Neuroscience and Biobehavioral Reviews 51 (2015) 87–99

Contents lists available at ScienceDirect

Neuroscience and Biobehavioral Reviews

journal homepage: www.elsevier.com/locate/neubiorev

Review

Neurofeedback and its possible relevance for the treatment of Tourette syndrome

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ARTICLE INFO

Article history:
Received 27 August 2014
Received in revised form
22 December 2014
Accepted 12 January 2015
Available online 20 January 2015

Keywords:
Neurofeedback
Cognitive control
Tourette syndrome
Neural oscillations
Basal ganglia

ABSTRACT

Neurofeedback is an increasingly recognized therapeutic option in various neuropsychiatric disorders to treat dysfunctions in cognitive control as well as disorder-specific symptoms. In this review we propose that neurofeedback may also reflect a valuable therapeutic option to treat executive control functions in Gilles-de-la-Tourette syndrome (GTS). Deficits in executive control functions when ADHD symptoms appear in GTS likely reflect pathophysiological processes in cortico-thalamic-striatal circuits and may also underlie the motor symptoms in GTS. Such executive control deficits evident in comorbid GTS/ADHD depend on neurophysiological processes well-known to be modifiable by neurofeedback. However, so far efforts to use neurofeedback to treat cognitive dysfunctions are scarce. We outline why neurofeedback should be considered a promising treatment option, what forms of neurofeedback may prove to be most effective and how neurofeedback may be implemented in existing intervention strategies to treat comorbid GTS/ADHD and associated dysfunctions in cognitive control. As cognitive control deficits in GTS mostly appear in comorbid GTS/ADHD, neurofeedback may be most useful in this frequent combination of disorders.

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1. What is neurofeedback?

Neurofeedback (NF), also referred to as EEG biofeedback (Butnik, 2005; Hammond, 2007), utilizes two important aspects of human behavior: firstly, a significant part of behavior is based on and can be modulated by operant conditioning. Secondly, this form of learning can be applied to the underlying neurophysiology by teaching recipients how to modulate particular patterns of their neural activity and providing positive reinforcement (Arns et al., 2014; Gevensleben et al., 2014; Heinrich et al., 2007; Van Boxtel and Gruzelier, 2014). Aiming to modify mental states or processes, which are associated with different neural frequencies, NF is used as a behavioral therapy tool in order to improve the ability to

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http://dx.doi.org/10.1016/j.neubiorev.2015.01.012
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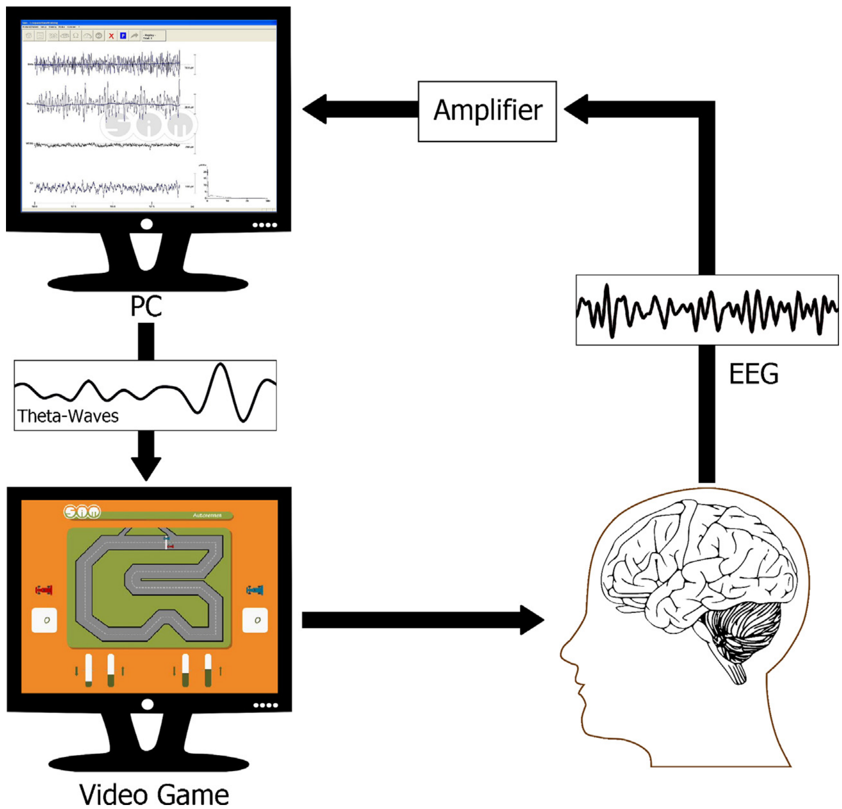

Fig. 1. Schematical illustration of a neurofeedback setup. Patients may play a video game on PC. This video game is controlled by their brain activity. Neurophysiological processes are recorded using the EEG and decomposed in its constituting frequency components. The power in on or several of the frequency components is estimated and used to control the video game.

self-regulate these neuronal firing patterns and, therewith, mental states (Arns et al., 2014; Butnik, 2005; Van Boxtel and Gruzelier, 2014).

During NF, cortical activation is recorded from the head of a participant using 3–7 electrodes. The EEG is then decomposed into its frequency bands and the relative power of each frequency band is estimated. The information about the power of the frequency bands is then used to control a game (e.g. speed of car on a race course). Using this feedback, the participants are trained to "adjust" the relative power of certain frequency bands in EEG (refer Fig. 1).

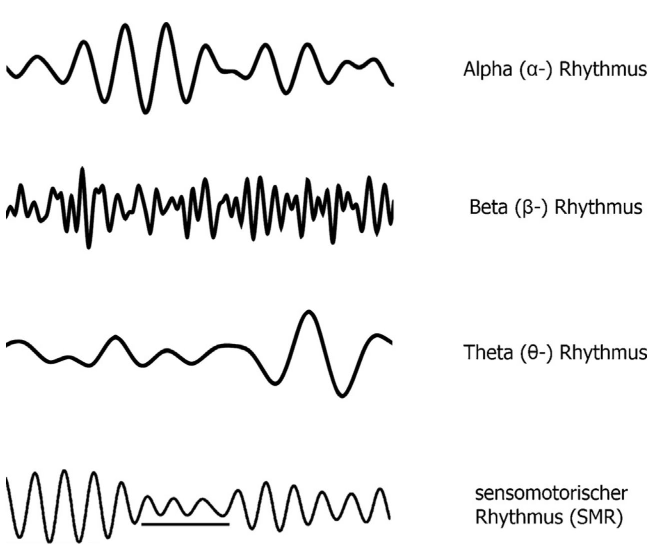

Fig. 2. Different frequency bands used during neurofeedback.

As outlined above, NF is based on the modulation of the power (strength) of different frequency components in the EEG. The different EEG frequency bands are shown in Fig. 2.

Whereas alert states of arousal and focused attention are reflected in higher frequencies such as fast beta waves (13–21 Hz), slow wave theta activity (4–8 Hz) has been reported as characteristic for inalert, daydream-like states that are associated with mental inefficiency (Butnik, 2005; Hammond, 2007). Opposed to the latter, excessive theta activation has also been reported during the performance of complex memory and attentionally demanding tasks requiring high cognitive control (Gevins et al., 1997; Yordanova et al., 2006). The increase of theta frequency with rising memory load as well as after extensive practice has been interpreted as reflecting effortful attention which is required for maintaining information in mind for the time of cognitive processing (Gevins et al., 1997). Against this background, theta waves might not only reflect mentally idle states, but also focused effortful processes (Butnik, 2005; Yordanova et al., 2006). Alpha waves (8–12 Hz) represent a relaxed, but more standby state (Hammond, 2007) typically observed during memory processes. This frequency is supposed to index memory performance or processing capacity (Klimesch, 1997, 1999; Ray and Cole, 1985). The slowest frequencies are those of the delta band (<4 Hz) which occur during sleep (Hammond, 2007).

2. Overview of neurofeedback protocols

Modulating specific brain waves and psychological states in the context of NF protocols can range from frequency band protocols targeting the sensorimotor rhythm (SMR), the theta-beta ratio (TBR) or slow cortical potentials (SCP) such as the contingent