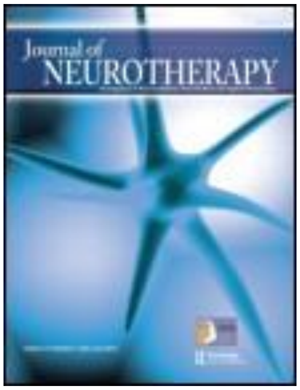

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Neurofeedback 2.0?

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EDITORIAL

NEUROFEEDBACK 2.0?

Our field is developing rapidly without many of us being fully aware of the fundamental progress taking place at the time of writing. In 1999 the web was developing at a fast pace and becoming widely known by the general public. However, most of the regular users in those years were not fully aware of the fundamental change the Internet was going through, from Web 1.0 to Web 2.0.

In the 1990s the Internet was a source of information enabling people to exchange information via e-mail. This is currently referred to as Web 1.0, first coined by DiNucci (1999). At that time the Internet was rather passive. Many companies had a website posting information. Nowadays, Web 2.0 is a completely different Internet, more personally oriented, more interactive, as people can place their minute-to-minute experiences online (using services like Facebook, Twitter, and LinkedIn), where virtually everyone has a web presence by means of a blog, personal website, or YouTube video. Furthermore, much of the data and software used by our personal computers are stored and retrieved from ''the cloud,'' that is, word-processing tools in a web browser, and data retrieval is done without need of locally installed software. Also, the first Internet TVs have been announced by Google, demonstrating how far the Internet is penetrating our lives. Who would have envisioned in 1999 that right now 6% to 8% of all sales would consist of e-commerce sales (Forrester, 2009)? That our children are broadcasting their everyday experiences across the Internet using Twitter? That a ''Web 2.0 suicide machine'' would exist to delete all your social networking profiles (http://www.suicidemachine.org)?

In view of the history of the media these developments might come as less of a surprise. The invention of the printing press in the late 15th century gave rise to the possibility of printing books. Later, however, this process was further automated and perfected giving rise to many new—and more rapidly changing—content by means of newspapers, magazines, and so forth, which in turn made the media more ''personal'' by having different newspapers per political stream and possibilities of submitting letters to the editor, among other things. Looking at the history and future of neurofeedback in the broadest sense, it is also important to be aware of our past, in order to better judge what will be happening in the future. In Volume 14, Issue 4, Martijn Arns introduced the Historical Archives feature. Some of the early works on classical conditioning from the 1940s were summarized (Arns, 2010), also called ''associative learning'' of the alpha blocking response (Jasper & Shagass, 1941a). In 1949, Jasper and Shagass (1941b) demonstrated for the first time ''voluntary control'' of the EEG, based on classical conditioning principles. Later, in 1962, Wyrwicka and Sterman replicated this principle of classical conditioning using electrical stimulation of the basal forebrain. They paired the electrical brain stimulation to an auditory stimulus, and eventually the auditory stimulus alone triggered the sleep preparatory behavior initially observed after the basal forebrain stimulation (Wyrwicka, Sterman, & Clemente, 1962). In that same year Joe Kamiya presented his first results on ''voluntary control'' of the alpha rhythm (Kamiya, 2011), which was followed by Sterman's first report of operant conditioning of the SMR rhythm (Wyrwicka & Sterman, 1968), which was found to exert anticonvulsant effects (Sterman, LoPresti, & Fairchild, 2010). Since these early days—also by advances in computer technology—neurofeedback has become widely used, both clinically and as a research tool.

The recent National Institute of Mental Health Multimodal Treatment Study of Attention Deficit Hyperactivity Disorder (ADHD) findings have been published at 8 years follow-up, demonstrating that both medication and behavior therapy do not result in clinical benefits beyond 2 years (Molina et al., 2009), which sparked the interest of many psychiatrists investigating different treatment modalities for the treatment of ADHD, neurofeedback among them. Several known ADHD and autism researchers such as the groups from Ohio State University (Eugene Arnold and Nicholas Lofthouse), Radboud University Nijmegen (Jan Buitelaar), and University of California, Los Angeles (Jaime Pineda) have all conducted research into the utility of neurofeedback in the treatment of ADHD and autism. In Internet years, this marks the point of neurofeedback 1.0. The neurofeedback technology is known everywhere, practiced widely, and more and more accepted, although questions remain and there is room for improvement.

At the beginning of this century we experienced the bursting of the Internet bubble; similarly, we may now expect a bursting of the ''commercial neurofeedback 1.0 bubble'' when many major electronics and toy companies such as Mattel, Neurosky, and Emotiv (and other commercial providers selling ''*the magic neurofeedback software that fixes all*'') are hyping this technology, possibly leading to yet another bubble bursting, explained by either ''underdelivery'' or ''unwanted side effects'' due to the large-scale and unsupervised use of neurofeedback technology.

So where would Neurofeedback 2.0 be heading? Many of you are probably thinking . . . LORETA Neurofeedback? fMRI Neurofeedback? However, using the same analogy as with Web 2.0, we should first look back rather than forward! LORETA neurofeedback and fMRI neurofeedback, although very promising, are a modification and improvement on the same theme, that is, more ''processor intensive'' but not a fundamental change. So where did we start? Our field started with classical conditioning, followed by pairing of stimuli to specific brain stimulation: associative learning.

In the latest issue of *Nature*, Engineer et al. (2011) pointed to a possible new direction of where neurofeedback 2.0 might be going! They employed simultaneous pairing of auditory stimuli with vagus nerve stimulation (VNS). VNS was chosen as a ''less invasive'' method to directly trigger the release of neuromodulators known to promote plastic changes, and VNS is also shown to result in desynchronized EEG (Engineer et al., 2011). In their first experiment they demonstrated that the pairing of VNS with a specific auditory stimulus resulted in a drastic change in the plasticity of the primary auditory cortex as shown on the frequency map. In a second experiment they used an animal model of noise-induced tinnitus and further tested if this technique could renormalize the pathological plasticity and subsequently eliminate the tinnitus. In this part they paired the VNS to multiple tones. So essentially they are employing ''associative learning'' principles, where an auditory stimulus is paired to specific brain stimulation (VNS) capable of promoting cortical reorganization. This ''associative learning'' represents a very basic neural principle, which has been demonstrated in Aplysia Californica (a marine invertebrate consisting of only 20,000 neurons; Hawkins, Kandel, & Bailey, 2006) and could also be explained by Hebbian plasticity (cells that wire together, fire together). Hence in neurofeedback there may have been an overfocus on ''operant conditioning,'' and we should maybe investigate and explore more the implications of associative learning.

The first two patients with tinnitus in Dirk de Ridder's Belgian clinic have been treated in the way just described. A first clinical observation was that ''the patient reported an improvement, but was not Tinnitus-free,'' demonstrating a proof-of-concept in humans.

So can we still call this neurofeedback? We cannot call this ''feedback,'' but this form of associative conditioning could lead the way for further developments in neurofeedback. Pairing sounds with tinnitus-matched frequency to negative feedback and sounds different from the tinnitus pitch to positive feedback might be worthwhile investigation—especially if combined with LORETA, which, for example, targeted dorsal cingulate activity. However, if we consider neurofeedback to be a neuromodulation technique in which learning principles are involved, this associative conditioning technique could be considered a form of neurofeedback. In analogy, in 1990, would we have considered broadcasting ''I just ate a sandwich'' via Twitter to be Internet? Or rather a form of radio broadcasting? Therefore, this might be a first demonstration of ''Neurofeedback 2.0,'' which will be characterized by neuromodulation techniques combined with learning theory principles, with a focus on ''associative learning.'' So let's broaden our horizon and spot the new developments!

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