

The Proposal of Investigating the Possible Extraversion Effect in the Neurofeedback

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Abstract Optimal cognitive functioning is an essential prerequisite of an effective learning. However, during the learning process, in addition to basic cognitive processes and abilities and from the perspective of intrapersonal factors, the personality of the learner significantly influences on his/her learning outcomes. Prior psychological research demonstrated significant differences in teaching methods and learning outcomes between people who have high and low levels of extraversion. This moderating effect of personality is especially visible in certain learning models, such as the operant conditioning. Taking into account the biological basis of cognition and personality, the question is whether it is possible that different personality traits have the effect on the operant conditioning of brainwaves (neurofeedback)? In other words, is it possible to explain the various neurofeedback training results by the moderation effect of personality traits, especially extraversion? Moreover, some critical validation studies have indicated that extraversion might be the cause of various findings on the effectiveness of neurofeedback, since it has not been controlled in these studies. Therefore, the main focus of this review is to present the research proposal for studying the possible extraversion effect in neurofeedback.

Keywords Neurofeedback efficiency, Extraversion effect, Differences in operant conditioning

1. Introduction

The ultimate goal of psychology is to provide right answers about improving, protecting and strengthening the psychological experience and functioning in humans. It is crucial that psychology as a social science applies scientific methods that enable researchers to set research questions and get clear answers to them. In certain scientific disciplines within psychology (such as biological psychology), there is overlap and the strong need to integrate with other scientific disciplines such as medicine, with the aim of obtaining answers to various questions about the human psychological health. Finally, it is not only important to stay healthy and not to get sick, but it is important to be happy and satisfied, to feel healthy and fulfilled, and ultimately to increase the level of our psychological well-being (Rijavec, Brdar & Miljković, 2008).

Therefore, the neurofeedback (NFB) is the method of the brain-feedback that today presents one of the methods by which it is possible to improve cognitive performance in people who do not have any specific problems/disorders/diseases. Also, NFB can help in solving various difficulties that occur in great number of disorders (e.g. attention deficit and hyperactivity disorder, epilepsy, stress, headache, etc.).

Although this method is applied in Croatia and worldwide in the private psychological practice (Hammond, 2011), smaller number of studies have shown inconsistent results about evaluation of the NFB-efficiency for various reasons that are later discussed.

This paper presents a research proposal in which personality trait extraversion has been presented as the significant mediator for NFB-efficiency regarding the enhancement of learning, attention and memory. In other words, this hypothesis provides a possibility to get the answer on the question: *Are there any significant differences in the possibilities of operant conditioning for extraverts and introverts, what could imply different levels of efficiency of this method?* Besides that, the NFB will be presented as an educational intervention (Gruzelier, Foks, Steffert, Chen & Ros, 2014). However, prior to detailed description of neurofeedback (NFB), a brief description of biofeedback method is presented since the NFB is functioning on the same feedback principle.

2. Biofeedback or the Method of Body Feedback

Biofeedback method or the method of body feedback is defined as a therapeutic method of mind and body that is based on the use of electronic devices, which help people to achieve a higher level of awareness and control over their own psycho-physiological processes (Sitaram, Ros, Stoecke,

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Haller, Scharnowski, Lewis-Peacock, Weiskopf, Blefari, Rana, Oblak, Birbaumer & Sulzer, 2016). This method applies a biofeedback device that provides insight into the relation between individuals' own thoughts and emotions with immediate physiological changes and processes in the body. Based on this insight people are able to acquire control and ability to change the mind-body relation (Frank, Khorshid, Kiffer, Moravec & McKee, 2010). Therefore, this is a self-regulatory method that enable the use of holistic approach in solving a wide range of problems, or integrative bio-psycho-social approach in the so-called psychosomatic medicine and psychological practices (according to Havelka, Havelka & Delimar, 2009). Since there are different manifestations of physiological reactions in the human body (Author6), there are various electrical appliances that measured specific physiological reactions related to specific body organs and functions (brain, heart, other muscles, sweating, breathing, blood pressure, skin temperature, etc.). In addition to that, there are various biofeedback devices for measurement: muscle activity, skin temperature, electro-dermal activity, breathing, heart rate, heart rate variability, blood pressure, brain activity and blood flow in the brain (Yucha & Gilbert, 2004). Biofeedback, alone or in combination with other behavioural therapies, shows a high level of efficiency in resolving various difficulties that may arise from headaches to high blood pressure or in solving differently conditioned states of stress, mood disorders or lower cognitive performance (Yucha & Gilbert, 2004). The same authors report the basic features of this method relating to its use as the additional method to the primary or secondary therapeutic methods in solving certain problems, as this method has no side effects and is non-invasive. The same characteristics apply to Neurofeedback method; which is used more often. However, research studies have also shown that there are a number of people, in some studies up to 50% (Nan, Wan Wai & Da Rosa, 2015), who showed no significant positive or expected changes after NFB-trainings. Yucha and Gilbert (2004) pointed out that it remains a challenge to modern science to clearly define the cause of these differences, and to set clear guidelines of those characteristics for which biofeedback and neurofeedback can have a significant positive effect. This article questions these challenges and issues in its bases, what will be discussed later on.

In medical and psychological practice, biofeedback is applied in the context of two basic models for addressing the wide range of human well-being properties. One model may arise in order to improve academic, sports, music or business activity and performance, and the other that can occur in the context of certain problems, disorders and/or diseases in order to improve the health of individuals. The first model refers to the operant (instrumental) conditioning and the other on psychophysiological psychotherapy (Frank et al., 2010). Operant conditioning presents the behaviouristic learning model, which uses the consequences of certain behaviour as a means to change the appearance or the type of certain behaviour (Schwartz & Andrasik, 2017). Before each

training session, an initial examination of the individual is conducted and it serves for determining clear treatments' objectives. Based on the non-invasive monitoring of physiological function that is enabled by sensors placed on certain parts of the body, the individual is via a fast and incentive methods (e.g., watching a movie or playing some games) provided by reinforcement to those physiological signals that allow a change of the existing dysfunctional and disruptive physiology. Psychophysiological psychotherapy is based on individual approach to person, and it combines the basic feedback with the method of effective learning techniques to cope with stress when it is most efficient. Taking both models together, it is extremely important to examine all the individual characteristics that can influence the training, and set a clear goal of training, because it directly determines the type and numbers of trainings that have been used.

2.1. Brain Waves

Based on the fundamental knowledge in the field of electroencephalography it is possible to define a goal of NFB-training and to learn to change brain waves or to self-regulate them. This is based on distinguishing four types of brain waves (Alpha 8Hz-12Hz, Beta 13Hz-38Hz, Theta 4Hz-8Hz, Delta 0,2Hz-3Hz) and the characteristics of their occurrence in the context of normal human experience and behaviour (Pinel, 1997). As it is indicated, the brain waves occur with different frequencies, and some of them are very fast and some of them are very slow. They are measured in hertz (Hz), by electroencephalogram as the circles per second that occur. Beta waves are very small, fast brain waves that occur during a cognitive engagement, intellectual activity and a high level of alertness and concentration. They occur in a state of high focus and target excitation. In contrast, alpha waves are slower and higher, and are associated with states of relaxation, a certain lack of involvement in the state of preparations for a possible activity. For example, if a person closed his eyes and began to visualize calm and relaxed state for only half a minute, this will increase the alpha waves. Theta waves are even slower than alpha waves, and generally represent the state of daydreaming and such a brain state, which is not ready for any serious cognitive engagement. It is a very relaxed state. Delta waves are the slowest brain waves and have the highest amplitude that occur during sleep. As it is obvious, the type, shape, size and frequency of brain waves define different levels of consciousness. Each individual during daily activities has present all of these brain waves in different parts of the brain. The most effective cognitive functioning is present while beta waves are dominant. However, it is quite often that some children, adolescents and adults have slower waves as dominant ones, which prevent effective's cognitive performance. Therefore, it has been determined that delta waves are associated with various learning difficulties, theta waves with the emergence of various difficulties related to the impossibility of directing and maintaining attention (attention deficit, hyperactivity with or without attention

deficit, head injury, stroke, epilepsy and often chronic fatigue). When the dominance of slow waves in frontal regions of the brain that are responsible for executive functions is present, people find difficult to control attention, behaviour and/or emotions. Then, they experience the problems in maintaining concentration, memory, impulse control and mood swings or hyperactivity. They have difficulties in staying focused on tasks and they show diminished intellectual efficiency.

3. Neurofeedback or the Method of the Brain Feedback

Based on the described model of operant learning as a basic framework for the feedback method functioning, which was first applied in 1969 (Budzynski & Stoyva, 1969), and has been used in the monitoring and learning to control the brain waves, it is possible to understand neurofeedback. In the late 1960s and 1970s, researchers discovered that it is possible to re-condition or to re-train dysfunctional brain waves, i.e. to learn completely different brain waves (according to Hammond, 2006). That early research about the possibilities of operant conditioning of autonomic nervous system (Miller, 1969), has been followed by series of investigations conducted by Serman and Friar (1972). They have found that cats and people can learn to increase the frequency amplitude in the range of 12-15Hz recorded in the sensory-motor cortex. Serman and associates' findings directly contributed to the first application of EEG biofeedback for people with hyperactivity disorder and attention deficit (Lubar & Shouse, 1976).

Neurofeedback is clinical, therapeutic method based on the observation and monitoring of brain electrical activity (recorded by electroencephalogram), and giving feedback, with the aim of operant or instrumental conditioning of those brain waves that enhance cognitive performance in people (Thibault, Lifshitz, Birbaumer & Raz, 2015). In other words, neurofeedback training is the brain-biofeedback (Hammond, 2006) by which individuals learn to change their brain wave patterns through operant conditioning. Different states of consciousness have different effects on cognitive efficacy - allow or do not allow it. On this ground, this method, which includes the training and learning of self-regulation of brain activity, has been developed. In the first application of neurofeedback, researchers questioned is it possible to change the occurrence of certain brain waves in certain parts of the brain, or is it possible to change the ratio between certain brain waves in order to improve cognitive performance or reduce the difficulties experienced among children/people with the above problems/disorders/diseases. During a typical NFB-training, EEG cap or one/two electrodes are placed in a specific location on the head and ears. Since the placed electrodes are (whatever their number is) connected with the monitor, the person is able to monitor and observe (auditory and visually) his/her brain waves as they appear at a given time. Some of the NFB-devices use the

computer monitor and some of them a television monitor, on which person could observe his/her brain waves. Simultaneously, the brain waves are being monitored by the individual and by the licensed NFB-experts, but their computer software are different. An individual monitors his/her brainwaves within the computer or video games and audio signals. NFB expert explains the rules of the game, and the basic principle is that a person progresses in the game when (s) he increases those brain activities that is targeted. The points in the game present a positive reinforcement for those frequencies of brain waves that were determined to be improved. If during the game dysfunctional brain waves (usually the slow waves) are increased, a person starts to lose the points in the game and does not progress in the game. Over time, it is expected that the brain waves adjust to the new pattern. Although the protocols are different, the one that was just presented is so-called Frequency-NFB training or Beta/SMR protocol that usually lasts for 30-45 minutes. The usual range of training frequency is between 10 and 40 sessions, with smaller intervals (especially in the beginning of training) between each individual training, so to preserve the training effect. Usually, we are unable to perceive our brain waves and try to influence on them to be altered, but this situation enables such change. Therefore, observing them, one becomes aware of when different types of waves appear, and through operant conditioning, one is able to reinforce those waves that are more functional, what consequently lead one to altered brain waves and corresponding psychological functioning. With more trainings, it is more likely for brainwaves to change and for healthier patterns of brain waves to develop for a longer period.

Sitaram and colleagues (2016) provided a detailed overview of the mechanisms underlying neurofeedback. Among other important aspects, they described the neurobiology of learning and the basic models of neurofeedback learning. Within neurobiology of learning, they emphasized the STDP (spike timing-dependent plasticity) that is the main form of the long-term potentiation (LTP) which is a central mechanism underlying associative learning. Two major types of associative learning are classical and operant conditioning. In addition, "*dopamine is an intermediary that relates STDP to behavioural changes*" (Sitaram et al., 2016. p. 6). Finally, we learn when strong presynaptic and postsynaptic activation with dopamine release occur (Ashby & Ennis, 2006). Within this, "three factor learning", only those synaptic transmissions that receive dopaminergic input proportional to the reward prediction error (the difference between expected and actual reward perceived by the person) are strengthened. In addition, Sitaram and colleagues (2016) described six models of neurofeedback learning and the overlaps between them: operant (instrumental) learning; motor learning; dual process theory (integration of feedforward and feedback learning processes); awareness theory (the higher awareness of physiological response provides the voluntary control over it); global workspace theory (learning control of neural

activity is enabled by the wide, global distribution of the feedback signal in the brain so that it becomes conscious; p. 6); and skill learning. The same authors accentuated that future validation studies should clear up the overlaps and give the proper answers about their theoretical power in explaining the learning process in neurofeedback.

3.1. EEG Neurofeedback Protocols

It is extremely important to emphasize that before each NFB-training it is necessary to conduct individual testing of each person by a licensed NFB-expert. In other words, the proper application of Neurofeedback training is extremely complex and requires a high level of competence in this field (Hammond, 2011). Education for its use includes the acquisition of knowledge of the anatomy and physiology of the brain, brain waves, their patterns at different difficulties/disorders/diseases, technical features of neurofeedback devices, determination and the application of appropriate NFB-protocols, implementation skills for NFB-training and monitoring the changes in a person. Initial testing is carried out with the fundamental purpose of determining the NFB-protocol to be applied in the NFB-training. NFB protocols are as follows (Niv, 2013, p.676-7):

- 1) Beta/SMR or frequency NFB - beta waves present alertness and active concentration while the sensorimotor rhythm (SMR) is associated with semantic processing and sustained attention. SMR-neurofeedback training aims to strengthen thalamic inhibitory function and is used to reduce the difficulty of learning, attention deficit and hyperactivity disorder, as well as disorders with seizures. This protocol could be combined with the decreasing of theta waves, and then is called as theta/beta protocol and has the aim of increasing the attention.
- 2) Alpha/Theta - in this protocol the slow waves should increase, so the greatest contribution of this protocol could be seen in reducing excessive arousal with post-traumatic stress disorder. This protocol also improves the creativity. In the performance of musicians and dancers who have gone through this protocol in the NFB-training showed significant improvement in their performances.
- 3) Slow cortical potential (SCP) training - slow waves are short evoked brain potentials and when they are positive they represent behavioural inhibition in order to maintain attention. The contingent negative variation (CNV) is the anticipation of an event, and is inhibited by some disorders of attention - its upregulation enhances attention.
- 4) Alpha asymmetry - relatively higher right over left prefrontal activity is related with internalizing symptoms (anxiety, depression). Therefore, this ALAY protocol is aimed at reducing the major activities of alpha waves in the left side (with alpha activity represents neural hypo-activity) and at the same time at increasing the low activity of alpha waves in the right part (neural hypo-activity). This reduces the tendency of people to experience negative emotions.
- 5) q-EEG - this is an example of a holistic protocol implemented by mapping the entire brain. In some practices, this protocol attempts to bring person closer to a healthy q-EEG norm. Other practices use this protocol to determine hypoactive and hyperactive brain regions for training, i.e. an imbalance in the brain waves.
- 6) Infra-low frequency - this protocol aims brain waves with frequencies of 0.01 Hz.
- 7) Rtf-MRI (real-time functional magnetic resonance imaging) - this protocol, as the previous one is still under development and it is based on application of feedback of functional magnetic resonance imaging. Research is carried out in the field of tinnitus and pain.

3.2. The Fields of Applicability and Efficiency of the NFB-training

The NFB finds its application not only in clinical practice, but also in the everyday life of people who want to improve their cognitive performance, such as athletes and musicians and people who simply want to improve their cognitive merit (Albright, 2010; Dempster & Vernon, 2009; Egner & Gruzelier, 2001, 2003). In the clinical practice it was determined that NFB significantly affects the improvement related to the following problems/disorders/illnesses: a) Epilepsy (Tan, Thornby, Hammond, Strehl, Canady, Arnemann & Kaiser, 2009); b) Hyperactivity disorder with/without attention deficit, learning difficulties and academic and cognitive improvement (Becerra Fernandez, Harmony, Caballero, Garcia, Fernandez-Bouzas, Santiago-Rodriguez & Prado-Alcalá, 2006; Coben, Arns & Kouijzer, 2011; Jacobs, 2005; Micoulaud-Franchi, Geoffroy, Fond, Lopez, Bioulac & Philip, 2014; Monastra, 2005; Nan, Wan Wai & Da Rosa, 2015; Sonuga-Barke, Brandeis, Holtmann & Cortese, 2014; Vernon, Egner, Cooper, Compton, Neilands, Sheri & Gruzelier, 2003; Walker, Barabasz & Barabasz, 2006); c) Anxiety disorders, post-traumatic stress disorder and sleep disorders (Berner, Schabus, Wienerroither & Klimesch, 2006; Hammond, 2005; Larsen, 2006; Raymond, Varney, Parkinson & Gruzelier, 2005; Sattlberger & Thomas, 2000); d) Depression, withdrawal, hemispheric asymmetry, anger and premenstrual syndrome (Baehr, Miller, Rosenfeld & Baehr, 2004; Choi, Chi, Chung, Kim, Ahn & Kim, 2011; Hammond, 2001a, b, 2005; Putnam, 2001; Uhlmann & Fröscher, 2001); e) Addictions (Burkett, Cummins, Dickson & Skolnick, 2005; Horrell, El-Baz, Baruth, Tasman, Sokhadze, Stewart & Sokhadze, 2010; Trideau, 2000, 2005); f) Brain injury, stroke, coma, cerebral palsy and spasticity (Ayers, 1999, 2004; Bachers, 2004; Duff, 2004; Keller, 2001; Putnam, 2001; Thatcher, 2000); g) Chronic fatigue syndrome,

fibromyalgia and autoimmune dysfunction (Hammond, 2001; Kayiran, Dursan, Dursun, Ermutlu & Karamursel, 2010; Packard & Ham, 1995); h) Pain and headache (Ibric & Dragomirescu, 2009; Sime, 2004; Walker, 2011); i) Schizophrenia (Gruzelier, 2000); j) Obsessive-compulsive disorder (Hammond, 2003, 2004); k) Parkinson's disease (Thompson & Thompson, 2002); l) Tourette's syndrome (Benvenuti, Buodo, Leone & Palomba, 2011); m) Autism (Jarusiewicz, 2002); n) Creativity, optimal functioning, experience cognitive decline and aging (Angelakis, Stathopoulou, Frymiare, Green, Lubar & Kounios, 2007; Boynton, 2001; Gruzelier, Egner & Vernon, 2006; Vernon, 2005); o) Asthma (Othmer, 2012); p) Hypertension (Norris, Lee, Burshteyn & Cea-Arevena, 2001); r) Tinnitus (Schenk, Lamm, Gundel & Ladwig, 2005); s) Criminality (Martin & Johnson, 2005); t) Chronic diseases (Monjezi & Lyle, 2006).

3.3. If it is Possible to Learn to Change the Frequency of Brain Waves by Neurofeedback Learning, and Consequently Enhance Cognitive Performance, Why There are Differences in These Possibilities in Humans?

Sitaram and colleagues (2016) differentiated two major application fields of neurofeedback regarding its efficiency: scientific field and clinical field. As an independent variable in various research studies neurofeedback showed to be very good and useful scientific tool. However, there is a lack of integration of knowledge of training and learning psychology into neurofeedback protocols. In addition, there is a lack of objective and valid research on neurofeedback long-term impact on neuroplasticity and behaviour with its positive and negative effects. Also, it is not totally clear in the clinical sense, when its efficiency could be observed, for what difficulties in human functioning is it beneficial and to what extent? Therefore, in the future the research focus will be on more placebo-controlled clinical trials that are dealing with some specific behavioural patterns of the learned regulation. All of these pen questions leads us to the main reason for this research hypothesis. Namely, although a large number of studies describing the positive results regarding the effectiveness of various neurofeedback trainings' protocols, it is crucial to point out, that equally large number of studies have determined exactly the opposite findings – the success rate NFB training ranging from 60-90% (Wright & Gunkelman, 1998). One of the main reasons for having this result from late 90-ties is definitely connected with not performing the adequate assessment prior to neurofeedback training, which is aimed to creating the individualized neurofeedback program (Hammond, 2011). It includes detecting all specific characteristics of the individual, what could include personality traits. This is extremely important to emphasize since this proposed inter-disciplinary research presents the opportunity to provide answers on the following questions: *Why some children/adolescents/adults respond positively to NFB-training and others not? Is it possible that personality traits have the significant moderation effect on*

the specific difficulty that individual has and/or on the neurofeedback efficiency? Exactly, these questions present the basis of this article, and the following studies that will be presented suggest the topic should be thoroughly explored. The ultimate aim of each science is to examine relations between clearly measurable and operationalized variables with control of those that can potentially have an impact on the research aim by using objective, valid and reliable methods, and consequently, get answers on the questions about cause-and-effect relationship between phenomena (Cohen, Manion & Morrison, 2007). It is, therefore, extremely important, in efforts to obtain valid answers to the research problems, to thoroughly analyse existing research results in this field and try to set up a clear and high-quality research projects based on scientific methodology.

Gruzelier and Egner (2005) have critically reviewed of the validation study on neurofeedback. In their review, they use the theoretical framework that is underlying the therapeutic initiatives for attention deficit and hyperactivity disorder - the difficulty that has been indicated as a first one for this method so there is a large number of research about NFB-application on ADHD. Given the clearly defined very low levels of arousal in children with this difficulty, determined NFB-protocols, in which the main aim is to inhibit the theta waves and increase SMR and beta waves (Beta/SMR protocol or frequency training) proved to be an effective solution. Even though Sitaram and colleagues (2016) proposed some solution describing the application of neuroimaging methods of neurofeedback, Gruzelier and Egner (2005) have pointed out several methodological problems:

- 1) It is not possible to generalize the research findings since an extremely large number of studies did not use random samples or the randomized controlled trials (RCT) in the groups that were examined during the verification and evaluation of NFB-efficiency;
- 2) It is not possible to generalize the results since various NFB-protocols have been used, the NFB-protocols that were not sufficiently specific, same as cognitive tasks/tests that measured any change in cognition;
- 3) Focusing on specific brain waves in just one part of the brain, investigators have not paying attention to any changes or their absence, that are happening (or not) in other parts of the brain;
- 4) Other significant properties of participants have not been controlled, what was methodological mistake since these properties could possibly be the significant correlates of the NFB-efficiency, the subject's psychological (cognitive) and physiological (brain) aspects of functioning;
- 5) The number of NFB-training sessions has not been controlled (its range is from 5 to 40 sessions). This is extremely important, given that the number of NFB-trainings directly effects the efficiency of operant conditioning, as behaviourists clearly have established a long time ago;

- 6) The majority of studies have been carried out mostly on clinical samples. This is not sufficient to draw any clear conclusions regarding the fact that subjects in a clinical group can be, although all may have ADHD, completely heterogeneous depending on their real levels of arousal – in a line with the studies on clinical samples it is very important to run studies on the healthy samples with the same NFB-protocols;
- 7) It is not possible to talk about the effect of the NFB training since there are very few follow-up and longitudinal studies that are able to identify clear effects of learning through operant conditioning on the same subjects, what is the basis of the neurofeedback;
- 8) And finally, what is extremely important for this research, that there is an evident lack of studies, which test the efficacy/outcome of the NFB training controlling the effect of personality traits. This is, actually, unusual, given that Eysenck (1967) has clearly determined that the extraverts were very difficult to be conditioned and learn in a significantly different way than introverts who were easily conditioned. This basic assumption has been confirmed by the critical review of previously mentioned Gruzelier and Egner (2005). At the end of their objective analysis, authors emphasized that all future NFB-studies should include RCT, use NFB-protocols with slow waves, monitor and record changes in waves in the whole brain, monitor the long-term effects with longitudinal studies, and be sure to control the effects of personality traits.

In addition to these research guidelines, it is important to mention the study results of the significant predictors of the ability to learn through operant conditioning (Nan, Wan Wai & Da Rosa, 2015). The importance of the applicability and usefulness of the NFB-trainings is already described for the specific situations and/or difficulties in people. Therefore, it is important to test the so-called NFB's ability to learn, which indicates how efficiently a person can self-regulate his/her EEG-pattern, and try to understand the whole NFB-process, how to optimize the NFB-protocol, what effects of NFB-trainings will ultimately occur and how long will they last. The authors tested this hypothesis on 18 healthy volunteers (eight women) and tried to establish significant NFB-correlates, such as the characteristics of the recorded amplitude beta waves during the initial and rest measurement phase, and put them in relation with the effects of learning, or what is learned. Interestingly, the result of different operationalization of the ability to learn resulted with different division criterion for subjects' groups of those with high or low learning ability. That is, some subjects were in a group that has a high learning ability according to the first criteria and in the other group they have belong to the group with low learning ability according to the second criterion... The first operationalization was the average within-session change or the learning based on average change between each session. The second learning index was operationalized

as the linear regression slope of value over 5 sessions, what presented the learning ability across whole training process and indicated accumulative training effect (Nan, Wan Wai & Da Rosa, 2015, p.3). It was determined that low amplitude of beta waves during the initial phase and the resting phase is a significant predictor of less learning ability or re-training ability according to the protocol beta/theta relation in NFB-training in healthy individuals, and only in groups according to the second criterion, i.e. the cumulative effect of learning.

3.4. In Support of the Hypothesis about Significant Personality Effects on the Neurofeedback Training

Although today, the application and empirical verification of the Five-factor personality model (Costa & McCrae, 1989, 1992, 1995) is undoubtedly dominant in the context of psychology, the greatest number of studies about differences in learning among extraverts and introverts are conducted within the theoretical frame of Eysenck's dimensional personality model (1967). According to Eysenck (1967) two orthogonal personality dimensions could explain individual differences in humans: extraversion-introversion and emotional stability-neuroticism. Later on, psychoticism was added. Based on this personality theory, extraverts learn best through conversation and discussions with others. In fact, they love to be in the company of others, and their learning is most effective if they attain common information processing, i.e. if they learn in a group. At home, they create their own learning space. They do not like to work just on one thing for a long time, particularly if they are working alone; they prefer variety and a high level of activation, whereby they demonstrate forcefulness and enthusiasm. When acquiring new information and/or need to make a decision, they tend to frequently ask questions and think aloud. Thereby they often have less time between questions and answers, respond before thinking, and are characterized by understanding the world around them through their own activities and discussions. Therefore, when they get the option of discussing new learned information and to talk with others, that is when they show the best learning outcomes. Given these characteristics and needs of extraverts during learning, they should be provided with such a place in the class/classroom where distractions have been minimized, i.e. they should sit away from doors and windows. In addition, the previously mentioned possibilities for interactive learning, learning in pairs, on a team, through discussion and debate in a noisy atmosphere, represent circumstances, which are characterized by high levels of activation and are optimal for extraverts and their learning (Myers, McCauley, Quenk, & Hammer, 1998).

On the other hand, for introverts, calmer and quieter surroundings are ideal places for learning. In fact, introverts prefer to observe things before trying anything with them or when making a decision in relation to them. A high level of activation, noise and similar conditions are actually overtly stimulating and interfering for introverts. Therefore, they

prefer learning in small groups, connecting only with one individual or a small number of people. They like quiet places and enjoy working a long time on one thing. Since interaction with others can be very exhausting for them, they usually wait for others to make the first move. They learn more effectively when they have plenty of time to reflect on the information they are learning about, once they have managed to understand and process the information on their own. They like to think before they speak or act so they can feel very uncomfortable when asked to respond to some external request. They form their ideas very carefully before they articulate them. In addition, it often occurs that they require trust and closeness with others before they share their ideas. They have the tendency to look for opportunities to read, listen, watch and quietly observe, and they do not like interruptions. Also, they like to gather as much information as possible about what they are learning even prior the learning situations, which requires time. They are oriented toward independent learning and mentoring, i.e. learning one-on-one (Myers, McCauley, Quenk, & Hammer, 1998). In addition, introverts are conditioned faster; punishment has a greater effect on them, and they have a better-delayed memory. That is, introverts learn conditioned reactions to fear in conditions of low or medium excitation more easily and faster than extraverts do. They are prone to interference of the memory process, increase of the task difficulty has a more negative effect on them, and they have a slower pace of forgetting (Eysenck, 1983). This is supported by the study of Nichols and Newman (1986), which specifies that, unlike introverts, extraverts react faster in situations in which they expect a reward.

As for the impact of rewards and punishments on people during learning, most research was conducted as part of the Gray's Reinforcement sensitivity approach (Gray, 1982, 1987, 1991). This theoretical model of personality describes the personality using two main axes of human behaviour: The Behavioural Inhibition System – BIS, and the Behavioural Activation System - BAS. Persons whose behaviour prevails within the BIS usually show behavioural avoidance and withdrawal, and a high sensitivity to punishment. In contrast, individuals with a dominant BAS often exhibit behaviours of attraction and accession, and a high sensitivity to reward. When compared to the orthogonal display of Eysenck's extraversion and emotional stability, both the BIS and the BAS pass diagonally. Thus, the BIS diagonal, which passes between the high levels of extraversion and emotional stability, indicates low anxiety, and when passing between high neuroticism and high introversion, it shows a very high level of anxiety. In contrast, if an individual with his personality traits is located between high extroversion and high neurotic, he or she exhibits high impulsiveness, and if the traits are located between high introversion and high emotional stability, this indicates a low level of impulsiveness.

The Revised Reinforcement Sensitivity Theory (Gray & McNaughton, 2000) is based on empirical research that has shown that people with dominant BAS behaviours are

sensitive to the conditioned and unconditioned stimuli of rewards; they tie their emotions in anticipation of pleasure, and exhibit impulsive optimism. In contrast, people with dominant BIS behaviours often associate emotions with concern; they tend to be anxiety, try to solve all internal conflicts and put themselves in a non-confrontational situation, and quickly recognize the situation of vulnerability for themselves.

Five-factor personality model understand and define human personality as a set of five basic personality dimensions: extraversion, agreeableness, conscientiousness, neuroticism and openness to experience. Linking the process of teaching and learning to the Five-factor model of personality, specifically in situations of conditioned fear reactions, Pineles and colleagues (2009) determined that learning through conditioning is a lot more complex than scientific research managed to show it. In other words, they suggest that the answer does not lie in questioning learning outcomes of conditioned learning, i.e. conditioned fear reaction, by analysis of the five dimensions of personality, given that certain facets within a single personality trait may have completely different effects in these learning situations. By analysing electrodermal responses, Pineles et al. (2009) found that individuals who exhibit maintenance of the fear reactions also show high facet levels of warmth, activity and positive emotions within the dimension of extraversion. Within the dimensions of neuroticism, individuals with high levels of self-confidence show greater weakening of the reactions of fear during conditioning. A stronger differential conditioning of fear is found in individuals with a greater openness to feelings as part of the openness to experience. Within the agreeableness dimension, individuals who show an increased maintenance of the reaction of fear at the same time show low scores on the facets of aggression and anger, as well as those who show high scores on the facets of empathy and concern for others. Finally, people with a high need for compliance with their commitments and order show significantly greater weakening of the reaction of fear during learning, within the conscientiousness dimension.

It is necessary to add the above, the research findings on biological determination of personality traits (Author1,3,4,5, 6), in which, although due to the effect of habituation elevated levels of cortical arousal were associated with introverts, significant associations between extraversion and amplitudes of evoked brain potentials have not been found. However, a significant correlation between shorter latency P3-Slow-wave activity (P3-wave is related with attention allocation and updating of working memory) and higher extraversion was determined, what was interpreted in terms of faster processing of information among extraverts. Also, there was a significant association of lower amplitudes and prolonged latencies with higher neuroticism and depression, and prolonged latency with higher social desirability, while psychoticism showed a significant association with shorter latencies and high amplitudes of evoked potentials. Additionally, melancholic showed generally the longest EP latency, choleric showed the highest N1 (it relates with

selective attention) and P3 amplitudes and sanguine the highest N2-amplitude (it relates with stimuli detection and time reaction) in the first recording trial. Thus, the finding, that there is no significant relationship between P300-amplitude and extraversion regardless of the electrode and a series of recording, while there is a significant connection between short-P300 latency measured at parietal electrode group regardless of the series recording with higher extraversion, and it significantly expressed in relation to the trait adventurousness, could be explained in the context of the basic features of extraverts who are "prone to reacting" while introverts are "prone to observing" (Brebner & Cooper, 1985; Author2).

Finally, in the Laney's book (2002) about differences between introverts and extroverts, their different brain pathways are clearly described. This differences are very important to be emphasized in this article, since dopamine plays significant role in the learning process of neurofeedback. Shortly, while processing information, extroverts use shorter dopamine pathway, while extroverts use longer acetylcholine pathway. Introverts' behavioural reactions are based on the energy-conserving, parasympathetic nervous system, which use more different brain areas (**Reticular Activating System; Hypothalamus** (turns on the Parasympathetic); **Anterior Thalamus; Broca's Area; Frontal Lobe; Hippocampus; Amygdala**) and more blood flow. On the other hand, extroverts are related with the energy-spending, sympathetic nervous system with fewer brain areas (**Reticular Activating System; Hypothalamus** (turns on the Sympathetic); **Posterior Thalamus; Amygdala; Temporal and Motor Area**) and less blood flow in the brain. Therefore, the more dopamine is increased, the more active the extroverts are. On the other hand, introverts are highly sensitive to dopamine, so they easily get over-stimulated. Therefore, these obvious neurophysiological differences between extroverts and introverts (Laney, 2002), present one more argument for emphasizing the discourse about significant role of personality in neurofeedback, especially regarding significant role of dopamine in neurofeedback (Sitaram et al., 2016). Demonstrated theoretical frameworks and research results about the individual differences in the learning process and biological determination of personality traits, evidently showed that the personality variables have a significant role within the process of operant conditioning. Therefore, it could be assumed and argument that the differences in the effects of neurofeedback could be explained by individual differences in personality traits.

4. Conclusions

Recent studies in the field of neurofeedback clearly demonstrated the current findings on the fundamental understanding of this method and its potential benefits for human optimal functioning. On the other side, the same studies showed some open questions about NFB-efficiency.

Therefore, it is very important and justified to propose this interdisciplinary research based on psychology and medicine. These two sciences should, taking into account all the flaws of previous research, seek to provide an answer on NFB-efficiency in improving cognitive performance among people with higher and lower levels of functioning in attention, memory and learning with regard to the effects of personality traits. This experimental design could also be useful for clinical placebo trials. Therefore, using (quasi)experimental research design, normal and clinical subjects' groups, that are equalized by all other variables and have equal number of introverts and extroverts with placebo group should definitely provide an objective, valid and reliable answer about differences in NFB-efficiency in humans.

The main contribution of testing this hypothesis could be recognized in several aspects:

- 1) The results of this study should provide a more complete insight into the basic understanding of the NFB-effect in people with higher and lower levels of functioning in attention, memory and learning;
- 2) The results of the study should indicate the effectiveness of particular NFB-protocols in people with higher and lower levels of functioning in attention, memory and learning;
- 3) These research results should indicate the type of the relationship between the NFB-training and personality traits of participants in both groups;
- 4) Following the random distribution of participants in the groups, this study should show whether personality traits are significant predictors of the learning ability within the NFB-training, and what is the NFB-efficiency in both groups just in relation to certain personality traits;
- 5) The results of this study should result in clear implications for the application of neurofeedback as an educational intervention (Steiner, Frenette, Rene, Brennan & Perrin, 2014).

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