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Technical note

A validation of neural co-activation as a measure of attentional focus in a postural task

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ABSTRACT

Postural threat can induce conscious involvement in movement control. This internal focus has been implicated in compromising attentional processing efficiency during postural control, leading to behavioral adaptations that might increase the risk of falling in the elderly. It is suggested that electroencephalography (EEG) coherence, or 'communication', between T3 (verbal-analytical) and Fz (motor-planning) regions may provide an objective measure of internal focus in learned movement skills. However, it is currently unknown whether this experimental technique can be applied to the control of gait and posture; skills which develop early in life, without the use of declarative knowledge/explicit verbal cues to guide performance. We validate the utility of the EEG T3-Fz coherence analysis in a postural task. A total of 24 young adults produced small voluntary swaying movements in medial-lateral or anterior-posterior direction under conditions that directed their attentional focus either internally or externally. Although EEG coherence was sensitive to voluntary changes in attentional focus, the lack of observed between-group (High/Low-trait-reinvestment) difference in coherence may suggest that younger adults cannot be assumed to utilize explicit verbal cues to control voluntary postural sway unless explicitly instructed to do so. As a result, while these results indicate that EEG T3-Fz is a valid technique for assessing attentional focus in postural tasks, our data do not support the clinical application of this method of analysis in providing an objective indication of trait-reinvestment in tasks involving voluntary postural sway.

1. Introduction

Although the control of gait and posture requires some degree of conscious cognitive involvement, these processes can be governed using largely automatic processes [1]. However, researchers have demonstrated that anxiety can induce conscious involvement in these movements [2,3]; a phenomenon known as 'reinvestment' [4]. Reinvestment has been implicated in compromising attentional processing efficiency during postural control [5], leading to behavioral adaptations [2] that may increase the risk of falling in the elderly [3].

Neuroscientists have indicated that electroencephalography (EEG) may provide an objective measure of reinvestment. An increase in EEG coherence, or 'communication', between T3 (verbal-analytical) and Fz (motor-planning) regions, but not between T4 (visuospatial) and Fz regions, has been reported in high-trait-'reinvesters' during a golf-putting task [6], implying conscious (verbal) movement control. The emergence of low-cost, portable, EEG systems means that researchers now have an objective method of assessing attentional focus that could make substantial contributions to the clinical assessment of posture and gait.

However, Reinvestment Theory [4] originated from observing sporting tasks (ontogenetic, situation-specific skills learned by using declarative knowledge/explicit verbal cues to guide performance [4]). Indeed, the term 'reinvestment' relates to the process whereby performers 'reinvest' cognitive effort into controlling

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movements using explicit rules learned in early skill development. However, phylogenic skills ('generic' skills fundamental to normal development, such as postural control) are learned during early childhood and in the absence of declarative verbal knowledge. As a consequence of these fundamental differences, we cannot assume that the nature by which performers 'reinvest' will be consistent between ontogenetic and phylogenetic tasks [5].

Therefore, we examined whether EEG T3-Fz and T4-Fz coherence is sensitive to changes in attentional focus during a postural task. First, we compared low- and high-trait-reinvesters during a Baseline voluntary-sway task. Second, we compared changes in coherence during the same task performed when attentional focus was directed either internally or externally. We predicted greater T3-Fz, but not T4-Fz, coherence during Baseline sway in high-trait-reinvesters. Moreover, higher T3-Fz, but not T4-Fz, coherence was predicted following instructions to direct attention internally.

2. Methods

2.1. Focus-of-attention

Twenty-four young adults (male/female: 16/8; mean ± SD age: 25.6 ± 3.6) completed a voluntary sway task. Ethical approval was obtained via the lead institution. Prior to participation, individuals completed the Movement Specific Reinvestment Scale (MSRS; [7]) which includes two subscales of trait-reinvestment: movement self-consciousness ("monitoring" or self-presentational concerns; R-MSC); and conscious motor processing ("controlling"; R-CMP). Participants produced small swaying movements in either medial-lateral (ML) or anterior-posterior (AP) direction for one-minute. A non-demanding postural task was selected to minimize EEG-contamination from muscle activity artefacts. The swaying task was completed under three different focus-of-attention conditions: Baseline (no instruction other than to "sway at a comfortable speed"); External (swaying in time with a metronome normalized to individual sway-speed); and Internal (instructed to explicitly focus on swaying and to consciously control movement). Participants completed two one-minute trials of both ML and AP swaying, under each of the three conditions (12 trials total). Trial presentation was randomized. Self-reported focus-of-attention was measured as a manipulation check, using a shortened version of the MSRS [2]. However, given the high trial-count in the present research, we shortened the questionnaire further (one R-CMP item from the MSRS: "I am always thinking about my movements when doing this task"; one R-MSC item from the MSRS: "I am self-conscious about the way I look when moving during this task").

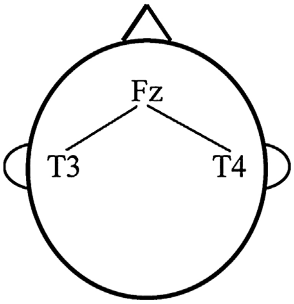

Fig. 1. The cortical locations of interest for the current study. Fz: motor planning. T3: verbal-analytic processing. T4: visuospatial processing.

2.2. EEG

EEG activity was recorded from 3 scalp locations (T3, T4, Fz; Fig. 1) referenced to the right mastoid using disposable electrodes (ARBO H124SG Ø 24 mm, Kendall, US), in accordance with the standard international 10-20 system [8]. The ground electrode was attached to the left mastoid. EEG was recorded and stored at a sample rate of 200 Hz using a wireless EEG device (PET 4.0, Brainquiry, NL) and real-time biophysical data acquisition software (BioExplorer 1.6, CyberEvolution, US). An impedance test was conducted to ensure a sufficient signal-to-noise ratio before each measurement. The EEG signals were pre-processed (low-pass filter: 42 Hz, high-pass filter: 2 Hz) to remove potential biologic artefacts. T3-Fz and T4-Fz coherence was calculated in 1 Hz frequency bins throughout the one-minute trials of swaying, using previously described algorithms [6]. Alpha (8–12 Hz) was selected as the most relevant frequency bandwidth, as it has been proposed that lower frequencies (i.e., alpha) are responsible for mediating long-range interactions between different brain areas, including frontal and temporal regions [9]. Furthermore, alpha activity is thought to reflect attentional processing; specifically, the retrieval of declarative knowledge [10]. Separate T3-Fz and T4-Fz coherence averages were calculated for each trial, for both alpha1 (8–10 Hz) and alpha2 (10–12 Hz) frequency bandwidths. These values were then averaged across the relevant conditions. EEG pre-processing and coherence calculations were conducted using custom scripts in a biophysical data processing and analysis software (BioReviewer 1.6, CyberEvolution, US).

2.3. Statistical analysis

2.3.1. Baseline comparison

Researchers have demonstrated between-group differences in T3-Fz coherence during a golf-putting task, when participants were split on the R-CMP subscale of the MSRS [6]. Therefore, R-CMP scores were selected as the most appropriate between-group variable for investigating trait-reinvestment. Participants were separated into low- ($N = 12$, mean ± SD = 10.92 ± 4.06) and high-R-CMP groups ($N = 12$, mean ± SD = 20.67 ± 2.46) using a median-split approach. Separate independent samples t-tests were used to compare the effects of R-CMP Group on Alpha1 (8–10 Hz) and Alpha2 (10–12 Hz) T3-Fz and T4-Fz coherence.

2.3.2. Attentional instruction

Separate repeated-measures ANOVAs were used to investigate the effect of Attentional Instruction on Alpha1 (8–10 Hz) and Alpha2 (10–12 Hz) T3-Fz and T4-Fz coherence. Data were log-transformed prior to statistical analysis.

3. Results

3.1. Baseline comparison

3.1.1. Alpha1 (8–10 Hz)

There was no between-group difference in either T3-Fz ($t(22) = -0.15$, $p > 0.05$, $d = 0.07$) or T4-Fz coherence ($t(22) = 0.36$, $p > 0.05$, $d = 0.14$).

3.1.2. Alpha2 (10–12 Hz)

There was no between-group difference in either T3-Fz ($t(22) = -0.42$, $p > 0.05$, $d = 0.18$) or T4-Fz coherence ($t(22) = 0.72$, $p > 0.05$, $d = 0.3$).

Table 1
Mean ± SD values for alpha1 (8–10 Hz) and alpha2 (10–12 Hz) T3-Fz and T4-Fz coherence.

	Between-Group Comparison		Focus-of-Attention		
	Low-R-CMP	High-R-CMP	Baseline	External	Internal
Alpha1 (8–10 Hz) T3-Fz Coherence	0.360 ± 0.10	0.366 ± 0.09	0.363 ± 0.09	0.351 ± 0.08	0.357 ± 0.09
Alpha1 (8–10 Hz) T4-Fz Coherence	0.310 ± .07 0.07	0.298 ± 0.09	0.304 ± 0.08	0.315 ± 0.08	0.313 ± 0.09
Alpha2 (10–12 Hz) T3-Fz Coherence	0.326 ± 0.08	0.342 ± 0.08	0.333 ± 0.08	0.335 ± 0.09	0.363 ± 0.1
Alpha2 (10–12 Hz) T4-Fz Coherence	0.290 ± 0.09	0.263 ± 0.09	0.277 ± 0.09	0.290 ± 0.09	0.299 ± 0.1

3.2. Attentional instruction

Manipulation checks revealed a significant effect of Attentional Instruction on self-reported focus-of-attention ($F(2,46) = 27.86$, $p = 0.001$, $\eta_p^2 = 0.55$), with higher levels of internal focus during Internal, compared to both Baseline ($p = 0.001$) and External ($p = 0.001$) trials.

3.2.1. Alpha1 (8–10 Hz)

There was no significant effect of Attentional Instruction on either T3-Fz ($F(2,46) = 0.93$, $p = 0.40$, $\eta_p^2 = 0.04$) or T4-Fz coherence ($F(2,46) = 1.01$, $p = 0.37$, $\eta_p^2 = 0.04$).

3.2.2. Alpha2 (10–12 Hz)

There was a significant effect of Attentional Instruction on T3-Fz coherence ($F(2,46) = 5.64$, $p = 0.006$, $\eta_p^2 = 0.20$). Post-hoc tests revealed that coherence was significantly higher in Internal, compared to Baseline ($p = 0.042$) and External ($p = 0.012$) trials. There was no significant effect of Attentional Instruction on T4-Fz coherence ($F(2,46) = 2.48$, $p = 0.095$, $\eta_p^2 = 0.10$) (Table 1).

4. Discussion

In a similar fashion to that described for sporting/ontogenetic skills [6], Alpha2 (10–12 Hz) T3-Fz coherence is sensitive to detecting changes in attentional focus during a voluntary-sway task. We observed no difference in T3-Fz coherence between Baseline trials or trials in which participants directed attention externally. This suggests that the current task occurred with relatively low levels of conscious control. However, significantly higher T3-Fz coherence was observed under conditions where participants directed their attention internally. This indicates that during these trials performance may have relied less on lower level automatic control pathways, and instead participants attempted to consciously control sway movements in a feedforward manner, possibly with the use of explicit verbal movement cues [6]; as posited by Reinvestment Theory [4]. However, based on the current data we can only speculate as to the specific mechanisms by which an internal attentional focus of attention resulted in increased T3-Fz coherence. This question warrants further investigation, particularly regarding potential temporal relationships between T3-Fz coherence and maladaptive behavioural consequences.

Contrary to predictions, we did not observe a between-group difference in Baseline coherence. This finding may indicate that younger adults cannot be assumed to utilize explicit verbal cues to control voluntary postural sway unless explicitly instructed to do so. As a result, our data do not support the clinical application of this method of analysis in providing an objective indication of trait-reinvestment in tasks involving voluntary postural sway. However, it is possible that this lack of between-group difference was caused by the low-level complexity of the swaying task, meaning that all participants, regardless of trait-reinvestment, could control the movement with relative automaticity. As these results can only be generalized to a simple voluntary sway task, future researchers should look to investigate this method of analysis during more challenging postural tasks, and in individuals with balance impairments, to further assess the clinical utility of this assessment tool.

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