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Application of alpha/theta neurofeedback and heart rate variability training to young contemporary dancers: State anxiety and creativity

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ABSTRACT

As one in a series on the impact of EEG-neurofeedback in the performing arts, we set out to replicate a previous dance study in which alpha/theta (A/T) neurofeedback and heart rate variability (HRV) biofeedback enhanced performance in competitive ballroom dancers compared with controls. First year contemporary dance conservatoire students were randomised to the same two psychophysiological interventions or a choreology instruction comparison group or a no-training control group. While there was demonstrable neurofeedback learning, there was no impact of the three interventions on dance performance as assessed by four experts. However, HRV training reduced anxiety and the reduction correlated with improved technique and artistry in performance; the anxiety scale items focussed on autonomic functions, especially cardiovascular activity. In line with the putative impact of hypnogogic training on creativity A/T training increased cognitive creativity with the test of unusual uses, but not insight problems. Methodological and theoretical implications are considered.

1. Introduction

We had earlier reported the efficacy of two biofeedback procedures in enhancing dance performance (Raymond et al., 2005a). Over five weeks competitive university ballroom and Latin dancers were randomised to either training with an EEG-neurofeedback protocol termed alpha/theta training (A/T) which aimed to increase the theta/alpha ratio in an hypnogogic state, to a biofeedback procedure which aimed to increase heart rate variability (HRV), or to a non-intervention control group. Dancers performing in male–female pairs were evaluated individually by two qualified dance assessors with a scale used for national dance assessments incorporating categories of technique, musicality, timing, partnering skill, performing flair and overall execution. Both training groups improved more than the control group in overall execution, while within the subscales, A/T training improved timing and HRV improved technique. Practice diaries indicated that the control group had practised more. The team went on to win the UK championship. The present study was designed as a constructive replication in a contemporary dance conservatoire.

The ballroom dance study of Raymond et al. (2005a) had followed a first attempt to evaluate the efficacy of EEG-neurofeedback with conservatoire musicians. In the musicians two randomised controlled trials (Egner and Gruzelier, 2003) had shown music performance enhancement to a professionally significant extent following A/T training, in comparison with mental skills training, aerobic fitness, the Alexander technique, and Sensory-Motor Rhythm (SMR) and beta1 neurofeedback training. Music performance may be divided into three domains: musicality, communication and technique (Harvey, 1994). In the first of the two studies improvement in all three domains correlated positively with the ability to enhance theta over alpha in the hypnogogic state. However, of the three domains the more reliable effects of A/T training across the two investigations were with the musicality domain which includes interpretative imagination, in other words creativity.

The A/T protocol had in fact originated from informal studies which aimed to enhance creativity (Green and Green, 1977), a factor often lost sight of when these pioneering attempts were unsuccessful (for review see Gruzelier, 2009). E. Green had drawn on both the extensive historical anecdotes inferring that the hypnogogic border between waking and sleeping facilitated creative associations stemming from ubiquitous cultural spheres (Koestler, 1964), and the view that the theta rhythm was the EEG marker of hypnagogia. The hypnogogic state at this time was of cardinal interest, being described by Schachter (1976) in Psychological Bulletin as consisting of spontaneous visual, auditory and kinaesthetic images, unusual thought processes and verbal constructions, and symbolic representations of ongoing mental and physiological processes. Since then the production of theta with eyes closed has been shown to accompany states of deep relaxation close to sleep, meditation and hypnosis (Vaitl et al., 2005). Subsequently theories of creativity invoking low arousal, defocused attention became popular (Martindale, 1999), though with an almost exclusive focus on alpha activity at the expense of theta. Indeed theta received no mention in a recent review in

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Psychological Bulletin of electrophysiological studies of creativity (Dietrich and Kanso, 2010).

Here we set out to re-examine: 1) our preliminary findings of the efficacy of A/T training for dance performance (Raymond et al., 2005a), 2) evidence for enhanced well-being reported in university students (Raymond et al., 2005b, as well as 3) the beneficial outcome in dancers of heart rate variability training. HRV is a measure of the moment by moment variation in the RR intervals in the electrocardiogram. This may be maximised with paced breathing at around 6 breaths per minute resulting in a regular sinusoidal waveform akin to respiratory sinus arrhythmia. It reflects the interplay between the sympathetic and parasympathetic branches of the autonomic nervous system governing autonomic flexibility and vagal tone, and is influenced by internal homeostatic control systems (Porges, 2001). The centrality of HRV to emotional regulation is underpinned by corticovisceral connections (Thayer and Lane, 2000). Low HRV has been associated with a range of cardiovascular pathology (Stys and Stys, 1998), and with a lack of flexibility for affective regulation as found in anxiety and depressive disorders (Friedman and Thayer, 1998; Gorman and Sloan, 2000). Lehrer and colleagues in the light of earlier research from Russia have pioneered the efficacy of training up the variability in heart rate demonstrating increases in baroreflex gain both during the training exercises and at rest (Lehrer et al., 2003). Beneficial applications include neurosis (Chernagovskaya et al., 1990), hypertension (McCraty et al., 2003; Lehrer et al., 2000), asthma (Lehrer et al., 2004) and in an uncontrolled pilot study fibromyalgia (Hassett et al., 2007). Six sessions over three weeks have been found to be efficacious in patients with depression, though without effects in a healthy control group (Siepmann et al., 2008). In patients with substance misuse and post traumatic stress disorder there was a reduction in substance craving (Zucker et al., 2009). Aside from emotional regulation, improvement in cardiovascular adjustment in itself would benefit dancers and athletes. To our knowledge the ballroom dance study (Raymond et al., 2005a) is the only journal report of a controlled study successfully optimising performance in healthy participants with HRV training.

Here we made comparisons between A/T and HRV training, and two control comparisons consisting of dance instruction choreology classes and a no-intervention control group. Primary outcome assessments included: performance of a filmed dance phrase in groups which was rated for technique and artistry by 4 assessors blind to group and pre–post-training order; mood assessed with the self-report Depression Anxiety and Stress Scale (Lovibond and Lovibond, 1995); two cognitive assessments of creativity with the Guilford Alternate Uses test (Guilford et al., 1978) and Insight Problems (Dow and Mayer, 2004). For exploratory interest a laboratory scale was devised to measure presence-in-performance.

2. Methods

2.1. Participants

Sixty-four first year BA students at Trinity Laban Conservatoire of Music and Dance, of whom 42 were female, were recruited and gave informed consent to participate in the study which was approved by the college and conservatoire ethics committees. They were randomised to one of four groups: Alpha–theta neurofeedback (AT), Heart-rate variability (HRV), Choreology Studies, No-intervention control. For neurofeedback up to 18 subjects were trained in 1.5 h in groups of six. Choreological practice was delivered in group sessions. Sessions were programmed twice a week between 8:45 and 10:15. Pre and post training assessments were 12 weeks apart.

2.2. Alpha/theta neurofeedback

Up to ten sessions of neurofeedback per participant were carried out with a NeuroCybernetics (Encino, CA) EEG Biofeedback System and ProComp (Thought Technology Ltd; Montreal, Quebec) differential amplifier. Participants sat in a chair designed for relaxation with head support and at a roughly 45° angle and relaxed with their eyes closed and listened via headphones to auditory feedback representations of ongoing changes in relative theta (5–8 Hz) and alpha (8–11 Hz) power with respect to an eyes-closed relaxed 2 min baseline. Sounds of waves gently breaking on the shore were associated with theta and a babbling brook with alpha. When participants' alpha was higher than theta power the brook sound was heard, and when theta was higher than alpha the sound of waves. Each band also had an amplitude threshold, and suprathreshold bursts of alpha or theta were rewarded by a high- or low-pitched gong sound respectively. These thresholds were set manually and updated such that alpha and theta amplitudes were over the threshold approximately 60% of the time. The participants were instructed to relax deeply in order to achieve an increase in the amount of theta sound representation while avoiding falling asleep. They were told that when they heard the waves they should visualise themselves dancing in the way they most wanted to dance or achieve whatever they wanted to achieve in life. An active scalp electrode was placed at PZ with the reference electrode placed on ipsilateral and the ground electrode on contralateral earlobes respectively (Egner and Gruzelier, 2003). Skin was prepared with NuPrep and electrodes were attached with Ten20 conductive paste. Participants were seated in a comfortable chair in a room along with five others. Each session lasted for 20 min, with EEG data being gathered in one-minute "runs." The feedback sounds were then faded out and the participant brought gently to full wakefulness. Participants were monitored for excessive delta activity or sleep like behaviour, whereupon they would be tapped gently on the knee until they acknowledged that they were awake.

2.3. HRV biofeedback

HRV training was carried out using the Freeze-Framer (Boulder Creek, California, USA). This features a photoplethysmograph that attaches to a finger with software that presents the pulse pressure wave on a screen and plots a graph of heart rate over time. The variability of the heart rate curve is converted to a "score" which represents rhythmic changes in heart rate with breathing. The score is in the form of a 5-box graphic showing Very Bad, Bad, Good, Very Good, Excellent, based on the mean low frequency band (0.04–0.15 Hz) value from a spectrogram of the frequency of the variation rate. In addition mean HR is displayed. Though not as reliable as the electrocardiogram photoplethysmography is widely used for convenience, as in our previous dance study (Raymond et al., 2005a).

Participants sat in a comfortable chair with head support and were monitored throughout the 10-session protocol for signs of hyperventilation and instructed to breathe slowly but no more deeply than usual and to report any symptoms to the experimenter. Each session was 20 min long.

2.4. Assessments

2.4.1. Dance performance. A 40 second dance phrase designed by the Laban faculty was practised in groups of five and was assessed in pairs from filmed performance by four dance experts. They rated the randomised film clips for artistry and technical performance blind to order and to training group.

2.4.2. Cognitive creativity. The Alternate Uses Test (Guilford, 1978) to describe creative uses of a household object, e.g., toothbrush, paperclip in five minutes. Insight Problems (Dow and Mayer, 2004) e.g. "A magician could throw a ping pong ball so that it would go a short distance, come to a dead stop, then reverse itself. He did not bounce the ball against any object or tie anything to it. How could he perform this feat?" Twenty minutes were allowed.

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2.4.3. Mood questionnaire. The short form of the Depression, Anxiety and Stress Scale (DASS) (Lovibond and Lovibond, 1995).

2.4.4. Presence-in-Performance. A laboratory questionnaire consisting of four 10-point scales: How much "present in the moment" did you feel during your performance? How much did you feel you were able to express yourself? How distracted were you by thoughts or surroundings unrelated to the choreography? How well were you able to focus on your performance? This was assessed in the studio dance phrase and in a smaller sample ($N = 34$) in a stage performance post training.

2.4.5. Personality questionnaires were administered and will be the subject of a separate report. They consisted of the NEO PI-R (Costa and McCrae, 1992), also called the Big Five, with scales of Neuroticism/Anxiety, Extraversion, Agreeableness, Conscientiousness, and Openness to Experience with particular interest in Openness involving receptivity to novel experiences. The short forms of the Fear of Negative Evaluation (Leary, 1983) and Socially Prescribed Perfection (Hewitt and Flett, 1989) scales.

2.5. Analysis

Thorough data screening was conducted in accordance with recommendations by Tabachnick and Fidell (2007). A number of the participants who completed 8 or more sessions, and who formed the data set for analysis, were not able to complete various assessments due to illness, injury, etc. Missing value analysis was performed for each variable using multiple t-tests with the dependent measure (e.g. mood) variable as the independent variable (missing vs. non-missing) and all other variables as dependent variables. Participants with non-missing data on mood scales demonstrated significantly higher scores on Openness ($t51 = 3.00$, $p < .005$), suggesting that participants with higher Openness scores were more likely to attend assessment sessions. In all cases missing data were estimated using regression techniques.

3. Results

3.1. Alpha/theta training

The effects of training were examined by ANOVA trend analysis which was conducted on alpha and theta amplitudes between and within sessions. The mean changes in amplitude across sessions are shown in Fig. 1. In line with the training goals there was a linear decrease in alpha ($F\ 1,9 = 9.2$, $p < 0.05$) with a linear increase in theta ($F\ 1,9 = 9.8$, $p < 0.05$). These effects were further reflected in the within session changes for each session shown in Fig. 2. Progressive changes can be seen: within session 1 there was no decrease in power in either frequency, followed in subsequent sessions by a decline in alpha, until in session 10 theta power was greater than alpha throughout the session denoting successful training, albeit on the slow side in our experience possibly due to training in groups of six rather than alone. These individual within session changes are shown in Fig. 3 for each minute of the 18 minute sessions. This figure conveys the standard result found in our previous studies, where for the majority of subjects alpha is initially higher than theta and declines in a roughly linear fashion ($F1,9 = 9.20$, $p < 0.05$), whereas theta declines at first, reaches a plateau above alpha, and may increase towards the end. While the trends were statistically significant in our experience they are rarely smooth due to day by day contingencies which either favour or militate against achieving hypnogogia in the laboratory (Gruzelier, in preparation-a).

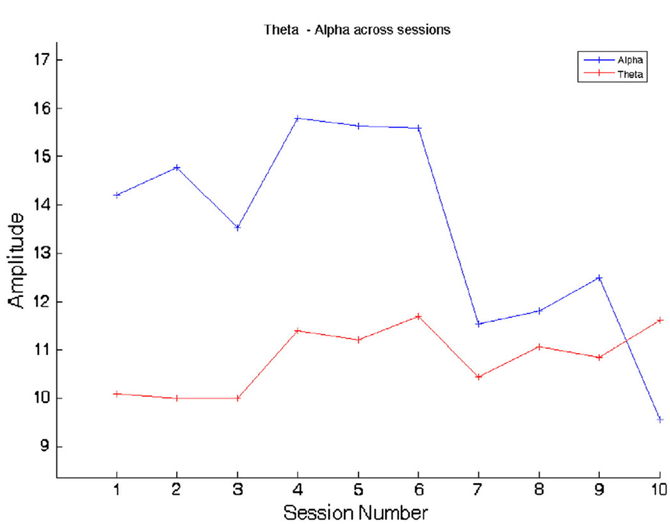

Fig. 1. Mean alpha and theta amplitudes in microvolts for the 10 training sessions.

3.2. Heart rate variability

As Lehrer (2003) has acknowledged participants respond well to feedback to increase HRV, as can be seen here in Fig. 4. This shows across-session learning with a linear increase in the variability in heart rate indexed by the standard deviation of the (normal to normal) RR interval (Linear, $F\ 1,8 = 6.227$, $p < 0.037$; Quadratic, $F = 2.10$, ns).

3.3. Dance performance ratings

Pearson correlations indicated that inter-rater reliability between the four assessors for Technical and Artistry ratings ranged between ($r = .54$ to $r = .67$, p's $< .001$) showing reasonable agreement on technical and artistic ratings at both pre and post assessment, and in order of magnitude comparable to judgements in the performing arts (e.g., $r = 0.53$, $p < 0.001$, Thompson et al., 1998; $r = 0.52$, $p < 0.001$, Gruzelier and Egner, 2004). Consequently mean artistic and technical ratings were constructed for both assessment periods. Means and standard deviations of pre and post training scores are shown in Table 1. The four groups were compared with repeated measures ANOVA. There were no significant main effects or interactions between Group and Pre/Post Assessment for either Artistry ($F = 0.62$) or Technique ($F = 0.25$).

3.4. Mood

For the Depression, Anxiety and Stress Scale scores (Table 2) the only group difference was in Anxiety ($F3,60 = 2.82$, $p < .04$; Depression, $F = 0.39$; Stress, $F = 1.37$). As can be seen in Fig. 5, there was a decrease in Anxiety over time with HRV training, with little change in the AT group and increases in Anxiety of a similar order in the other groups. Planned contrasts comparing each of the three experimental groups with the control group disclosed a significant difference between the HRV and control group ($t30 = 2.05$, $p < .05$), but no differences between the other two groups relative to the control group.

Importantly, reductions in Anxiety were associated with improvements in both artistry ($r = -.30$, $p < .05$) and technique ($r = -.25$, $p = .053$).

3.5. Cognitive creativity

Fig. 6 shows the results for the Alternate Uses test demonstrating an increase in the Elaboration score following AT training, in support of experimental hypotheses. In a one-way ANOVA there was a significant Group effect ($F3,45 = 4.60$, $p < .05$), with t-tests confirming a greater increase for the AT group compared with the control group ($t30 = 3.2$, $p < .01$). There was no impact on the Insight test (Table 2).

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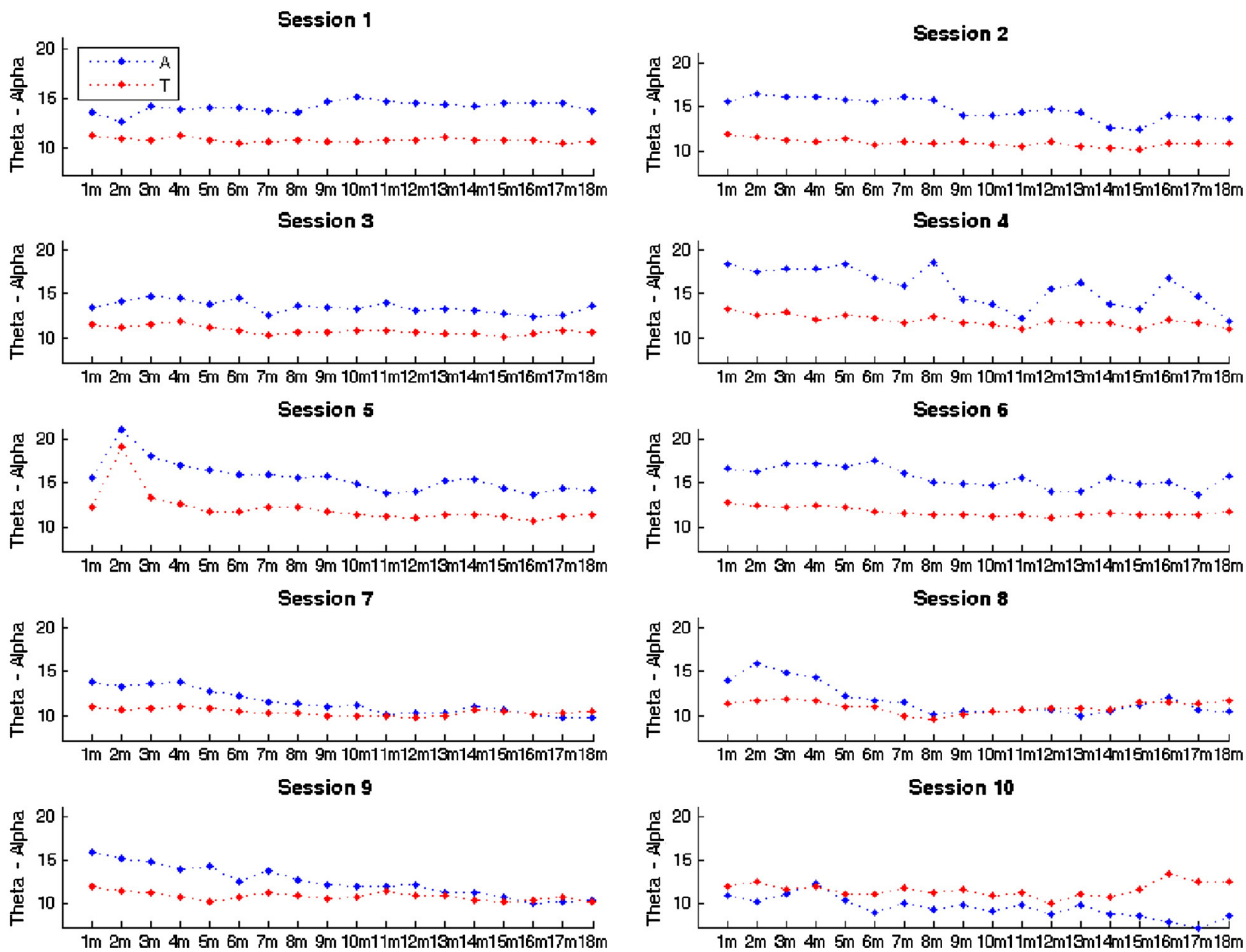

Fig. 2. Mean alpha and theta amplitudes within sessions for each of the 10 sessions.

3.6. Presence-in-performance

The four items of the presence scale were moderately correlated. Reliability assessed by Cronbach's alpha was 0.80 (studio) and 0.67 (stage), with an inter-correlation of r = 0.53.) The four items were therefore summated to form a single overall presence score. To aid interpretability, scores were rescaled to produce a minimum score of 0 (no presence) and a maximum score of 100 (maximum presence). Means and standard deviations are shown in Table 2. There were no group differences (studio F = 0.80; stage F = 0.40). A paired-samples t-test showed significantly higher presence scores ($t51 = 9.01$, $p < .001$) for the stage performance (M = 78.8) relative to the filmed studio setting (M = 49.9). Pearson's correlation between stage and studio presence scores indicated no significant association (r = 0.09,

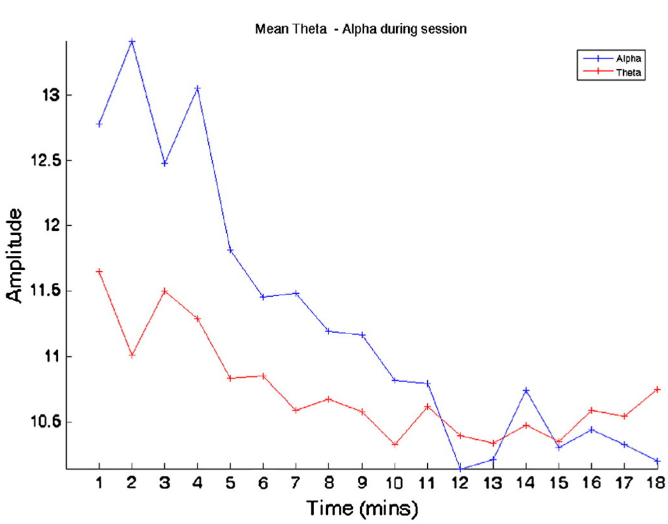

Fig. 3. Mean alpha and theta amplitudes within session.

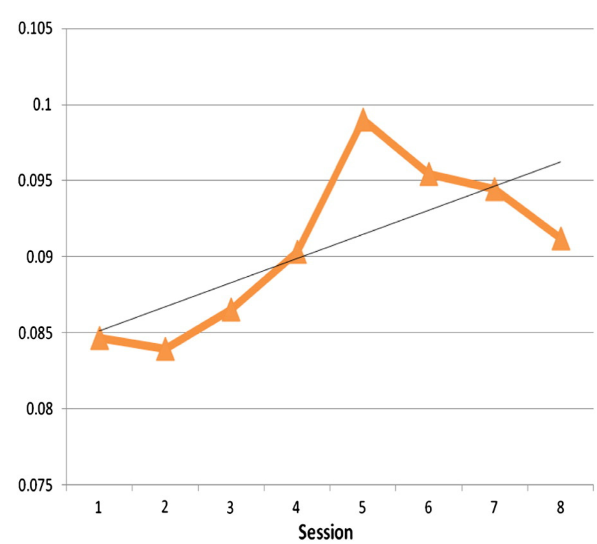

Fig. 4. Across sessions mean HRV. Mean HRV across sessions (SDNN).

Table 1
Dance ratings scores for Artistry and Technique; paired comparisons indicated no significant effects (p > 0.164).

Group technique	Artistry			
	Pre	Post	Pre	Post
A/T	6.21 ± 1.37	5.96 ± 2.02	5.89 ± 1.21	5.96 ± 1.73
HRV	7.31 ± 1.83	7.23 ± 1.62	6.96 ± 1.76	7.12 ± 1.70
Choreology	5.96 ± 1.95	6.50 ± 1.74	5.71 ± 1.72	6.24 ± 1.62
Control	6.19 ± 1.53	5.77 ± 1.79	6.12 ± 1.46	6.19 ± 1.35

n = 54, ns), suggesting that the experience of presence in one context may not be necessarily predictive of presence in another.

4. Discussion

Conducting applied neuroscientific research in performing arts conservatoires is challenging and the practical difficulties often necessitate compromise of basic research requirements. On the one hand the fulsome support of the arts institution, that we received here, is essential to ensure that the time consuming training and assessment sessions are integrated in what is typically a packed curriculum, and do not get usurped by unforeseen contingencies in the course of the study. Compromises here included the exclusion of 2nd and 3rd year students due to curriculum demands and the need to resort to 1st years who are under additional stressors such as adjustment in their first year to life inside and outside university. Here compliance with training was such that weekly sessions were sometimes missed. This we have shown may compromise the outcome of neurofeedback (Ros et al., 2009); in a study of trainee eye surgeons, those whose availability led to a relatively short intersession interval of 4.8 days in the last half of training sessions had a more successful surgical skills outcome than those with a longer 8.5 day intersession interval. The time available in the conservatoire curriculum was restricted leading to the need for neurofeedback training to be organised in groups of six, which likely did not facilitate hypnogogic training. Furthermore learning to raise theta over alpha was slower than in previous studies. Time limitations contributed to the brevity of the dance assessment, a 40 second dance phase, which may not have been long enough to disclose benefits, and could potentially have compromised the impact on dance performance of the three interventions including choreology classes.

These factors may have contributed to our inability to demonstrate improvements in dance performance with either A/T or HRV training, for this was unlike our previous competitive ballroom dance study where both interventions successfully improved artistry and technique relative to a non-intervention control group (Raymond et al., 2005a). The outcome was also in contrast to the beneficial results which were of professional significance for performance in our other studies in the performing arts, six in all (Gruzelier, 2012, in preparation-b). These ranged over advanced and novice music performance in young adults and children (Egner and Gruzelier, 2003; Gruzelier et al., in press; Gruzelier et al., submitted for publication) and creative acting performance (Gruzelier et al., 2010). In all of these studies artistic performances were longer than the dance phrase here.

The result having ecological relevance for contemporary dancers was the impact of HRV training on state anxiety seen in the reduction in DASS Anxiety (Lovibond and Lovibond, 1995). The relevance of this was endorsed by the correlation analysis which indicated that reduction in DASS Anxiety was associated with expert rating improvements in the dancers' technique and artistry. This impact on state anxiety provides support for the reported relevance of HRV for autonomic and affect regulation (Applehans and Luecken, 2006). Furthermore the fact that this did not extend to the DASS Stress scale, which we have found responsive to other forms of stress reduction intervention in first year university students such as Reiki (Bowden et al., 2010, 2011) and a yoga meditation (Bowden et al., 2012), is perhaps salient because of the specifically autonomic content of the items of the Anxiety scale. These numbered cardiovascular functions which were directly by HRV training. Items included breathlessness and rapid breathing, awareness of heart beat in the absence of exertion, heart rate irregularities, trembling, feeling scared, fear of panicking, and dry mouth. In contrast the Stress scale items were more generalised, covering over-reacting, touchiness, nervous energy, inability to relax, inability to wind down, intolerance and agitation. The reduction on the Anxiety scale in healthy young dancers adds to the reports of

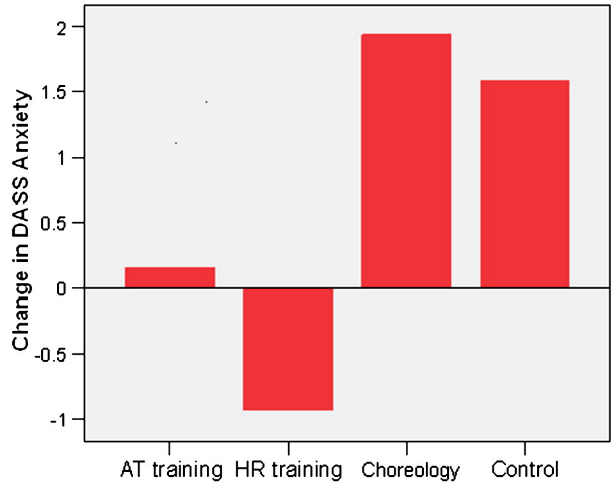

Fig. 5. Mean pre–post-training Anxiety changes for the four groups.

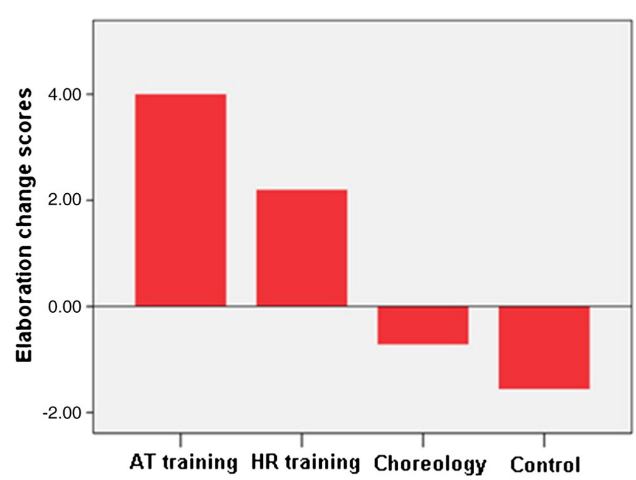

Fig. 6. Mean pre–post-training change in Guilford elaboration creativity scores for the four groups.

Table 2
Dependent measures for each group, [creativity elaboration scores are in Fig. 6].

Group	Insight problems	Depression	Anxiety	Stress	Presence (studio)	Presence (stage)
AT M	−1.42	.44	.16	.16	22.24	33.44
SD	(1.42)	(3.15)	(2.52)	(5.02)	(7.06)	(4.00)
HRV M	−1.33	.55	−.93	.72	22.44	32.86
SD	(1.86)	(5.04)	(4.37)	(4.37)	(6.46)	(4.86)
Cheoreology M	−2.18	1.59	1.94	2.17	22.61	33.13
SD	(1.07)	(3.94)	(2.65)	(3.80)	(7.05)	(3.68)
Control M	−1.18	1.59	1.58	−1.09	18.91	31.73
SD	(1.08)	(3.46)	(2.64)	(3.75)	(7.05)	(4.17)

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the successful application of HRV training to anxiety disorders (Chernagovskaya et al., 1990) and substance misuse (Zucker et al., 2009). Although six sessions were insufficient to show any advantage over conventional treatment in military personal with post traumatic stress disorder (Lande et al., 2010).

Presence-in-performance was experienced satisfactorily in the stage setting with a mean close to 80%. While there were no relations between the interventions and presence, we found that the experience of Flow (Csikszentmihalyi, 1996) as measured with the Flow State Scales (Jackson and Eklund, 2004) was enhanced in actors by EEG-neurofeedback compared with controls. Furthermore there were significant positive relations between the subjective flow experience of the actors and the objective ratings of acting of the expert assessors (Gruzelier et al., 2010).

Finally, returning to consider the effect on creativity which was the second of the two group effects, it is of theoretical interest that A/T training did result in a significant improvement in expressive creativity on the classical divergent thinking test (Guilford, 1978). An earlier attempt to investigate A/T effects on creativity tests in a controlled study had been unsuccessful (Boynton et al., 2001). The result in dancers was in support of the experimental hypotheses and the original development of the A/T protocol (Green and Green, 1977). The result also lends thought to considerations of the nature of creativity, the unitary nature of creativity, and its enhancement (Mackinnon, 1962; Koestler, 1964; Dow and Mayer, 2004; Gruzelier, 2009, in preparation-b). Certainly the results indicate constraints on cognitive generality, for the improvement on the Alternate Uses test (Guilford, 1978), a measure of divergent thinking, was not shared with a measure of insight with the Insight Problems task (Dow, 2004). However, bearing in mind our findings at large on the benefits of A/T for the performing arts including music, dance and acting (Gruzelier, in preparation-b), it supports the position there may be some generic components responsive to training that might encompass creativity in artistic performance and divergent thinking and through the sharing of long-range brain connectivity (Gruzelier, 2009).

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