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LIKE CATCHING A WAVE: QUALITATIVE STUDY OF EEG NEUROFEEDBACK GAME CONTROLS

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Abstract

Seven musicians engaged in EEG neurofeedback (NF) training of a new protocol designed to practice the switch between different mindsets. Three different sonic games programmed to reward distinct EEG parameters were administered twice in a row. Interviews were performed after each training session in order to obtain full description of the inner processes that surfaced while playing the NF game. The interviews were subjected to theoretically driven thematic analysis (Braun & Clarke, 2006) to identify the ways of direct interaction of the player with the NF game, through the optics of the player.

We were able to identify 22 different techniques that were used to control the game, further referred to as neurofeedback game controls, which can be loosely united under six superordinate terms: body movements, different levels of activation, direction of attention, interaction with the sound, thoughts that change the mindset, the flow.

Most of the individual game controls have a different function in each of the three different games of our training protocol, the effectivity of each one varying between players. Nevertheless, several game controls appeared to have power over all three games and across the subjects – a mindset characterized by thoughts scoping through the player's focus unwillingly while attracting her attention was leading to a failure in the NF game, while a mindset characterized by the absence of content attracting attention was associated with the success in the NF game.

Delving deeply into the game, concentrating without trying hard and closing the eyes also helped the players to better perform in all three games. Furthermore, the feeling of being successful in the game led to further success.

This paper aims to explore an insufficiently described area of NF research and possibly offer an alternative framework that, in the future, when more knowledge is accumulated, would provide neurofeedback researchers and practitioners with more vocabulary theoretically useful for further research and practice.

Keywords

EEG Neurofeedback, Thematic Analysis, Momentary Mental and Emotional State Self-Regulation, SMR Training, Frontal Beta Training, Alpha Asymmetry Training

1. Introduction

Though the effectivity of EEG neurofeedback (NF) as a method to offer relief from a specific set of symptoms was repeatedly claimed in multitude of papers (see Van Doren et al., 2018 for a latest meta-analysis of NF effectivity), few researchers engaged in detailed description of the neurofeedback experience. The field of neurofeedback research centers almost exclusively on bringing the proofs of the method's efficiency, even though several heavy methodological insufficiencies keep reoccurring across studies (Dagenais, Leroux-Boudreault, El-Baalbaki, Bégin, 2014; Micoulaud-Franchi et al., 2015).

Despite the fact that the validity of the experimental studies may or may not constitute a valid base for the method's accreditation and for its acceptance by a wide scientific community, new clients keep searching for neurofeedback providers. As 'science in making,' the neurofeedback practice exists in parallel to the NF research (Brennikmeijer, 2013). Though the scientifically solid proofs may constitute something like NF practice milestones and give the practitioners factual support, the research in this area reflects and describes only a fraction of what constitutes the neurofeedback scene in its entirety. Several researches engaged into mapping how and why the method works in the real-life context; to explore who decides to start the training, for what reasons, and at last, but not least, how does the training experience itself feel like. There are also several studies using a qualitative approach to describe training effectivity and experience (Dupee, Werthner, & Forneris, 2016). Brennikmeijer (2013) in her qualitative study listed and described a broad area of factors that constitute the NF training,

stretching out the complexity and organicity of the process, describing the training, using the term coined by Pickering, a 'dance of agency.'

This paper presents outcomes of a research study designed to address some of these insufficiently described phenomena and elements. After facilitating a NF training for our subjects, we gathered qualitative data covering wide array of NF training related issues in post-session interviews. Consequently, this paper describes the experience of playing a neurofeedback game using first person optics. We set forth to reconstruct the experience of playing the NF game, to describe what exactly is going on in the moment of training, as the trainee sees it. Though the thematic analysis of our interviews uncovered a variety of topics (including trainees' preconceptions of the training, doubts about its meaningfulness and suggestions and ideas for the future development of the neurofeedback scene), this paper, for the sake of brevity, deals only with one specific area of this complex net of motives – with the act of playing the neurofeedback game, as a game.

1.1. How to map the NF players' strategies

Though the voluntarily induced changes in EEG activity are considered specific program controls in the area of Brain Computer Interfacing (Wolpaw, Birbaumer, McFarland, Pfurtscheller & Vaughan, 2002), the EEG neurofeedback training researchers scarcely describe the specific ways the trainees use to get control over the game.

To address this topic, Kober, Witte, Ninaus, Neuper & Wood (2013) designed a study using both qualitative and quantitative methodology to take a closer look at what exactly people do while playing a neurofeedback game. They found out that people being successful in the sensorimotor rhythm (SMR) training actually described no particular strategy at all, in contrast to people that according to statistical analysis of the EEG recordings never learned to improve their game performance.

Nan et al. (2012) asked their probands to choose any mental technique before starting a specific NF round of alpha training and then stick to it till the end of the round and write it down afterwards together with self-rating of their own performance in the specific round. These notes were later subjected to thematic analysis and the correlation of specific themes with a self-rating score was observed. As result, several techniques were identified to work well across the trainees – love, friends and family, while other techniques, or mental states, were associated with bad NF performance – anger or internal counting.

Angelakis and her colleagues (2006) were interviewing NF trainees (elderly people, n=4) about the specific strategies and techniques they employed during their Peak alpha frequency increase training. Strategies listed as successful included remembering their children while they were young, remembering travels, imaging that everything in life will be fine, thinking about food, internally counting, internally singing and emptying the mind. Thinking about the quotidian problems led to worse NF performance.

In contrast to Kober, Witte, Ninaus, Neuper & Wood (2013), we decided to not to engage in the mixed methods approach. The only context we used to evaluate the validity of specific game strategies was its efficacy as experienced by the player itself (similarly to Nan et al. (2012), but without using the self-rating scales and subsequent analysis). This approach allowed us to get closer to the trainees' experience of the act of playing the NF game and consequently obtain a richer and more colourful picture than the approach applied by Kober, Witte, Ninaus, Neuper & Wood (2013) that aimed to evaluate the objective and quantifiable validity of specific strategies.

Our goal was to catch and describe the variability of players' moves and the distinct ways of their interaction with the game (similarly as Angelakis et al. [2006]). Using this qualitative method allowed us to start covering some blank areas in the NF research, describing the neurofeedback as an existing phenomenon, leaving the ongoing discussion about efficacy of distinct approaches, protocols or strategies aside for the time being.

Concentrating solely on analysis of players' experience, we created a partial map of the possible ways of active engagement with the NF interface. As result, this paper is coining a new term in the field of the NF research, 'the neurofeedback game control,' and exploring its possible usefulness, offering a new angle, an alternative way of approaching and describing this widely discussed training and therapeutic method.

2. Method

2.1 The session

We performed 16 neurofeedback sessions altogether with 7 participants (each participant undergoing a minimum of one and maximum of three sessions). Every session of the NF training consisted of seven steps – a baseline measurement round, followed by six training rounds. Each round took three and half minutes and consisted of one specific game with its specific goal and underlying EEG parameter that was to be trained. The following table features details about the three specific games.

Table 1: *The Game Controls*

	Game	Electrode location	NF parameter	Sound	Game parameter	Range	Goal
1	**Tone-goes-low**	C4	12-16 Hz	Sine wave tone	pitch	8 steps' chromatic scale	Make tone's pitch sound low
2	**More-tones**	F3	16-20 Hz	Chord	Number of tones in chord	0-7	Make the chord sound wide
3	**The arpeggiator**	F4	8-12 Hz	Looped sequence of tones	Number of tones in sequence	0-16	Make the sequence rich with different tones

The three games were administered twice in a row (first game, then second, then third, then first again and so on). There was at least 40 seconds break between the rounds, expanding further on occasions when the participant needed to rest for a while or when they were talking with the researcher about the goal of the game ahead. The goal of each game was explained in a few words before the start of each round, otherwise the communication between participant and researcher was kept at a minimal level. Each training session was immediately followed by a semi-structured interview with average lengths of 12 minutes.

2.2 Our neurofeedback protocol

Each of the three games that form our protocol is based on a different underlying EEG parameter. In NF practice the common approach is to train one or two parameters from the beginning to the end of a number of sessions (for a review of common NF protocols see: Marzbani, Marateb & Mansourian, 2016). With our multiparameter design we aimed to facilitate an experience of getting through number of different mindsets during one session. The skill to train here would be the ability to voluntarily switch between the distinct mental states.

The first game, the **tone-goes-low**, is designed to reward increase in the relative power of sensorimotor rhythm (12-16Hz) on the C4 location. This parameter is being extensively used to reduce symptoms of ADHD or epilepsy. SMR rhythm is being associated with the mental state of relaxed alertness (Faber, 2005), characterized by low levels of stress and anxiety (Egner & Gruzelier, 2004). The effects of long term systematic training of the SMR rhythm include improved declarative learning and shortened duration of sleep onset (Hoedlmoser et al. 2008).

The tone-goes-low game consists of one sine wave tone which varies in pitch on the chromatic scale of one octave. The player is supposed to keep the tone's pitch down most of the time.

The second game, the **more-tones**, is driven by the beta band (16-20Hz) relative power on F3 location. This parameter is in extensive use by NF practitioners as well, especially to enhance capability of will-driven concentration (for an interesting discussion about beta training see: Bluschke, Roeesner & Beste, 2016). Beta band activity forms part of the brain waves system known as the 'local mode frequencies.' Augmentation of power of local mode frequencies under a specific electrode indicates increased activity of the cortical neural populations right under the electrode (Knyazev, 2007).

The player's task in the more-tones game is to generate a full chord composed of nine tones panned across the stereo span. When the player is being unsuccessful in directing the underlying EEG parameter to the desired levels, the game reacts with silence. Of course, most of the time the game oscillates in between the two described poles – the number of tones the player hears will change dynamically from moment to moment.

The third game called **the arpeggiator**, is designed to reward positive fluctuations in right frontal alpha activity. The relative power of alpha band (8-12Hz) on F4 location is an integral parameter of frontal alpha asymmetry neurofeedback training (Harmon-Jones, Gable, Peterson, 2010). More pronounced alpha activity in the right frontal and prefrontal areas of cortex is being associated with positive emotions, or with the approach reaction to the stimuli (Allen, Harmon-Jones & Cavender, 2001). Less pronounced right alpha activity is commonly found in people diagnosed with depression (Henriques & Davidson, 1990).

The arpeggiator game has a start point and an end point, in contrast to the first two games that just flicker in between two extremes. In the beginning of each round the player hears one tone repeated in a loop, then another tone appears and the two tones get repeated one after another in the same rhythm, until the third tone complements the sequence, then fourth, fifth and so on. The sequence continues growing, getting richer and more colourful throughout the three minutes duration of the game round. The game parameter that the player is in charge of here is the number of tones that will appear in the looped and growing sequence during one round. If he or she is doing well, in whatever way this might be achieved, the sonic scape will gradually and relatively quickly get rich and colourful. If the player is not so good at it, the resulting soundscape will remain relatively poor all through the round.

Running successfully through the three games twice in a row constitutes the training experience. As each game will tend to reward a different mindset, players should be encouraged

to react dynamically, training the process of voluntarily switching between different states of mind.

2.3 EEG acquisition and processing

A modified Emotiv Epoc EEG acquisition device with golden cup passive electrodes positioned on F3, F4 and C4, with reference and ground on the ear lobes, was used to record the EEG stream (sample rate 256Hz) and send it via Bluetooth for processing that took place in OpenVibe and Pure Data software. At OpenVibe, the EEG signal from each electrode was filtered for a specific frequency band (see the table 1) using Butterworth filter and consequently sent at sample rate 10Hz via OSC to Pure data for further processing (calculation of relative powers, mean, SD). Pure Data software provided the environment for all the sound related programming and game administration.

2.4 Research sample specification

Our sample consisted of seven probands (all male, age 26 to 42), all residing and working or studying in the city of Prague and at the time, all of them dedicating a considerable amount of their time to music performance. One of the participants was a professional musician, music being his main source of income and main occupation, the other six all regularly practiced their instruments and all regularly performed live concerts with their bands and ensembles. Two of the subjects were PhD. students of oriental culture and languages, one was a master's student of philosophy. One participant had a regular office job. One subject worked as writer from his home. One subject worked as a self-employed sound engineer. All but two (the professional musician and the sound engineer) had attended university. The two subjects without the master's degree are nevertheless considered highly educated professionals in their area of expertise.

The deep interest and experience in the area of music was chosen as the main criterion to enter this study. The choice of the criterion was made for several reasons:

a) The game we were researching is purely sonic. We expected that the musicians could give us more specific feedback about the sound properties of the neurofeedback environment, including specific suggestions that could in theory be implemented in the next version of the training platform, than musically naive participants.

b) We made an assumption that people that regularly play a musical instrument together with and in front of other people, will be able to have the necessary introspection into the training situation, and will be capable of subsequent description of their introspective experience. It is somehow normal for them to control their momentary mental and emotional set with a goal

of producing very specifically defined sounds. It is common for them to engage in an action (playing an instrument) and parallelly monitor its running results using the sense of hearing.

All participants gave an informed consent to participation in the study before the first session. Before starting first session we also explained the purpose, aims and design of the study in full to each individual participant (including description of NF basic principles and of the individual games). After the last interview, we did an individual debriefing with each subject (average time 11 mins) sharing our point of view on neurofeedback and responding to all the questions that were not attended to during the sessions, in order to not to distort subjects' experience.

2.5 Nature of the collected data

Our main goal was to refer to how it feels to get to play a neurofeedback game. We were interested in what is going on from the perspective of the player. This task, trying to uncover the first-person perspective, was inherent to our approach to the NF training sessions and interviews. When talking to the participants, when asking them about the training, we encouraged them to give an account of impressions they had, personal or private thoughts and feelings. Whenever it felt appropriate, we assured the participants, that our aim here was to collect subjective opinions and that we were not seeking verification or assurance of the practical applicability of the training. We encouraged them to talk about what they felt, what crossed their minds, to mention whatever notions and impressions they might get during the session, however unsure they might be about their practical application or direct link to the NF. Whenever asking questions, we were trying to emphasize that the topic of our research was basically the participant, his feelings, thoughts, content of his mind - the participant interacting with the neurofeedback.

As all the data were gathered during interviews, a process which requires both sides to actively participate, the collected data were inevitably angled by the preconceptions of the researcher that was performing the interviews. We are aware of this fact, and we hope that our findings will be always interpreted in the broad context of the research described in this paper. To ensure that we have not further distorted the data during the process of analysis, the first version of this paper was sent to 3 randomly chosen subjects, to check the validity of the presentation – to date no misinterpretation was reported.

2.6 Data analysis

Our data set consisted of three hours of recordings of the after-training interviews. As a first step, all the recordings were listened to several times, edited and marked with notes in the

software program Reaper. Notes that were acquired during this familiarization with the data gave rise to the precode, a collection of labels describing the specific content of specific interview segments. The precode described the data set all through in its entirety. As a next step in data analysis, mutually similar precode items were united to form one code item. For example, the code item 'visual attention' originated synthesising precode items 'visual stimuli, observing surroundings, contemplating things, staring aimlessly, switching perspective, linking up visual and sonic attention.' In this fashion, a code containing 53 items was created. Consecutively, the data were re-listened to and time stamped with the code. Specific segments of data, pieces of interviews, might have got, and usually tended to get, labelled with more than one code item.

Originally, we scanned the data set for all the variety of motives we were able to identify, but in the later phases of the analysis our approach changed. From the point of tagging the data with the code, our approach to thematic analysis became theoretically driven (Braun & Clarke, 2006). Further on, we focused only on pieces of data directly related to our research question. Hence in the next section of this paper we work only with the parts of data that are directly related to the scope of this paper – with 22 code items, or motives (out of the original 53), that directly refer to process of controlling the game.

Code items like 'empty mind,' 'thoughts out of control,' 'associational stream,' 'flow,' 'closed eyes,' 'the breath' or 'concentration on sound' got selected for the final phase of analysis, for now, other motives, like 'the role of instructions,' 'feeling in control,' 'how do I feel today' or 'neurofeedback visions' are not dealt with here, for the sake of brevity, and are to be worked with further elsewhere, at a later date.

3. NF Game controls

Every game (chess, poker, ice hockey, Doom II, the staring contest…) is composed by elements that you can influence while playing - **the game parameters**. In our design, each of the three games that form the NF session has just one distinct training parameter. Each parameter is driven by a segment of Fourier-transformed EEG stream gathered from one electrode positioned on a specific location on the cortex, and it manifests itself in specific changes of the game sound.

As the only input to the system is EEG activity, it is as well the only means to control the game, the shape of the sound. In contrast to a simple computer game, let us say Super Mario Brothers, where each game parameter has its assigned (and graspable) **game control** (you push the arrow up and Mario jumps, you push the arrow down and Mario ducks), every NF game

parameter can usually be influenced by a multitude of game controls. There is never only one way to make the frontal alpha go down. There is, in fact, a wide multitude of factors that will influence the value of the frontal alpha relative power, some of them already described by researchers, some of them not that well defined. And there is of course great interindividual variety. In the interviews with our subjects we have been able to obtain descriptions of many different techniques, mental strategies of how to get control over the game. Each of these could be seen as a NF game control, an imaginary arrow up to push when you want the game to react. Each of the NF game controls is a specific momentary mental and emotional state, or specific mental or bodily technique.

Table 2: *The Game Controls*

GAME CONTROLS		tone-goes-low	more-tones	the arpeggiator
Body movements	contracting muscles		+	
	closing eyes	+	+	+
	opening eyes		+	
	Breathing	+	+	+
Different levels of activation	falling asleep	+	-	+
	getting calm	+		+
	getting activated		+	
	getting stressed	-	-	-
Direction of attention	looking inwards	+	-	
	looking outside	+	+	
	switching perspective		+	
Interaction with the sound	delving deeply into it	+	+	+
	forgetting it	- +	+	+
	sound is just feedback	- +	+	+
Thoughts that change the mindset	performing mental tasks	-	+	
	Imaging			+
	contemplating memories			+
	deliberate thinking	-	+	
	emptying the mind			
	thoughts out of control	-	-	-
The flow	associational streams			**+**
	feeling of flow	**+**	**+**	**+**

The table presents a list of all identified game controls. The three columns on the right of the table indicate the context in which the game controls happened to be discovered, the game in which they were used and the plus or minus sign, indicating its effects on the game sounds. 22

distinct motives, or code items reappearing in different contexts across participants and training sessions have all had one thing in common. All these singular pieces of data set constituted a description of specific interaction with the NF game, as well as of the perceived results of this interaction, through the optics of the player himself.

The individual game controls (listed in the second column) that had mutual similarities, which were complementary or contradictory to each other, or those which seemed to share a common denominator, were united under the same theme, that designates the specific family of game controls (these are listed in the first column of the table).

In total, 6 themes (families of game controls) were identified. The following section presents briefly each theme's crucial aspects. The descriptions are interlaid by exemplary samples from transcribed interviews.

All the interview excerpts were translated from the Czech language by two translators, one of them having deeper knowledge of the research situation and the data set. All featured samples are tagged - the P followed by a number is the identifier of the participant, the S precedes the number of the participant's session in which the statement was recorded.

3.1 Body movements

As it might seem at first sight, this family of game controls has little to do with training the regulation of the brain's electric activity. It is a well-known fact that the EEG acquisition device registers and reflects changes in muscular tension. Body movements interfere with the game, becoming NF game controls, in fact, easily accessible ones. Influencing the NF game through body movements can prove useful especially early on in the training – the player can observe a direct link between his or her behavior (blinking, flexing muscles, clenching teeth) and the game (that responds through changes in the soundscape): "Sometimes there were moments when I had the impression that it just happened to work, that I yawned or burped and the signal spiked. So I saw it worked, but otherwise, I did not see any correlation (P3, S1)."

One of our subjects was able to experience the way that the neurofeedback tends to behave, just by flexing and relaxing the facial muscles. He observed that the NF reacts the best to the moments of change. As by the underlying design of our protocol, as well as by the nature of the EEG data itself, the game system reflects the best the dynamic changes in the electrical activity, rather than mirroring stable unchanging longer-time-span-occupying processes: "I think that the first time on the second game I contracted my face muscles, and it always worked. But it wasn't that I would keep them contracted, but it worked only when I contracted them

occasionally, when there was the oscillation of contraction, relaxation, contraction, relaxation... (P3, S1)."

As easily as the player can flex and relax the forehead muscles, he or she can open or close her eyes. The act of blinking itself produces an electrical wave which is considered an artefact, and for the most part it should be filtered out by the software that prepares the NF game parameters (Urigüen & Zapirain, 2015). However, the act of closing the eyes has a specific and profound effect on the electric activity of specific regions of the cortex - usually the alpha activity would get more pronounced (Faber, 2005). Our participants noticed, that closing eyes and keeping them closed, affected the game soundscape of the first and the third game: "Closing your eyes, that helped (P2, S1)." ; "When the eyes were closed. It worked best then, the third game (P1, S2)." ; "It was better with eyes closed, I think (P3, S2)."

Several of our subjects stated that the act of paying attention to breathing was beneficial while playing the game: "It worked best when inhaling or exhaling... when I paid attention to breathing (P2, S1)." Though one subject was surprised that slowing down the rhythm of breath did not seem to have any influence over the game sound.

3.2 Different levels of activation

The level of activation, or the level of arousal, gets, according our subjects, reflected in the NF games' soundscape. As each game was designed to react to a different EEG parameter, changes in activation level had distinct impact over respective games.

The first game, tone-goes-low, reacted in a desirable way, while our subjects happened to calm down deeply, even start falling asleep: "I think I dozed off on occasion. So that obviously worked (P2, S2)." ; "It calmed me down, I almost fell asleep during it (P4, S1)." On the contrary, the more-tones game rewarded exactly the opposite process – the process of waking up: "Today it made me fall asleep sometime and, paradoxically, it felt that the chord sounded the most at the point when I started falling into a state of stupor, then I woke up again, and then that short moment before I could fully focus again – that's when it started sounding the most (P5, S2)."

The reason behind the frequent incidence of motives related to activation might lie in the fact that every single one of our three games in theory required a different amount of activation from the player. The tone-goes-low game designed to reward augmentation of so called sensorimotor rhythm in the right motoric cortex, was many times perceived as a relaxing game - a game that requires relaxation: "In the first game I felt that all you need is to do nothing and stay completely calm (P7, S1)." Or as the game that induces relaxation: "The music also prompts this,

or at least that low tone which is not at all dynamic – it prompts you to be completely calm (P7, S1)."

The relaxed state, perceived as necessary to manage the game by all our subjects, could have been achieved in more than one way (as we have seen above, calming your breath, closing your eyes, are amongst the game controls). One of the techniques used by our subjects consisted in making your mind calm, or empty: "It seemed to me that you might want me to get into a meditative state, one without any thoughts (P2, S1)." It was this state of low-activation, with low amounts of content in perception, that seemed to work well in the tone-goes-low game.

When the participants were talking about the more-tones game, designed to reward augmenting in the relative power of the left frontal beta band, there was no mention of drowsy or sleepy, or calm, states making this game work well. The more-tones game was rewarding the state of mind, characterized by a higher level of arousal: "...the chord, I had a feeling that it is reacting then... I basically saturated my mind with activity, and it jumped up (P3, S2)."

During the more-tones game players were required to engage in a state different from relaxation, or absentmindedness, that could prove useful while playing the first game: "Like activity more than passivity (P3, S2)." The more-tones game required higher arousal than the tone-goes-low game. Yet, one of our subjects mentioned that he found both games working on a similar principle. He had to get to certain state of mind, being both attentive and relaxed to a certain degree at the same time. Only the second game seemed to require more of this ambiguous mind setting. "I had to work the hardest to achieve the desired effect, I think, for the middle game, the one with the chord. In the first game it may have been the same case or a similar mental state, although it was easier. But still, my mindset was not really relaxed (P5, S2)."

If we imagine a horizontal line representing distinct mindsets characterized by different levels of arousal, there would be the state of falling asleep on one end, continuing through various levels of attention and concentration. The other end would be occupied by the state of stress. As expressed by our participants, the mindset that could be described with the word stress never led to the success in the game.

None of our subjects happened to voluntarily evoke the mental state of stress or anxiety as attempted game control, yet the presence of stress was mentioned repeatedly. Most frequently, the stress was triggered by the feeling of not meeting the demands of the game: "And when there was this silence, I was getting stressed, it was like, this should not be happening, I guess (P2, S3)." One subject stated that he got more relaxed as he somehow learned for himself what he

should do to get control over the game sounds, as he grew more experienced with the NF games: "There was no longer this searching, which can be stressful... It seemed that I was more concentrated and maybe more relaxed than previously. I was more present (P6, S2)."

3.3 Directing your attention

When a specific mental technique got rewarded in one game there was a quite universal tendency amongst subjects to try to use it again in a different game. When any player discovered a game control, one that seemingly worked on a specific occasion, he stuck to it and experimented with its functions in the next game: "... in the second one I had the feeling of experiencing it. Then I tried to apply it everywhere. In the third one it also worked, but in the first one, I felt as if the relationship is inversed... I'm not sure how to express this. It's like perceiving the outside as opposed to perceiving the inside. When I actively tried to perceive the outside, the brain activated in a certain way which made the chord broader. When I looked inwards, the chord went down to nothing (P3, S2)."

As well as the 'getting calm and getting activated' game controls described in detail in the previous section, the game control identified here has power over two different games, behaving antagonistically. It is an axis. On one pole there is the attention aimed inwards, which gets rewarded during the sensorimotor cortex training, in the tone-goes-low game, and on the other there is the attention aiming outside, to the external world, which gets rewarded in the more-tones, frontal beta activity based, game.

The direction of attention in some cases might be tied to visual attention, but not exclusively. The player can have her eyes wide open, but she does not have to be really concentrating on what lies in her visual field. This empty staring at a specific point external to him helped one of our subjects make the tone pitch go down in the tone-goes-low game (which is supposed to reward attention aimed inwards, the opposite state, according the above cited subject): "Focusing on one spot on the table and just shutting down (P1, S3)." It is quite probable that the empty stare at one random space, a stain, had little to do with the attention directed towards the exterior. On the contrary, in this case staring could have been used as a technique to switch-off, to calm down, to restrain oneself from other stronger, interior or exterior, stimuli. Nevertheless, active participation in visual attention seemed to be the main feature of this family of game controls: "When I actively tried to perceive the outside, the brain activated in a certain way which made the chord broader (P3, S2)."

Besides directing the focus and attention (both visual as well as mental) to the outside world, one player discovered for himself a powerful game control that worked well in the more-tones game: "I oscillated between focusing on this jack, and the floor, as I wanted to see what it will do, and it seemed to me to work a bit at that moment just when I had to change perspective... As if the chord sounded the most at that moment (P5, S3)."

One subject expressed that he at first struggled with the more-tones game, trying to get hold of the game by thinking of topics that he would think about in situations where he needed to concentrate. He did not really feel a correlation between himself and the game sounds until he changed his strategy and started using visual-attention-directed thinking, some form of active contemplating of things in his visual field: "I first tried to think, but this just made me lose my flow, so in the second round, I just let my mind wander over various things – I got the impression that I was being successful at exactly the moments when I was with the given thing, that is not just looking at it, but actually understanding the function it serves (P1, S2)."

3.4 Interaction with the sound

As we worked with purely sonic feedback, the sound was basically the only stimulus the player was exposed to while playing the game. Consequently, focusing on the sound was a natural strategy to play the game. And it might have proven effective, in some cases, it might have helped the player to fulfill the goal of the respective game: "Trying to delve into it. I guess I focus most on what's supposed to be there, that deep tone, that full chord. It seemed to work in some way, as if the more you concentrated on the desired effect, the more you got it (P6, S1)."

For this particular participant the game reacted in the desired way, as he managed to 'delve deeply into it:' "Specifically, the low tone in the third game came just as I was getting into it. In the whole sequence of the tones as they unfold and rise into higher and higher frequency, I got the impression that the more I get into it, the more they come (P6, S1)."

As the player gets more experience with the neurofeedback, he or she might start to apply a different strategy, a different approach to the sound: "There was a big difference from the first session when it was all new and I had the impression that I am most successful in the game, as it was taking up all my momentary mental capacity. It is the same now, but I am no longer preoccupied so much with how it should sound, but rather with attempting to let go of the mind, leaving it to settle down as much as possible (P5, S3)."

In this case, during our third and final training session, the participant discovered for himself that he might not have to focus as much on the sound. Rather, the sound became

a part of the background, an indicator of success in the game, a guide to walk him through the round. But he did learn to not to lay his full focus upon it anymore.

Several participants reported, that while playing the first game, the tone-goes-low, the act of focusing on the sound paradoxically led to a failure in the game. Focusing on sound in the tone-goes-low game, which had proven to be an effective game control for some players in specific points of training (for one participant even proving useful in all the games across all sessions, while a couple of others mentioned the importance of this game control while playing the arpeggiator game, whose sound scape was the most complex one), was identified as the antagonist of a game control. The act of focusing on sound here made the game behave in an undesirable way: "In the first game, I stuck with attempting to not sleep, but somehow shut down, but the change of tone always perturbed me at the moment of its onset (P1, S3)." ; "What I did (in the first game) was supposed to be the solution of this problem. To just forget about the tone, to not even listen to it, and just to try continuing on without it. But that's when you lose track of the objective and then it is hard to regain it. As if you were supposed to think about a problem which in fact does not exist (P4, S2)."

Furthermore, the sound as the only stimulus to which the players are exposed to while playing the game might be perceived as some objective, neutral agent, an indicator of how the players' brain behaves at the present moment. But the sound, closely resembling music, has at the same time some degree of influence over one's momentary mindset: "The sound insinuates itself as an indicator, right? Or at least I understood it as such, as something which the person assumes is the neutral feature of the whole thing. But rather, at the moment when you get flustered from all the other stimuli, and you are just alone with your mind and the sound, the sound becomes the biggest influence on your emotional state, right? The sound draws associations of its own (P1, S3)."

3.5 Thoughts that change your mindset

For many participants, engaging in specific work with thoughts and imagination constitutes a means to influence and change their momentary mindset. As one participant expressed: "I know that imagining music can evoke a mental state. So you do not have to arise specific memories or something (P7, S1)."

Performing some form of mental task was used to induce a state of activity: "Like counting things or some sort of focused thinking, for instance about something I am supposed to do. And then in the second round, when I tried the opposite, that is to stay calm, it didn't work

very well. So I tried to return to the former, active state where I had to utilize my mental faculties (P7, S1).” As it was observed by this subject, this particular game control stood in opposition to ‘just calming down,’ which proved to be a useful game control in the first game. Performing a mental task had a desirable effect over the more-tones game.

Several subjects engaged in a specific form of imaging. Imaging performing some activity like playing music, listening to music or dancing was used to get a specific form of focus, to get into a mindset known from performing such activities for real: “Various types of concentration, how I would concentrate on sport, for instance (P7, S1).”

Some participants decided to test how thinking about daily tasks, or imaging having to deal with tasks they commonly encounter, influences the game sounds. “Focusing on some things in the form of mental images, pure abstraction, pure analysis, and then I approached it practically, and started thinking about what I was going to do today (P4, S2).” ; “I first tried to think, as I do when I have to deal with some task … but this just made me lose my flow… (P1, S2).” The two above cited subjects both referred to an occasion while playing the more-tones game. For one of the subjects the strategy proved to have desirable impact over the game, for the other it was the opposite. During the interviews one fact that might explain the ambiguity of this game control surfaced: “Everyone feels different during these procedures, these day-to-day, quotidian tasks (P4, S2).”

Though the work with thoughts might prove to be a useful game control on occasions, involuntarily created thoughts attracting the focus of the player were mostly unwelcomed during the training situation.

Being it a single thought, related to the game goal, “At the moment when I started to have a concrete thought, although the thought may have been a wish for me to do better in the game, it just stopped working (P5, S1).” Being it a continuous stream of unwanted thoughts: “As there were too many thoughts working on my mind, I got locked into the state of not focusing fully on the game (P5, S2).” Or the voluntary act of jumping from one thought to another: “(In the third game) I tried to let my mind wander about the room, and just play around with the thoughts, and I think that nothing really happened (P2, S3).” It usually led the player to momentary failure in all three games that constituted our session.

On the contrary, the antithetical mindset to the one described above, the one mindset where little to no focus is concentrated upon thoughts, seemed to work as powerful game control, having some form of impact over all three games: “So I tried to get into a state of meditation in

which I would pause the inner dialogue and not think too much about anything, to calm down, or something like that (P4, S1)."

Even concentration on the game sounds could be willingly faded down in order to apply this particular game control: "It was enough to somehow focus the mind, or simply calm it down without having to imagine how it will sound, and suddenly it started working all of its own in certain places (P5, S3)."

3.6 The flow

Some of our subjects discovered that they perform best in the moment when they reach to get to a state described by a word flow: "Like catching a wave, like going with the flow of the game (P5, S3)."

This hard to achieve and hard to maintain mindset proved to be the game control, at least for the above cited subject, that had all the power over the game, over all of the three games that formed the NF session. Basically, this subject felt that he performed best simply when he was performing the best. The fact, that he felt successful in fulfilling the game demands led him to perform better, to maintain the mindset that in turn helped him to keep going, to keep performing well: "It is a game, right? Or at least that is how I approached it. When you play a game, you usually enjoy it more the better you are at it. And that happened to me with the chord. The satisfaction that I am succeeding did not break my concentration. On the contrary (P5, S3)."

Closely tied to the 'flow with the game' game control lies one very similar to it, similar in the perceived automatism or easiness. Rather than wilfully applying this game control, the related mindset was brought by the act of playing the game. Its occurrence was limited to the arpeggiator game: "It wasn't that I said to myself "Be happy" or something, but I rather floated through an associative map of things I, for example, was looking forward to... It set off a chain of associations about Paris or something, or my girlfriend, and the flow just continued from there (P1, S2)."

The word 'flow' was used by the above cited subject to describe what was going on in his mind during one, in his eyes, very successful round of the arpeggiator game. In contrast to the 'flow with the game' game control described right above, this mental set was characterized by an abundance of imaginative content, fluently coming in and going out to the center of the player's focus: "In the third game, it kind of guided me all of its own. Just by the music being pleasant, I was imagining some dance, or that I was dancing, or that I somehow added another layer to the rhythm, which was pretty complex of itself. It started connecting with some

visualizations of a rather pleasant nature – some flowers, movement, dance, all kinds of things (P7, S1)."

4. Conclusions

All the participants, not regarding doubts and preconceptions, felt some kind of link between themselves and the neurofeedback games. Their actions were reflected in a way in the shape of the game. The actions that were considered as having influence over the game shape varied inter-individually and in time. The three different games (driven by distinct EEG bands obtained on different locations on scalp) were to be identified as behaving (or reacting) differently one from another (action that would work in the first game, would have the opposite of the desired effect in the second game…).

Some players, though, were able to identify a strategy that seemed to work well across the three different games. This game control could be named "unwitting concentration." The games worked well when you focused and forgot them in the same time, when you concentrated without really trying hard. This mental set was, as the sessions were going by, associated with the moment of success in the game. From what we heard from our subjects it could be abstracted that basically the success in the game was one of the most powerful game controls – when you caught the wave, when the chord sounded wide, when you perceived the game sounds as a soundtrack to a stream of associations that just happened to flow through your mind – that's when you got hold of the game, when you became successful at it. On the contrary, when your thoughts wandered around, when you had to struggle to achieve the game goal, that is when you performed badly.

4.1 Future direction of our research

The presented research has many methodological insufficiencies of which the reader might have become aware. For instance, the sample has characteristics that deem the skew and limit the obtained results. The identified game controls have only partial effectivity. The order in which they are presented in this paper is only one of the possible ways to approach the systematization of the NF game strategies. The game controls are presented as they happened to be talked about by our subjects. Some of them could be perceived as similar or nearly identical to one another (as 'getting calm' and 'emptying the mind,' or 'getting stressed' and 'thoughts out of control'). Therefore, the presented results are not by any means to be generalized, abstracted and assumed to be omnipresent across the population, hence our sample was very specific, as well as

our study design and approach to the data analysis. This study could be considered one of the pilot studies concerning the first person optic on neurofeedback as a game. The presented results, the list of so called NF game controls, stand here for further discussion in the context of other research studies, always bearing in mind the context of data acquisition.

The strong side of this paper is that it is very timely – the results were analysed and this report was created in matter of months after the collection of the data. Our aim was to prepare a framework and present first, rather preliminary, results to open a discussion on this heavily underreported topic. Simultaneously, our team is working on more comprehensive mixed methods study of the NF training experience, that will build on top of the results presented here.

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