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Immediate effects of alpha/theta and sensory-motor rhythm feedback on music performance

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ABSTRACT

This is one of a series of investigations comparing two EEG-neurofeedback protocols – Alpha/theta (A/T) and Sensory-Motor Rhythm (SMR) – for performance enhancement in the Arts, here with the focus on music. The original report (Egner and Gruzelier, 2003) established a beneficial outcome for elite conservatoire musicians following A/T training in two investigations. Subsequently this A/T advantage was replicated for both advanced instrumental and novice singing abilities, including improvisation, while SMR training benefited novice performance only (Gruzelier, Holmes et al., 2014). Here we report a replication of the latter study in university instrumentalists who as before were novice singers with one design change — post-training performances were conducted within the tenth final session instead of on a subsequent occasion. As before expert judges rated the domains of Creativity/Musicality, Communication/Presentation and Technique. The proximity to training of the music performances within the last session likely compromised gains from A/T learning, but perhaps reinforced the impact of SMR training efficacy. In support of validation there was evidence of strong within- and across-session A/T learning and positive linear trends for across-session SMR/theta and SMR/beta-2 ratio learning. In support of mediation learning correlated with music performance. The A/T outcome was markedly discrepant from previous studies and should dispel any impression that the hypnogogic state itself is transferred to the performance context. The effects of SMR ratio training are consistent with an impact on lower-order abilities required in novice performance such as sustained attention and memory, and benefiting all three domains of music assessment.

1. Introduction

The present report is one in a series exploring the effect of EEG-neurofeedback in the performing arts (Gruzelier, 2012, 2013a) including creative music (Egner and Gruzelier, 2003; Gruzelier et al., 2014a, b), dance (Raymond et al., 2005a; Gruzelier et al., 2013), and acting performances (Gruzelier et al., 2010). With neurofeedback, putatively through instrumental conditioning principles of reinforcement, an index of a physiological parameter is fed back to the participant in real time so that they may learn self-regulation. The ability dates back to the 1960s (Kamiya, 1969; Sterman et al., 1969). Through convention 'neurofeedback' is the term applied when the feedback involves the central nervous system via methods of EEG (Gruzelier, 2013 a,b, 2014), fMRI (Ruiz et al., 2014), MEG (Florin et al., 2014), NIRS (Kober et al., 2013) and transcranial Doppler sonography (Duschek et al., 2011), while an earlier term 'biofeedback' has become reserved for the feedback of peripheral nervous system measures.

1.1. Enhancing creativity in elite musicians

In the performing arts gains of pedagogic significance followed neurofeedback in music, dance and acting conservatoires (Gruzelier, 2013a). Here the focus is on novice musical abilities, in contrast to the earlier evidence of benefits for elite music performance (Egner and Gruzelier, 2003; Gruzelier and Egner, 2004). In two intervention studies at the Royal College of Music (RCM), London, we discovered that training slower rhythms in the EEG spectrum with the aim of raising theta (4–7 Hz) amplitude over alpha (8–12 Hz) amplitude in an eyes closed, quasi twilight or hypnogogic state, termed alpha/theta (A/T) training, was associated with professionally significant improvements in music performance as assessed by expert judges. Elevation of theta over alpha indexes stage 1 sleep (Niedermeyer, 1999), and hypnogogia has been associated with the production of creative insights in ubiquitous cultural spheres (Koestler, 1964). In the first of the studies benefits occurred across all the three domains of music performance that had been agreed on by the Associated Boards of the Royal Schools of Music (Harvey, 1994). The domains were Musicality/Creativity, Technical Competence and Communication/Presentation. Performance enhancement was found to be especially the case with the domain of Musicality/Creativity, which included the sub-category of Interpretative

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Imagination. While the musicians experienced all three of the EEG protocols, so that conceivably benefits may have accrued from a cumulative effect, correlations between the various neurofeedback protocol learning indices and the various rating domains and domain subcategories disclosed significant correlations only with the Alpha/Theta protocol. All three were compared in separate groups in the second investigation with a new student cohort. This time benefits aside from improving Performance Overall enhanced the Musicality/Creativity domain only. In neither study were gains in music performance found with the faster wave Sensory Motor Rhythm (SMR 12–14 Hz) or Beta-1 (15–18 Hz) protocols, nor incidentally with other interventions such as mental skills training, aerobic fitness or the Alexander technique (Gruzelier et al., 2002).

1.2. A/T: beyond anxiety reduction

When psychological factors come to mind in the world of the performing arts the primary association is the reduction of anxiety in its various appearances, including stage fright. Importantly, whereas all the interventions reduced pre-performance anxiety, only alpha/theta (A/T) training advanced music performance. The preferential gains following A/T training supported associations between the hypnogogic or twilight state and creative production (Koestler, 1964; Green and Green, 1977; and see Gruzelier, 2009). Hence the benefits for performance went well beyond anxiety reduction, yet at the same time A/T training has been found helpful in elevating mood (e.g., Peniston and Kulkosky, 1991; Raymond et al., 2005b).

1.3. Novice musical abilities and protocols

Here the focus was on novice music abilities which was the aim of three investigations funded by the National Endowment for Science, Technology and Arts (NESTA, UK). This was the second of two adult investigations (see also Gruzelier et al., 2014a), and there was a further study of eleven year old school children (Gruzelier et al., 2014b). In all three studies two protocols were compared. The A/T protocol involves participants relaxing with their eyes closed listening via headphones to auditory feedback in the form of pleasant sounds that were contingent on changes in theta and alpha power, with the aim of raising the amplitude of theta above alpha indexing hypnogogia and stage1 sleep, and putatively a state that favours creativity (Gruzelier, 2009, and see the Discussion). This was contrasted with a faster-wave protocol which involved elevating the sensory-motor rhythm which aims to induce a relaxed and efficient sustained attention. Elevation of the SMR is rewarded via points on a computer screen without concurrent rises in theta (4–7 Hz) and high beta (22–30 Hz; beta2), termed inhibits, and involves, as does the A/T protocol, frequency band ratio training.

1.4. SMR ratio training and behavioural outcomes

While SMR training had not benefitted elite music performance (Egner and Gruzelier, 2003), it was hypothesised that it would assist novice performance for the following reasons. In novice performance there are greater demands on attention, memory and technical skill when compared with playing compositions once they have been rehearsed in advanced performance. Ancillary studies in the conservatoire musicians had disclosed that the faster-wave protocols had a favourable impact on sustained attention (Egner and Gruzelier, 2001, 2004), and in the case of SMR training this extended to Calmness self-ratings (Gruzelier, 2013c). Similarly in an interpretative phenomenological analysis of a subsample of the musicians (Edge and Lancaster, 2004) fast-wave training was described as relaxing; as one musician said it "lets my mind breathe". But these advantages had not carried over to the elite music performance as assessed by the experts.

There is in fact growing evidence (see Gruzelier, 2013a,b, 2014 for review) of benefits from SMR training in healthy participants with a range of higher-order processes beyond attention, including working memory (Vernon et al., 2003), recognition memory in children (Barnea et al., 2005), visuo-motor skills (Ros et al., 2009), mental rotation (Doppelmayr and Weber, 2011), and creative acting in sophomores (Gruzelier et al., 2010). This evidence supplements the clinical benefits of SMR training for sustained attention in ADHD (e.g., Lubar et al., 1995; Rossiter and LaVaque, 1995; Linden et al., 1996; Fuchs et al., 2003; Gevensleben et al., 2009).

1.5. Creative improvisation

As in the first novice singing study (Gruzelier et al., 2014a) we included creative music improvisation in addition to the singing of popular folk songs. This would provide a further source of evidence where A/T training may play a role in enhancing creativity, for by definition improvisation is a creative exercise (Sawyer, 2000). Improvisation, being unprepared, was additionally seen as another facet of novice-level performance upon which SMR training may also have an impact.

1.6. Replication and aims

We set out to replicate the gains found in the first adult novice singing study (Gruzelier et al., 2014a) where the beneficial effects of A/T training were found to extend in two ways. Firstly, in judging vocal improvisation there was an increase in Interpretative Imagination, the primary creativity rating. Secondly, in the singing of the folk song Emotional Commitment improved, and this was endorsed by lay ratings of Confidence, Stage Presence and Expressiveness. Accordingly improvement was seen in the domains of Musicality/Creativity and Communication/Presentation. With regard to SMR training, despite some limitations in feedback learning for the group as a whole, in support of the experimental aims there was improvement in the domain of Technique through higher ratings of Pitch accuracy in vocal improvisation. Stronger evidence in support of the value of both protocols was found in an ancillary music study with children (Gruzelier et al., 2014b).

Summarising the aims of the study, the effects of a slow versus a fast wave neurofeedback protocol were examined on the novice singing ability of instrumentalists drawn from a university Music department. As has been customary in the majority of our neurofeedback studies, in order to validate the occurrence of neurofeedback learning, learning curves were obtained both within-sessions and across-sessions: see Gruzelier (2014) for a review of the role of learning indices in the validation of neurofeedback for optimal performance. Evidence of mediation through correlational analysis was also sought between learning and performance. Singing was examined both with well known folk songs and a creative improvisation exercise. While it was hypothesised that as before A/T training would facilitate music performance, and that SMR training would also benefit musical performance at the novice level, compliance constraints due to university pressures led to the post-training music pieces being performed at the end of the last training session. It was therefore likely that, should A/T training have been successful, the effects of hypnogogia and stage I sleep would not have worn off, and would likely compromise rather than facilitate music performance. On the other hand the additional load on low-order processes such as sustained attention, working memory and technique might provide a more rigorous test of the hypothesised benefits from SMR ratio training on lower-level processes in performance.

2. Methods

2.1. Participants & design

19 undergraduate music students volunteered from the Music department at Goldsmiths University of London, who who were

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