neurofeedback treatment for ADHD including what they have determined to be lasting effects. Arns et al. (2014) concluded their review noting that neurofeedback for ADHD treatment should be considered evidence-based treatment. In this regard it is not necessary to include neurofeedback for ADHD in this meta-analysis as using neurofeedback for ADHD treatment is evidenced to increase current physical and mental health outcomes for individuals and communities.

Summary and Conclusions

Since the 1950s, neurofeedback has continued to evolve in technique, software, and hardware, leaving considerable debate about efficacy. The treatment approach has been identified by the American Academy of Pediatrics (2013) as a level 1 intervention for attention and hyperactivity behaviors and by Arns et al. (2014) as efficacious in treating ADHD. Beyond efficacy in ADHD, the literature has yet to establish the efficacy of neurofeedback for physical and mental health outcomes. Considering the evolution of the field, including the new technologies and approaches, as well as new studies not included in meta-analytic studies, it is possible that neurofeedback can effectively treat various physical and mental health conditions. Cumming (2013) referred to meta-analysis as the estimation of the effect across multiple studies resulting in information that is practical and usable for researchers and clinicians as meta-analysis answers broad questions about effectiveness (how large, how many, to what extent) rather than typical yes or no questions presented by null hypothesis significance testing which are frequently misleading. The results of the meta-analysis offer a much-needed analysis of the state of the art for the efficacy of physical and mental health conditions, other than ADHD.

Chapter 3: Research Method

Introduction

When conducting systematic reviews, researchers follow a distinct methodical and systematic approach to selecting and reviewing existing research studies to critically analyze the studies' data using statistical calculations to integrate and synthesize those data (Moher et al., 2009). Researchers give thoughtful consideration to the selection and review of the existing studies, including the procedures used for selection, data collection, coding, and statistical analysis, because these methods lend to the quality, significance, and outcomes of the meta-analysis. The quality of a systematic review and meta-analysis can be improved by following established guidelines such as the PRISMA guidelines (Gates & March, 2016). Systematic reviews and meta-analyses serve as research evidence that is likely to be used by practitioners in a field of study to maintain current information to make informed decisions for assessment, diagnosis, treatment, and future research (Gates & March, 2016).

Research Design and Rationale

I used quantitative meta-analysis to investigate the efficacy of neurofeedback for physical and mental health outcomes because the meta-analysis presented the opportunity to synthesize the results of multiple studies into a single source with data quantified via overall effect size (Huffcutt, 2004). Meta-analytic research is an important tool in psychology education because the critical evaluation of evidence across a diverse body of research on a topic is a valuable and necessary skill in the discipline. This systematic review and meta-analysis of the efficacy of neurofeedback has pedagogic value for educators working to provide instruction on the body of evidence on neurofeedback rather than focusing on a few pivotal studies.

A single research study may show statistical significance, whereas a meta-analysis pools meaningful data, including those regarding potential benefits of a particular treatment, from much of the existing available research to arrive at an overall look at the state of the art as a whole (Haidich, 2010). The synthesized data provided evidence to either support the use of neurofeedback for physical and mental health interventions, or to show the inefficacy of neurofeedback for these interventions. In this meta-analysis, I provide practical suggestions for current decisions regarding the use of neurofeedback and suggest directions for future primary research.

Methodology

Selection Criteria

In accordance with the Walden University institutional review board approval number 06-13-18-0138407, I proceeded with the following processes for this meta-analysis. My primary goal for the literature search was to locate all scientific research studies published or unpublished on the use of neurofeedback for physical and mental health. This identification and selection of studies for inclusion in the meta-analysis followed a series of predetermined steps, including maintaining records of how studies were selected or rejected for inclusion in the final sample used for meta-analysis. I used the PRISMA guidelines flowchart shown in Figure 1. This flowchart represents the study selection process as it progressed from identification to screening, then to eligibility, and finally to those studies included in the meta-analysis (see Gates & March, 2016). In accordance with PRISMA guidelines for stating eligibility criteria for study inclusion or exclusion, I included as many studies as possible, excluding only those that did not meet the criteria for inclusion. Studies that were not appropriate for data extraction for the meta-analysis and studies that lacked data appropriate for calculating effect sizes were not eligible for inclusion in the meta-analysis, but I reviewed them for information on interpreting effect size calculations. I also reviewed these studies for advice in reporting directions for future research.

I searched the following electronic databases for studies to include in the meta-analysis including Medline, CINAHL, PsycARTICLES, PsycINFO, SocINDEX, ScienceDirect, IEEE Xplore Digital Library, PubMed, clinicaltrials.gov, OHRP, NIH, FDA, and Cochrane Register of Controlled Trials. Keywords searched included *EEG biofeedback*, *neurofeedback*, *fMRI*, and *ADHD*. For the latter two, I used the Boolean operator *NOT* to reduce the number of studies that would need to be excluded later.

After studies were identified for possible inclusion in the meta-analysis, I reviewed abstracts of those studies for inclusion and exclusion criteria. For inclusion in the meta-analysis, studies needed to be (a) published in English; (b) published within the previous 10 years (if published); (c) quantitative, empirical studies (not meta-analysis or reviews) of only human subjects; and (d) on a specified method or protocol of neurofeedback. Duplicate studies, qualitative studies, reviews, meta-analyses, editorials, and expert opinion articles were excluded from this meta-analysis. Published studies included peer reviewed publications and unpublished studies included gray literature documents such as conference proceedings, clinical trials in progress, clinical trials not published, reports, and dissertations. Studies that appeared to meet the inclusion criteria after I reviewed the abstracts and were available in full-text were further analyzed to determine if inclusion criteria were met. The studies that did not report means, standard deviations, correlation coefficients, or *t*-test data that could be used to calculate effect sizes were excluded. After these steps were completed, the remaining studies were marked for inclusion in the meta-analysis.

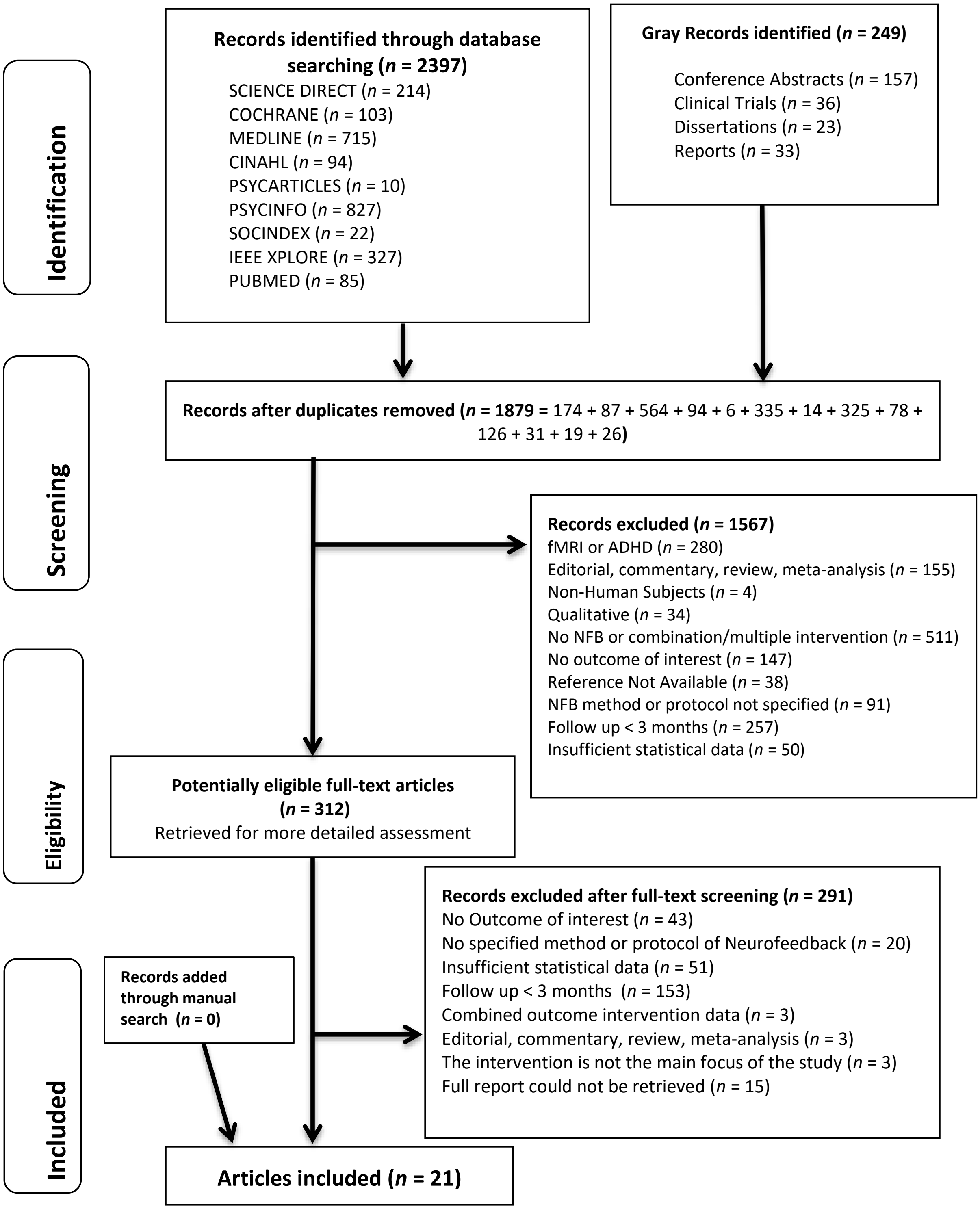

Figure 1. PRISMA meta-analysis flowchart.

Data Extraction and Analysis

Each study meeting the inclusion criteria was organized and manually coded by data format (sample size, means and standard deviations, correlations, and *t*-tests). Effect sizes for Cohen's *d* were manually calculated for each outcome. The newest version of Comprehensive Meta-Analysis (CMA, 2015) software Version 3 was used to compute the statistical analyses for the meta-analysis. CMA (2015) accepts multiple data formats (sample size, means and standard deviations, correlations, and *t*-tests) for computation of effect size and confidence intervals. Once each study was organized and coded by data format and outcomes, I entered the data into the spreadsheet interface in CMA (2015) for computation of the meta-analysis including data statistics for each study; Hedges' *g* and confidence intervals at 95%.

Effect Size Calculation and Statistical Procedures

Research studies included in the meta-analysis based on the criteria had available statistical data including sample size, means, standard deviations, effect size, correlation coefficients, or *t*-test data that I used for new statistical calculations to address the research question in this meta-analysis: What are the effects of neurofeedback on physical and mental health outcomes? Research case studies that included statistical data, could be calculated to determine an estimated effect size, and met the inclusion criteria were included and calculated for the estimated effect size.

Threats to Validity

Internal validity in a meta-analytic research study is based on the compilation of each of the independent research studies included. Threats to the internal validity of this study could have occurred when an included research study was not of good quality or did not provide data appropriate for answering the research question (see Creswell, 2014). Because a meta-analysis involves the synthesis and calculation of data from all included studies, any imperfection in a single included study may negatively impact the resulting outcomes. Since research is not a perfect process, even when significant effort is exerted to reduce imperfections in a study, human and systematic error are always possible. These internal threats to validity are difficult if not impossible to control for in a meta-analysis, indicating the need for researchers to follow predetermined guidelines for study selection and to evaluate each research study for quality and fit into the meta-analytic research. Any determined bias can be considered when reporting the final interpretation of the overall meta-analytic study outcomes (Card, 2011).

Threats to the external validity of a meta-analysis present when the included studies are not generalizable to the broader population. I designed this meta-analysis to determine the efficacy of neurofeedback for physical and mental health outcomes, with documented support for the exclusion of fMRI neurofeedback and ADHD. An example of threats to the external validity of this meta-analysis would be the inclusion of research that is focused on fMRI neurofeedback or ADHD, as these characteristics are not generalizable to the types of neurofeedback included nor to the population that might benefit from the results of this meta-analysis. The clinical populations receiving fMRI neurofeedback or neurofeedback for ADHD are not reflective of the typical population to which this meta-analytic study can be generalized. As such, I guarded against threats to external validity by excluding treatment variations and populations that were not of interest when answering the research question. Studies with different designs, different patients, and different symptomology (outside of ADHD) were included to allow for increased generalizability, another measure for ensuring external validity.

Threats to Reliability

Reliability in research is defined as research that can be repeated in the future yielding the same or similar results given the same study conditions. A meta-analysis, begins with data extracted from each independent research study included. Threats to the reliability in this meta-analysis included the potential for inaccurate data extraction of each independent research study included. A potential solution could have been to use more than one researcher, but this was not practical for this meta-analytic dissertation. The alternative I chose was to review the extracted data from each of the independent research studies on two separate occasions, which proved to be a practical solution for this meta-analysis (see Card, 2011).

Ethical Procedures

As part of the systematic review and literature selection process, I reviewed studies for ethical treatment of the participants. Given the nature of meta-analytic research utilizing secondary data, I did not directly use participants in data collection. The data that was used in the meta-analysis was pooled from statistical data of the included researched studies, which was data that had been previously collected from participants. Given that participants were not used in this meta-analysis because it used secondary data, ethical treatment of the participants was not a concern.

Summary

This study consisted of a meta-analysis of published and unpublished research into the efficacy of neurofeedback for physical and mental health outcomes. I followed a strategized plan for locating relevant studies in this chapter (see Figure 1). Table 1, included in chapter 4, outlines the major characteristic qualities of the research that I compiled for inclusion in this meta-analysis. I analyzed the extracted data with CMA (2015) software specifically designed for the statistical analyses involved with meta-analytic research. Chapter 4 includes the results and interpretations of the statistical analyses as they connect to the original research question. The results and interpretations of this meta-analysis that I reported in chapter 4 create the foundation for the conclusions about the efficacy of neurofeedback for physical and mental health outcomes in chapter 5.

Chapter 4: Results

In this meta-analysis, I addressed the overall efficacy of neurofeedback for physical and mental health outcomes while acquiring pedagogic value in understanding a body of evidence. According to the World Health Organization (2018) physical and mental health outcomes are important to society in areas of existence like safety and peace. Neurofeedback offers an innovative approach to physical and mental health, yet its efficacy has remained unclear in the clinical research (Alkoby et al., 2017; Marzbani et al., 2016).

In this study, I aimed to determine the effects of neurofeedback on physical and mental health outcomes across published and unpublished studies. To determine the efficacy of neurofeedback, I developed the following research question for this meta-analysis: What are the effects of neurofeedback on physical and mental health outcomes across published and unpublished studies? The hypothesis was that neurofeedback has a significant effect on physical and mental health outcomes across published and unpublished studies, and the null hypothesis was that neurofeedback does not have a significant effect on physical and mental health outcomes as determined by a meta-analysis of published and unpublished studies.

I included the results from 21 studies with neurofeedback used as a physical and mental health intervention for obesity, depression, attention in intellectual disability, intelligence, insomnia, food craving, dysgraphia, autism, clinical personality accentuations in alcohol use disorder, pain, peripheral neuropathy in cancer survivors, fibromyalgia, tinnitus, and so forth. A total of 756 participants were included across the

21 studies ranging in age from six to 80. In this chapter, I present data collection procedures, study data of each included study, data management procedures, and results of the meta-analysis.

Data Collection

I conducted a literature search for English-language publications on the use of neurofeedback for physical or mental health outcomes, excluding ADHD and fMRI. I attempted to collect all scientifically relevant investigations on the use of neurofeedback for physical and mental health outcomes including published and unpublished studies. To reduce the potential for bias, published studies included peer reviewed publications and unpublished studies included gray literature documents such as conference abstracts, clinical trials in progress and not published, reports, and dissertations.

The initial searches of academic databases led me to the following results (by database): ScienceDirect (n = 214), Cochrane Register of Controlled Trials (n = 103), Medline (n = 715), CINAHL (n = 94), PyscARTICLES (n = 10), PsycInfo (n = 827), SocINDEX (n = 22), IEEE Xplore Digital Library (n = 327), PubMed (n = 85), and the following for unpublished studies clinicaltrials.gov, OHRP, NIH, FDA, resulting in conference abstracts (n = 157), clinical trials (n = 36), dissertations (n = 23), and reports (n = 33; see Figure 1).

Keywords searched included *EEG biofeedback*, *neurofeedback*, *fMRI*, and *ADHD*. For the latter two, I used the Boolean operator *NOT* to reduce the number of studies that would need to be excluded later. In addition to limiting the searches to English-language publications, I also limited the searches to studies published within the last 10 years (from 2009), and studies involving human subjects. I did not include books, but did include conference papers and presentations, magazine articles, dissertations, early access articles, and clinical trials. This search resulted in an initial body of references totaling 2,397 sources. After the removal of duplicates, 1,879 sources remained.

A goal of meta-analysis is to include as many scientifically relevant sources as possible. With this goal in mind, I predetermined specific inclusion and exclusion criteria to maintain the integrity and quality of the results of the meta-analysis. As such, my review of the 1,879 article abstracts resulted in exclusion of 1,567 articles because they did not meet the inclusion criteria described in Chapter 3. Studies excluded with no outcome of interest include those with a primary intervention of EEG biofeedback, EMG biofeedback, or those using EEG to measure brainwave patterns or changes during varying tasks such as meditation, guided imagery, drawing, playing video games, and so forth, but that did not use neurofeedback as an intervention for physical or mental health outcomes. Studies excluded for insufficient statistical data include those that did not report means, standard deviations, correlation coefficients, or *t*-test data that could be used to calculate effect sizes. Reasons for article exclusion are as follows: editorial, commentary, review, and meta-analysis articles ($n = 155$); fMRI or ADHD ($n = 280$); non-human subjects ($n = 4$); qualitative ($n = 34$); no neurofeedback or combination intervention ($n = 511$); no outcome of interest ($n = 147$); neurofeedback method or protocol not specified ($n = 91$); follow up under 3 months ($n = 257$); insufficient statistical data ($n = 50$); and reference abstract not available ($n = 38$). A total of 312 studies remained for full text retrieval and review.

During the full text review of the 312 studies, 291 studies did not fit the inclusion criteria and were excluded. Studies excluded with no outcome of interest include those with a primary intervention of EEG biofeedback, EMG biofeedback, or those using EEG to measure brainwave patterns or changes during varying tasks such as meditation, guided imagery, drawing, playing video games, and so forth, but do not use neurofeedback as an intervention for health or mental health outcomes. Studies excluded for insufficient statistical data include those that did not report means, standard deviations, correlation coefficients, or *t*-test data that could be used to calculate effect sizes. Of the 291 excluded studies, reasons for exclusion were as follows: editorial, commentary, review, and meta-analysis articles (*n* = 3); no specified method or protocol of neurofeedback (*n* = 20); no outcome of interest (*n* = 43); combined outcome intervention data (*n* = 3); follow up under 3 months (*n* = 153); insufficient statistical data (*n* = 51); the intervention is not the main focus of the study (*n* = 3); and full report could not be retrieved (*n* = 15). Thus, I included 21 published studies and 0 unpublished studies.

I manually searched the references lists of the 21 studies included in the meta-analysis for additional studies meeting the inclusion criteria for this meta-analysis. Six articles were selected from the manual review of included studies to be pulled for further review. After further review of the six articles, I found that none met the inclusion criteria. Two lacked a follow up of three months, three did not have sufficient statistical data, and one article could not be retrieved in full text.

Table 1 illustrates the major characteristics of the studies included in the meta-analysis. Of the 21 studies, six were conducted in the United States with U.S. participants, and the remaining 15 studies were conducted outside of the United States. A single study had more the 100 participants, 6 studies had up to 51 participants, 12 studies had up to 26 participants, and 2 studies had between 62 and 70 participants. Six studies used up to 19-channel neurofeedback training, the remaining used four or fewer channels for training, with single-channel training being the most commonly used (at eight studies). Eleven studies included QEEG, and the average number of neurofeedback training sessions across the 21 studies was 32.5 sessions. Interestingly, the highest number of neurofeedback training sessions was used in combination with up to 19-channel training and QEEG, with up to 160 sessions in one study, up to 120 sessions in another, then up to 84, up to 59, and 48 in others. This seems to contradict the idea that the use of QEEG and up to 19-channel training in session can reduce the number and frequency of neurofeedback sessions required to create symptomology improvement (Wigton & Krigbaum, 2015).

Table 1

Major Characteristics of the Studies Included in the Meta-Analysis (N = 21)

Reference	Total N	Design	USA or non-USA	EEG neurofeedback for:	# of scalp training electrodes	# of neurofeedback sessions	QEEG used	Outcome measure(s)	Health or mental health
Chirita-Emandi and Puiu (2014)	34	Controlled pilot	Non-USA	Obesity	3	20	No	Eating behavior (TFEQ) and quality of life (KINDL)	Health and mental health
Crocetti, Forti, and Del Bo (2011)	15	Case controlled	Non-USA	Tinnitus	4	12	No	Tinnitus Handicap Inventory (THI)	Mental health
Dalkner et al. (2017)	25	Controlled study	Non-USA	Clinical personality accentuations in Alcohol Use Disorder (AUD)	3	12	No	Inventory of Clinical Personality Accentuations (ICP) and the NEO Five Factor Inventory (NEO-FFI)	Mental health
Hammer, Colbert, Brown, and Ilioi (2011)	8	Pre-post pilot	USA	insomnia	2	15	Yes	Pittsburgh Sleep Quality Index –Total (PSQI-T)	Health
Hong, and Lee (2012)	14	Controlled trial	Non-USA	Intellectual disability (attention)	3	36	No	Children’s color trails test -2, stroop color and word test, and digit span test	Mental health

Reference	Total N	Design	USA or non-USA	EEG neurofeedback for:	# of scalp training electrodes	# of neurofeedback sessions	QEEG used	Outcome measure(s)	Health or mental health
Imperatori et al. (2017)	50	Randomized controlled trial	Non-USA	Food craving (non-clinical sample)	1	10	Yes	Food Cravings Questionnaire-Trait (FCQT) and Global Severity Index (GSI)	Health and mental health
Jensen et al. (2013)	10	Pre-post case series	USA	Spinal Cord Injury (SCI) and chronic pain	2	12	Yes	0-10 Numerical Rating Scale of pain intensity (NRS-11)	Health
Kayıran et al. (2010)	36	Randomized controlled trial	Non-USA	Fibromyalgia	1	20	No	Visual Analogue Scale (VAS) for pain, VAS for fatigue, Hamilton Depression Scale (HDS), Beck Depression Scale (BDS), Hamilton Anxiety Scale (HAS), and Beck Anxiety Scale (BAS)	Health and mental health

Reference	Total N	Design	USA or non-USA	EEG neurofeedback for:	# of scalp training electrodes	# of neurofeedback sessions	QEEG used	Outcome measure(s)	Health or mental health
Kouijzer et al.(2010)	20	Randomized controlled trial	Non-USA	Autism Spectrum Disorders (ASD)	1	40	Yes	Social Communication Questionnaire (SCQ), Social Responsiveness Scale (SRS), Children's Communication Checklist (CCC-2)	Mental health
Kouijzer et al. (2013)	13	Randomized controlled trial	Non-USA	Autism Spectrum Disorders (ASD)	1	40	Yes	Social Communication Questionnaire (SCQ), Trail Making Test (TMT), stroop task, Tower of London (TOL), Test of Sustained Selective Attention (TOSSA), digit span from the Wechsler Intelligence Scale for Children 3rd version (WISC-3)	Mental health

Reference	Total N	Design	USA or non-USA	EEG neurofeedback for:	# of scalp training electrodes	# of neurofeedback sessions	QEEG used	Outcome measure(s)	Health or mental health
Prinsloo et al. (2018)	62	Randomized controlled trial	USA	cancer survivors with Chemotherapy-Induced Peripheral Neuropathy (CIPN) symptoms	≤19	20	Yes	MD Anderson Symptom Inventory (MDASI), 36-Item Short Form Survey (SF-36), Brief Fatigue Inventory (BFI), and Pittsburgh Sleep Quality Index (PSQI)	Health
Saki, Davoodi, Nosratabadi, and Yadollahpour, (2016)	10	Controlled trial	Non-USA	Tinnitus	Not specified	15	No	Tinnitus Severity Index (TSI) and Tinnitus Questionnaire (TQ)	Mental health
Sokhadze and Daniels (2016)	11	Pre-post case series	USA	Prevent drug abuse; increase positive emotional state	1	12	No	Continuous Response Digital Interface (CRDI) - happiness	Mental health
Strehl, Kotchoubey, Martinetz, and Birbaumer (2011)	70	Pre-post trial	Non-USA	IQ (in epilepsy)	1	30-35	No	Wechsler Adult Intelligence Scale (WAIS) - IQ	Mental health

Reference	Total N	Design	USA or non-USA	EEG neurofeedback for:	# of scalp training electrodes	# of neurofeedback sessions	QEEG used	Outcome measure(s)	Health or mental health
Surmeli and Ertem (2011)	36	Pre-post case series	Non-USA	Obsessive Compulsvie Disorder (OCD)	≤19	9-84	Yes	Yale Brown Obsessive-Compulsive Scale (Y-BOCS)	Mental health
Surmeli and Ertem (2010)	21	Pre-post case series	Non-USA	Mental retardation (DSM-IV)	≤19	80-160	Yes	Wechsler Intelligence Scale for Children – Revised (WISC-R)	Mental health
Surmeli and Ertem (2009)	13	Pre-post case series	Non-USA	Antisocial personality disorder	≤19	80-120	Yes	Minnesota Multiphasic Personality Inventory (MMPI), and Symptom Assessment-45 Questionnaire (SA-45)	Mental health
Surmeli, Ertem, Eralp, and Kos (2012)	51	Pre-post case series	Non-USA	Schizophrenia	≤19	58-59	Yes	Positive and Negative Syndrome Scale (PANSS) - Total	Mental health
Surmeli et al. (2017)	40	Prepost case series	Non-USA	Postconcussion Syndrome (PCS)	≤19	48	Yes	Symptom Assessment-45 Questionnaire (SA-45) and Global Severity Index (GSI)	Mental health

Reference	Total N	Design	USA or non-USA	EEG neurofeedback for:	# of scalp training electrodes	# of neurofeedback sessions	QEEG used	Outcome measure(s)	Health or mental health
Walker (2012)	26	Controlled case series	USA	Dysgraphia	1	5-10	Yes	Checklist of written expression	Health
Walker and Lawson (2013)	186	Pre-post case series	USA	Drug resistant depression	1	6	No	Rush quick self-rated depression inventory	Mental health

Assessment of Methodological Quality

To assess for methodological quality, I reviewed each of the studies for participation bias, attrition bias, outcome measurement, and data analysis and reporting. Participation bias required assessing for an adequate description of the key characteristics and inclusion and exclusion criteria applicable to the study population. Attrition bias required assessing for whether the study had a follow-up at least three months after the conclusion of the study and documentation of any missing participant data. Outcome measurement required assessing for an objective outcome definition provided in advance of the intervention. Data analysis and reporting domain required assessing for alpha (type 1) and/or beta (type 2) error specifications and inclusion of outcome data. Table 2 illustrates each criterion and whether or a not a study met that criterion.

Table 2

Methodological Quality of Studies Included in Meta-Analysis (N = 21)

Criteria	Criteria met	
	n/N	%
Participation bias		
Adequate description of key characteristics	19/21	90
Adequate description of inclusion/exclusion criteria	21/21	100
Attrition bias		
At least 3 months to follow-up	21/21	100
Documentation of missing participation data	21/21	100
Outcome measurement		
Objective definition of outcome	21/21	100
Definition provided in advance of outcome	21/21	100
Data analysis and reporting		
Alpha and/or beta error specifications	21/21	100
Outcome data included	21/21	100

Statistical Analyses

The 21 studies included in the meta-analyses included appropriate data for calculating effect sizes. A single study by Kouijzer et al. (2013) involved two independent participant samples, which I have referred to as Kouijzer et al. (2013a) and Kouijzer et al. (2013b) in Tables 4 and 6; this increased the overall number of comparisons used for the meta-analysis to 22. Of the 22 comparisons, 12 used an intervention and control group and reported pre and post means and standard deviations for the intervention and control group. Nine studies included in the meta-analyses used a pre-post within-group design and reported pre and post intervention means and standard deviations. The remaining study used a pre-post within-group intervention design and reported dependent *t*-test and correlation values. I used the data in each study to calculate an effect size, Cohen's *d,* for each of the included outcomes because it is necessary to transform data into a common metric when combining results from different study designs (Morris & DeShon, 2002; Lipsey & Wilson, 2001).

The calculated effect size, Cohen's *d,* offers a measure of the strength of the relationship between variables without making assumptions about the relationship and how accurate it reflects the population (Card, 2011). Each effect size calculation for Cohen's *d* in this study followed the formula of Lipsey and Wilson (2001) where subtracting mean differences of the control or pre-group data (X1) and intervention or post-group data (X2) then dividing by the standard deviation (S) equals *d*:

$$d = \frac{X1 - X2}{S}$$

Data entered in CMA (2015) converts all effect sizes to Hedges' *g* after computing the standardized mean difference. A benefit of using CMA (2015) appears in the ability of the software to accept multiple data formats, convert to Hedges' *g*, and run the analysis. Data formats used in CMA (2015) for this meta-analysis include "Independent groups (means, SDs)" for the control and intervention post-test scores, "Paired groups (mean, SD)" and a pre-post correlation of .99 for the single group pre-post test scores, and "change in each group" for the control and intervention change scores.

The data collected from the 22 study comparisons resulted in Hedges' *g* calculations for 94 outcomes of interest. Using multiple outcomes from the same sample would violate the assumption of independence by assigning more weight to the study even though the same participants and study are being used more than once in the meta-analysis (Morris & DeShon, 2002). To avoid violating this assumption, multiple outcomes in the same study with the same population were combined to a single effect size using CMA (2015).

Study Results

The purpose of this meta-analysis was to evaluate and synthesize the evidence for the efficacy of neurofeedback determined by statistical analyses of the results of included studies that examined efficacy for physical and mental health outcomes. Data for each of the 94 outcomes was entered into CMA (2015) and after multiple study outcomes were combined, 22 outcome statistics were reported as one of the 21 included published studies used two independent samples. CMA (2015) version 3 was used to generate the meta-analysis results and included statistics for Hedges' *g* and confidence intervals (at 95%). Hedges' *g* is interpreted similarly as Cohen's *d* is interpreted, with a small effect at 0.20, a medium effect at 0.50, and a large effect at 0.80 (Lipsey & Wilson, 2001).

CMA (2015) allowed for the analysis to be completed with random or fixed effects models or both. A fixed effects model assumes that that there is only a single true effect size where the random effects model assumes that moderators can create variation in the effect size and is more amenable to generalization purposes when considering differences in sample sizes of included studies (Borenstein, Hedges, Higgins, & Rothstein, 2010). The random effects model weights small studies and large studies so as to not discount a study with a small sample size or overly credit a study with a large sample size, keeping the outcome data in balance when merging a pool of data as is done in meta-analysis. A random effects model was used for this meta-analysis for better generalization and because of the varying procedures and measures used across the studies included in the meta-analysis. Effect size estimates completed in CMA (2015) were weighted by sample size and sampling error corrections were applied.

Effect sizes can be overestimated in meta-analysis when considering publication bias (Lipsey & Wilson, 2001). Frequently studies with significant findings are the ones published, resulting in publication bias which can artificially increase the knowledge base. CMA (2015) offers the funnel plot as a method to explore publication bias by viewing the study size in relation to the effect size; large studies are towards the top, the point of the funnel, and smaller studies towards the bottom, the opening of the funnel. Symmetrical distribution occurs around the average effect size of each studies effect sizes if there is not any evidenced bias. If publication bias is evidenced, symmetry might remain towards the top with studies missing towards the middle and bottom of the plot; the missing studies or gaps in the plot are where the insignificant or unpublished studies would be found (Borenstein et al., 2010).

Figure 2 shows the funnel plot for this meta-analysis. The funnel plot shown in figure 2 appears to be a symmetrical inverted funnel, but lacks studies towards the middle and bottom of the plot, indicating the probability of publication bias (Lipsey & Wilson, 2001). There are three outliers shown in the plot, which represents three studies that varied enough in effect size and standard error to fall outside of the funnel. The outliers are identified in the studies by Prinsloo et al. (2018), Hedges' *g* = 4.29, SE = 0.49, Kayiran et al. (2010), Hedges' *g* = 7.97, SE = 1.00, and Walker (2012), Hedges' *g* = 10.09, SE = 1.57. It is important to consider that this meta-analysis included a lower number of overall studies, 21, with 22 study comparisons, which according to Borenstein et al. (2010) might negatively influence the interpretation of the plot; interpretation of funnel plots can be subjective.

Considering the potential subjectivity of funnel plot interpretation, another option of inquiry for publication bias in meta-analysis is Classic Fail-Safe N. According to CMA (2015) Classic Fail-Safe N is a calculation of the number of studies missing that would be required to be added to the meta-analysis to cancel out the effect, or create statistical insignificance (CMA, 2015). The more studies required to cancel the effect, the less likely it is that the true effect is zero or not significant. For this meta-analysis, 6,139 studies would be required to cancel the effect. Of note, the focus of the Classic Fail-Safe N is statistical significance and not on substantive significance, which is perhaps an archaic approach to determining publication bias in a meta-analysis (Borenstein et al., 2010).

Conducting sensitivity analyses were beneficial to the meta-analysis as they offered me an opportunity to view the impact of removing a single study on the overall results and average effect size (Morris & DeShon, 2002). I performed a sensitivity analysis to determine if a study had a greater impact on the average effect size more than another study included in this meta-analysis.

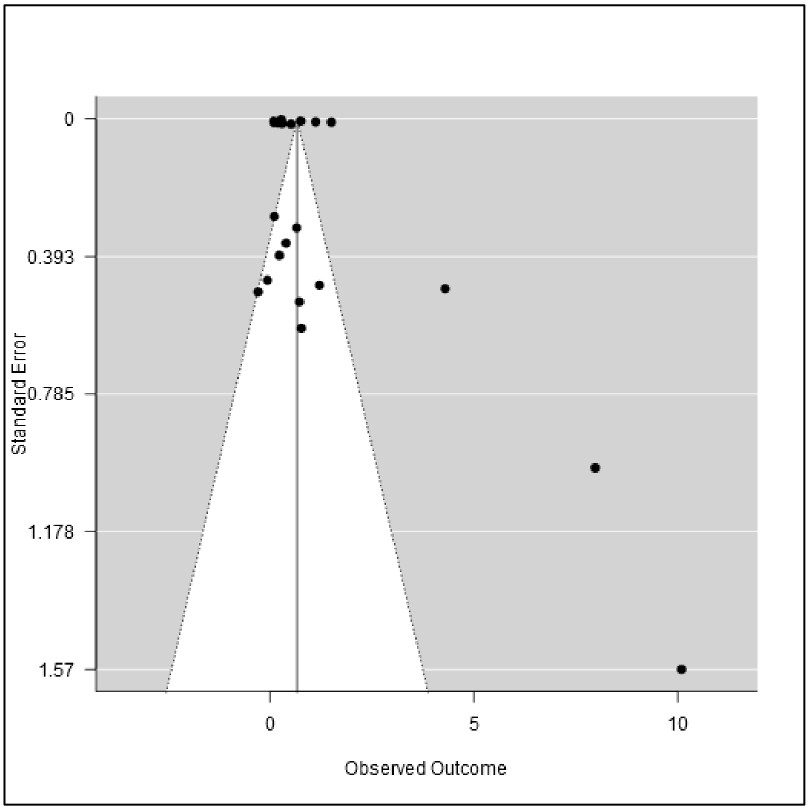

Figure 2. Funnel plot for meta-analysis**.**

Table 3 depicts the meta-analytic data for study outcomes in this meta-analysis. The number of independent samples is represented by *k*, for this meta-analysis, *k* = 22 for overall studies included, when excluding the outliers, *k* = 19, the moderator for health outcomes, *k* = 7, and for mental health outcomes, *k* = 18. Hedges' *g* effect size is represented by *g*, the standard error of Hedges' *g* is represented by SE_g, the 95% confidence interval of Hedges' *g* is represented by 95% CI and LL for lower limit and UL for upper limit, the Q statistic is represented by Q, I squared is represented by I^2, and tau squared is represented by T^2.

I included the results for the meta-analysis in Table 3. For the overall meta-analysis, g = 0.70, 95% CI = [0.49, 0.92], indicating there is a positive effect of neurofeedback on overall outcomes. After removal of the outliers, g = 0.50, 95% CI = [0.27, 0.72], indicating a similar positive effect of neurofeedback on outcomes when the outliers are not included in the analysis. I completed moderator analyses for neurofeedback for physical and mental health outcomes. Neurofeedback for physical health resulted in a positive effect, g = 0.81, 95% CI = [0.54, 1.08] and neurofeedback for mental health resulted in a positive effect, g = 0.59, 95% CI = [0.34, 0.82]. The confidence intervals for neurofeedback for physical and mental health moderators overlapped between the two outcomes, suggesting that the effect of neurofeedback did not differ between physical or mental health outcomes.

Data describing heterogeneity is in Table 3. Heterogeneity was assessed with the Q Statistic. The Q statistic depicts the presence or absence of heterogeneity, or whether the included studies are homogeneous (Card, 2011). I^2 expresses the degree of heterogeneity as a percent of variance due to heterogeneity rather than variance due to chance (CMA, 2015). The overall meta-analysis resulted in I^2 = 99.9%, with outliers excluded I^2 = 99.9%, for physical health outcomes I^2 = 97.9, and for mental health outcomes I^2 = 99.9%. The high I^2 statistic indicates that variance within this meta-analysis has occurred with a normal distribution between studies. T^2 is a measure of variance of the effect sizes between the included studies.

Table 3

Meta-analysis for Study Outcomes

				95% CI				
	K	*g*	SE_g	LL	UL	*Q*	I^2 (%)	T^2
Overall	22	0.70	0.11	0.49	0.92	24653.19**	99.9%	.18
Overall (excluding outliers)	19	0.50	0.12	0.27	0.72	24470.98**	99.9%	.19
Health Outcomes	7	0.81	0.14	0.54	1.08	281.74**	97.9%	.06
Mental Health Outcomes	18	0.59	0.12	0.34	0.82	24422.85	99.9%	.20

Research Question

What are the effects of neurofeedback on physical and mental health outcomes across published and unpublished studies?

The hypothesis was that neurofeedback has a significant effect on physical and mental health outcomes across published and unpublished studies. The null hypothesis was that neurofeedback does not have a significant effect on physical and mental health outcomes as determined by a meta-analysis of published and unpublished studies.

After running the meta-analysis for the 22 included study comparisons the overall effect size, Hedges' *g* was moderately significant, $g = 0.70$, 95% CI = [0.49, 0.92]. Table 4 displays the effect sizes for each of 22 comparisons. After removing the outliers and running the meta-analysis for the 19 studies effect size, Hedges' *g* was moderately significant, $g = 0.50$, 95% CI = [0.27, 0.72]. These findings permit the rejection of the null hypothesis and confirm the hypothesis that neurofeedback has a significant effect on physical and mental health outcomes across published and unpublished studies.

Table 4

Overall Hedges' g

Study	Variable	Hedges' *g*	SE_g
Imperatori et al. (2017)	Combined	0.11	0.28
Hong, and Lee (2012)	Combined	0.73	0.52
Kouijzer et al.(2010)	Combined	1.22	0.48
Dalkner et al. (2017)	Combined	0.23	0.39
Prinsloo et al. (2018)	Combined	4.29	0.49
Saki et al. (2016)	Combined	0.77	0.60
Kayiran et al. (2010)	Combined	7.97	1.00
Walker (2012)	Dysgraphia	10.09	1.57
Kouijzer et al. (2013)a	Combined	-0.06	0.46
Kouijzer et al. (2013)b	Combined	-0.29	0.49
Sokhadze and Daniels (2016)	Happiness	0.66	0.31
Strehl et al. (2011)	IQ	0.10	0.01
Jensen et al. (2013)	Pain	0.30	0.01
Crocetti et al. (2011)	Tinnitus	0.10	0.01
Surmeli and Ertem (2010)	Intelligence	0.23	0.01
Surmeli and Ertem (2009)	Combined	0.20	0.01
Surmeli et al. (2017)	Post-concussion Symptoms	1.51	0.01
Surmeli el a. (2012)	Schizophrenia	0.76	0.01
Surmeli and Ertem (2011)	Obsessive Compulsive Disorder	1.12	0.01
Walker and Lawson (2013)	Depression	0.28	0.00
Hammer et al. (2011)	Insomnia	0.52	0.02
Chirita-Emandi and Puiu (2014)	Combined	0.40	0.36

Separating the effects of neurofeedback on physical and mental health outcomes across published and unpublished studies was not specifically part of the research question, but was used in moderator analyses to provide additional data for this meta-analysis. The additional data using moderator analyses for physical and mental health might have offered insight into whether or not neurofeedback had efficacy for physical or mental health outcomes rather than physical and mental health outcomes. Table 5 displays the effect sizes for each of the included health outcomes. After I conducted the analysis using health outcomes as the moderator, the seven studies' effect size was g = 0.81, 95% CI = [0.54, 1.08] indicating a large effect; a positive effect for the use of neurofeedback for health outcomes. Table 6 displays each of the included effect sizes for the mental health outcomes. The moderator analysis for mental health outcomes of 18 studies resulted in an effect of g = 0.59, 95% CI = [0.34, 0.82], a medium effect; also indicating a positive effect of neurofeedback for mental health outcomes. A closer look at the confidence intervals indicated overlap among physical and mental health outcomes, suggesting that the effect of neurofeedback did not differ based on outcome type.

Table 5

Health Outcomes Hedges' g

Study	Variable	Hedges' g	SE_g
Imperatori et al. (2017)	Food cravings	0.05	0.28
Prinsloo et al. (2018)	Combined	4.29	0.49
Kayiran et al. (2010)	Combined	7.69	0.96
Walker (2012)	Dysgraphia	10.09	1.57
Jensen et al. (2013)	Pain	0.30	0.01
Hammer et al. (2011)	Insomnia	0.52	0.02
Chirita-Emandi and Puiu (2014)	Combined	0.37	0.35

Table 6

Mental Health Outcomes Hedges' g

Study	Variable	Hedges' *g*	SE_g
Imperatori et al. (2017)	Overall psychological distress	0.18	0.28
Hong, and Lee (2012)	Combined	0.73	0.52
Kouijzer et al.(2010)	Combined	1.22	0.48
Dalkner et al. (2017)	Combined	0.23	0.39
Saki et al. (2016)	Combined	0.77	0.60
Kayiran et al. (2010)	Combined	8.12	1.01
Kouijzer et al. (2013)a	Combined	-0.06	0.46
Kouijzer et al. (2013)b	Combined	-0.29	0.49
Sokhadze and Daniels (2016)	Happiness	0.66	0.31
Strehl et al. (2011)	IQ	0.10	0.01
Crocetti et al. (2011)	Tinnitus	0.10	0.01
Surmeli and Ertem (2010)	Intelligence	0.23	0.01
Surmeli and Ertem (2009)	Combined	0.20	0.01
Surmeli et al. (2017)	Post-concussion Symptoms	1.51	0.01
Surmeli el a. (2012)	Schizophrenia	0.76	0.01
Surmeli and Ertem (2011)	Obsessive Compulsive Disorder	1.12	0.01
Walker and Lawson (2013)	Depression	0.28	0.00
Chirita-Emandi and Puiu (2014)	Combined	0.42	0.36

Summary

The results of the meta-analysis were reported in this chapter, including how the collected data answered the research question. Overall there is a positive effect for neurofeedback on physical and mental health outcomes. The positive effect remains evident when the outliers are removed and when the data is moderated by physical or mental health outcomes separately. The included funnel plot addressed possible publication bias through visual inspection of the location of the studies within the funnel and identified three outliers that were studies with enough variation in effect size to fall outside of the funnel. The funnel plot for this meta-analysis indicates the probability of publication bias, a lack of studies with unfavorable outcomes being published. The systematic review for this meta-analysis resulted in 1,879 records and after further review, 21 published research articles were included with a single article having two independent study samples resulting in the inclusion of 22 study comparisons in the meta-analysis. The meta-analysis results depict efficacy for neurofeedback for health and mental health outcomes. The efficacy of the treatment remains evident after the three outlier studies are removed. Chapter 5 includes a summary and interpretation of the results, limitations, and directions for future research.

Chapter 5: Discussion, Conclusions, and Recommendations

Symptoms of diminished daily functioning such as those experienced in physical or mental health diagnoses are potentially uncomfortable, unpleasant, and difficult to overcome. Most clinical treatment modalities meant to improve physical or mental health, including neurofeedback, have the potential for side effects (Hammond & Kirk, 2015). Without clear knowledge regarding the efficacy of neurofeedback, it might not makes sense for an individual to undergo the treatment and risk the potential side effects or placebo effects. According to King (2016), psychologists regularly examine available evidence to provide valuable insight about the data and how it relates to human existence. Thus, in addition to demonstrating mastery of meta-analysis research protocols, this systematic review and meta-analysis of the efficacy of neurofeedback has pedagogic value for understanding the body of evidence on neurofeedback for physical health and mental health outcomes.

Summary of the Findings

After a systematic review of 1,879 records connected to neurofeedback, I included 21 studies in the meta-analysis and statistically analyzed 22 study comparisons after including the two independent samples from a single study. I determined that neurofeedback has a significant positive effect on physical and mental health outcomes. When outliers from three articles were removed from the analysis, the significant effect of neurofeedback treatment remained. After moderating the data for physical health outcomes and again for mental health outcomes, significant results remained. This is indicative of efficacy of neurofeedback for physical and mental health outcomes, yet caution should still be exercised when considering neurofeedback as a treatment option due to evidence of probable publication bias. It remains possible that neurofeedback studies reporting inefficacy have not been published.

Interpretation of Findings

Skinner's (1938) theory of operant conditioning holds that delivery of positive and negative consequences directly following behavior can change future behavior. This theory appears applicable to neurofeedback. The positive results of this meta-analysis agree with Kobayashi et al. (2010) who found that in the theory of operant conditioning there is a connection between brain waves and behavior that is exploited in a functional way with neurofeedback to create brain wave and behavior change.

In this meta-analysis, I determined that using neurofeedback treatment distinguish and healthy from unhealthy brain functioning and, by extension, healthy from unhealthy daily levels of functioning increased physical and mental health outcomes. When separating the physical from mental health outcomes, I included more mental health outcomes (18) than physical health outcomes (seven) in this meta-analysis. After conducting moderator analysis using physical health outcomes and then mental health outcomes as moderators, I found that both showed a positive effect of neurofeedback. It is important to note that the confidence intervals for the moderator analysis of physical and mental health outcomes indicated overlap among these outcomes suggesting that the effect of neurofeedback did not differ based on outcome type. Studies were not excluded if they did not have a placebo or control condition, overcoming the argument by Thompson and Thompson (2016) that dismissing studies without a placebo or control condition might overlook a significant portion of the available clinical research and not contribute to an increased understanding of the efficacy of neurofeedback.

Cumming (2013) discussed meta-analysis as a systematic method for combining multiple studies to determine effects that are practical and usable for researchers and clinicians. Adding teachers or future teachers to the discussion is valuable for meta-analytic research, the knowledge base, and education as the process of active engagement in the method and the determination of efficacy for a body of evidence. Meta-analytic experience has value for increasing effectiveness of instruction and for offering a much needed analysis of the state of an art, such as neurofeedback (Horn et al., 2014; Thompson & Thompson, 2016).

Limitations of the Study

A limitation to this meta-analysis was a lack of available research on the use of neurofeedback for physical and mental health outcomes that included more than 100 participants. The majority of the studies included in this meta-analysis had small sample sizes with up to 51 participants. According to Creswell (2014), researchers should select a sample size large enough to reflect the population from which it is drawn with the alterative option being the use of a power analysis to compare populations or groups. Cuijpers and Cristea (2016) noted that researchers demonstrating an effect in test subjects without quantifying the population is likely to result in positive outcomes and research that is difficult to compare to other research involving significantly larger numbers of subjects.

I restricted data in this meta-analysis to those from studies published in English. The possibility remains that searching in a different language or searching scientific databases in different languages could result in an increase in the number of available studies for inclusion in a similar meta-analysis.

My goal in this meta-analysis was to determine the effects of neurofeedback on physical health and mental health outcomes, not physical health or mental health outcomes. I used moderator analyses to determine if, after separation of the included 22 comparisons by physical health outcome or mental health outcome, either physical or mental health were not suited for treatment via neurofeedback. Of note is that after separation of the included comparisons, this meta-analysis included more mental health outcomes (18) than physical health outcomes (seven). If neurofeedback is better suited for mental health outcomes or health outcomes, then the use of the treatment becomes limited and can be better focused on the outcome it is better suited to treat.

The number of studies excluded for not having a follow up study at least three months following the completion of the study is limiting to determining long term efficacy of a treatment. Retention of learned skill, as in neurofeedback, is important to the practical application of the treatment for practitioners and consumers. If the reported positive effects of neurofeedback were not sustainable and did not last, the use of the treatment becomes limited as it would need to be repeated to maintain the same or similar results.

Recommendations

Prior to the publication of new research, future meta-analytic investigations to determine the effect of neurofeedback on physical and mental health outcomes could include studies published in languages other than English. It is possible that searching databases not in English and obtaining research not written in English could add to the number of studies available for inclusion in the meta-analysis. Future meta-analysis might include neurofeedback with combined interventions and compare the effects of neurofeedback as a stand-alone treatment and the effects when combined with other treatments. Another option for future meta-analyses is to include studies with under a three-month follow up and compare outcomes or retention of learned skills between those with and without a three-month follow up.

None of the included research studies had physical or mental health specifically identified as the outcome being investigated. While the outcomes were fitting for categorization as physical or mental health outcomes, future researchers investigating neurofeedback could focus specifically on physical or mental health as the outcomes of interest rather than on things like depression or tinnitus. A whole-body approach might increase the understanding of the treatment and application.

Implications for Social Change

According to the World Health Organization (2018) physical and mental health are more complicated than simply the absence of disease and are fundamental to safety and peace within societies and communities. The World Health Organization (2014) noted that physical health and mental health are states of physical, emotional, and social well-being that could be evidenced by an ability to handle normal life stress, work, and contribution to society. The potential for positive social change through the use of neurofeedback treatment for physical and mental health is simple; increased physical and mental health increases safety and peace in societies and communities. For the individual, increased physical and mental health increase one's ability to handle normal life and work stress and contribute to society.

In this meta-analysis, I achieved mastery learning through the active construction of knowledge. Mastery learning increases the quality and effectiveness of future instruction and learning (Ouyang & Stanley, 2014; Horn et al., 2014). Increased quality of instruction can increase the quality of learning for students, and an increase to both can positively impact social change in individuals and communities through increased education and potential action of the members of communities and families.

Conclusions

In this meta-analysis I sought to understand the efficacy of neurofeedback for physical and mental health outcomes while simultaneously acquiring pedagogic value in conducting meta-analytic research. I increased my understanding of the state of the art of neurofeedback for physical and mental health outcomes in this meta-analysis, because it indicated a significant and positive effect on physical and mental health outcomes. The number of included research articles was limited (21), as was the number of included study comparisons for analysis (22), yet it was still possible to interpret the overall results of the meta-analysis that neurofeedback has efficacy for improving physical and mental health. The findings support the theory of operant conditioning and the ability of neurofeedback to utilize the theory to create improvement to physical and mental health for those who undergo a series of neurofeedback treatment training sessions.

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