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Quantifying Brain Activities and Lower-Limb Movements during Dual Task Activity Assisted with Auditory Biofeedback: A Pilot Study

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Abstract **–** Conducting multiple tasks at the same time is a staple habit in our daily life. But during multitasking, there are notable reductions in performance and movement mechanics. Studying the effects of 'dual task' protocols will provide an understanding about its impact on movement and cognitive processing. During dual tasking scenarios, cognitive processing is strained, resulting in additional cognitive resource allocation to maintain performance. Biofeedback methods have been used to improve movement mechanics in upper and lower body (particularly during walking) and have yielded promising results. However, questions arise about whether a cognitively challenging setting such as a 'Dual Task' protocol, with a biofeedback method, impairs tasks further because the brain must process additional external information while already under stress. The aim of this pilot study was to explore the role of rhythmic cues as a biofeedback method in changing lower limb movement patterns in a cognitively challenging arrow matching dual task protocol. Five young adults participated in a foot tapping + flanker task dual task experiment, where rhythmic metronome beats were provided as biofeedback to match foot taps during a dual task protocol (the rhythm of a metronome was set from the natural foot tapping frequency of the participants which was determined before the experiments commenced). Electroencephalography, kinematic data of the ankle joints, and foot tap forces were collected and analysed. Findings suggested rhythmic biofeedback from the metronome negatively impacted on foot tapping variability during dual task protocol. Additional observations indicated that biofeedback diverted attention towards having a more stable foot tapping performance, but at the cost of performance in the arrow matching task (decreased accuracy). Further studies will assist in identifying the usefulness of biofeedback methods for improving multitasking capabilities, including performing both tasks efficiently.

***Keywords*:** Dual Task, Biofeedback, Cognition, EEG, Brain Activity

1. Introduction

Multitasking refers to the ability of being able to conduct and execute multiple tasks concurrently [1] (e.g. listening to the radio while driving, talking on the phone while walking). Although multitasking is viewed as a hallmark of efficacy, there is evidence that multitasking negatively affects natural movement patterns. Many studies have performed 'Dual Task' protocols, demonstrating the negative effects of performing a distracting secondary task concurrently with a priority-based movement task [2]. This is explained by using the capacity model of attention: increased cognitive demand of one task creating a bottleneck effect and disrupting the performance of the other task [3]. The reason for this could be the act of additional cognitive resource allocation on maintaining the dual task performance [4]. Different modes of biofeedback are used to improve dual tasking capabilities [5], for example, acoustic rhythmic cues/stimuli have positive effects on gait performance [6]. However, in terms of cognitive processing, it is reasonable to assert that the extra information from biofeedback increases cognitive load, which further deteriorates movement performance. The purpose of this pilot study was to investigate the effects of biofeedback based rhythmic beats from a metronome on brain activities and movement performance in dual task scenario. This study used foot tapping as the primary task, and a secondary cognitive task was performed as the dual task. This study provided insight into how brain and movement performances are effected by distraction (dual task) and rhythmic cues (biofeedback). It has potential applications in the areas of driving and construction work safety and future studies could compare older adults with and without dementia develop a new diagnostic tool.

2. Methods

2.1. Participants

There were five participants (Mean age 22.5 ± 0.3, 2 females) in this study. All participants had normal cognitive capacity as determined by the SMMSE (Standardised Mini Mental State Exam). All participants had no prior history of brain trauma, neurodegenerative disease or difficulties in lower-limb movement. The study was approved by UOW Human Research Ethics Committee (Reference no. 2023/112).

2.2. Equipment

EEG Recordings were conducted using a Neuroscan's SynAmps2 amplifier and Acquire software (version 4.5.1). The EEG was recorded from DC to 70 Hz, with a notch filter at 50 Hz, and sampled at a rate of 1000 Hz. EEGs were recorded from 19 channels in accordance with the International 10/20 system using tin disc electrodes. All electrodes were referenced to A1, and A2 was recorded as an active electrode, and a ground electrode was located between Fpz and Fz. Four electrodes were fitted above and below the right eye, and on the outer canthi of both eyes to record EOG activity. EEG activity was digitally re-referenced and fourier transformed to provide absolute power estimates in the delta, theta, alpha and beta bands using Neuroguide software version 2.6.7. XSens Awinda motion tracking sensors were used to collect joint angles and other kinematic data of the ankle joints during the foot tapping task. Seven Xsens IMU sensors are attached to their lower body (covering the pelvis and all the upper and lower limb joints such as hip joint, knee joint and ankle joint, see figure 1, left figure). Vald Forcedecks force plates were used to collect force data during foot taps, to understand the frequency and variability of the foot taps in different conditions. Calibration was performed as per manufacturers' manuals.

2.3. Experimental Protocols

The foot tapping pattern that was performed was heel to toe tap, with participants tapping once on their heels and once on their toes (similar to a rocking motion). Three foot tapping conditions were tested. (1) ST or single-task condition: participants conducting the foot tapping task for two minutes. (2) Dual-task or DT condition: participants conducted the foot tapping task, while also conducting the flanker task, a selective attention-based task in which they had to press left and right buttons to indicate the direction of the middle arrow in a series of 5 arrows presented to them on a fixed computer screen. (3) Dual task or DT condition + biofeedback condition: participants repeated the dual task condition and were provided with a metronome beat to match their foot taps to while doing the flanker task, as a form of biofeedback. The beats per minute on the metronome was set according to the natural tapping frequency of the participant (How many taps they do in 1 minute at a natural pace). These taps were counted before the start of the experiment, by having the participant do 60 seconds of tapping as a practice session. The tapping frequency that was counted was verified by looking at the force plate data as well (every peak in the force plate data signified a single tap). Randomization was applied across different conditions to observe any effects due to randomizing for specific trials. Video recordings of the foot were done during each foot tapping task and combined with the force plate data, the accuracy % of the foot taps was determined (No. of Correct foot taps × 100/No. of total foot taps).

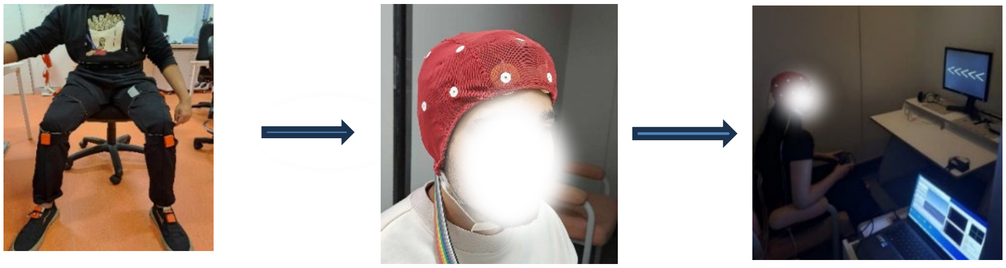

Figure 1: Xsens sensors on lower limb (Left), EEG Cap (Middle) & participant conducting the experiment (Right)

3.Results & Discussions

Table 1: Foot tapping and flanker task accuracy for conditions (1), (2) and (3)

Participant No.	Foot Tap ST Condition (1)	Foot Tap DT Condition (2)		Foot Tap DT + Biofeedback Condition (3)	
	Foot Tapping Accuracy (%)	Flanker Task Accuracy (%)	Foot Tapping Accuracy (%)	Flanker Task Accuracy (%)	Foot Tapping Accuracy (%)
P01	98%	95%	75%	88%	97%
P02	94%	91%	85%	97%	90%
P03	87%	46%	80%	36%	82%
P04	96%	88%	91%	86%	98%
P05	98%	100%	98%	93%	98%

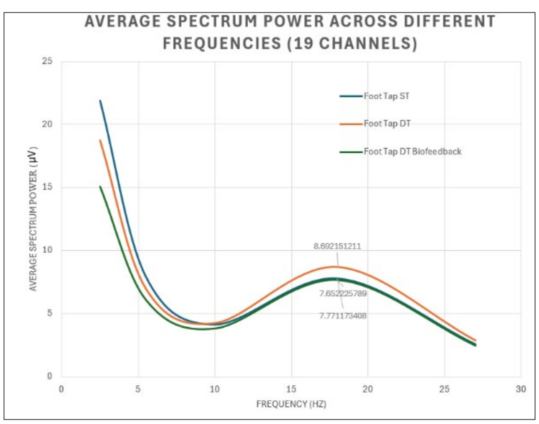

Figure 2: EEG Power Spectrum across different

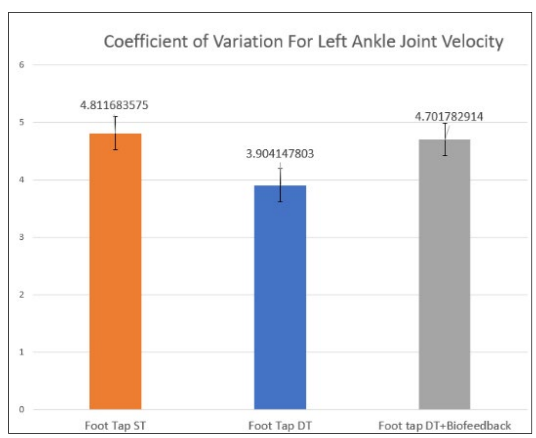

Figure 3: Coefficient of Variation for Left Ankle Joint Angle

Movement performance: Dual task reduced accuracy in foot tapping (Table 1). The accuracy improved when biofeedback was provided (dual task + biofeedback condition). Meanwhile, coefficient of variation (CoV) was computed for left ankle joint speed, and it was observed that between (1) Foot tap ST and (3) Foot Tap DT+Biofeedback conditions, the CoV values were quite similar (4.8 and 4.7), whereas in the (2) DT condition it was noticeably different (3.2). This change in variability suggests that (2) DT condition did have a negative effect in the movement of the ankle joint during foot tapping in the DT condition, and due to the presence of biofeedback (Rhythmic beats), the CoV returned to a value similar to that observed in the ST condition, suggesting foot tapping while conducting the flanker task has become similar to the natural foot tapping in terms of variability. Such changes can be explained by re-directing attention from the cognitive task (flanker task) to the movement task (foot tapping), as we found the accuracy in the flanker task decreased during the biofeedback condition (Table 1).

Brain activities: Average EEG spectrum power across all 19 channels was calculated across 5 participants by converting raw EEG signals into Fast Fourier Transform (FFT) to understand the spectrum power distribution across different frequency bands (see figure 2). Observably, delta (1-4 Hz) showed the most amount of variation in terms of power, across all three different foot tapping tasks. The DT condition with and without biofeedback (2) and (3), saw notable reductions in spectral power (Reduced to 18 uV and 14.7 uV from 22.5 uV). For the other frequency bands, observably the power values were similar. The dual task condition produced higher alpha (8-12 Hz) and beta (13-25 Hz) average power compared to the (1) ST condition (8.69 μV observed for DT condition, compared to 7.7. and 7.6 μV), which potentially indicates an increase in cortical activity due to the recruitment of additional cognitive resources [7]. During (3) DT rhythmic metronome biofeedback condition, the alpha and beta power decreased again and became similar to the power observed in the single task condition (7.7 μV for Single Task and 7.6 μV for DT + Biofeedback, indicating that the rhythmic beats provided as feedback from the metronome possibly acted as a guide, which makes the foot tapping movement more consistent while doing the secondary flanker task (Further supported by the ankle joint speed CoV data in table 2).

4. Conclusion

This pilot study provides insight into how distraction (DT dual tasks) and rhythmic cues (DT dual task + biofeedback condition) effects our brain and movement performance. Analysis of brain spectral performance across different frequency bands highlighted the possibility that cortical activity could be under less strain and using less resources to complete the (2) DT dual task with biofeedback when compared to (3) DT dual task without biofeedback condition. This emphasizes the potential of biofeedback to improve multitasking capabilities. Different types of biofeedback methodology should be explored to improve multitasking capabilities and movement in many day-to-day scenarios such as driving, construction work and, furthermore, future studies could also assist in understanding cognitive capabilities and even help diagnose possible cognitive impairment, as dual task protocol challenges the brain's cognitive resource distribution.

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References

[1] T. Mäntylä, "Gender Differences in Multitasking Reflect Spatial Ability," *Psychological Science*, vol. 24, no. 4, pp. 514–520, Mar. 2013, doi: https://doi.org/10.1177/0956797612459660.

[2] G. Yogev-Seligmann, J. M. Hausdorff, and N. Giladi, "The role of executive function and attention in gait," *Movement Disorders: Official Journal of the Movement Disorder Society*, vol. 23, no. 3, pp. 329–342; quiz 472, Feb. 2008, doi: https://doi.org/10.1002/mds.21720.

[3]D.Kahneman," Attention and Effort," *www.semanticscholar.org*, 1973. https://www.semanticscholar.org/paper/Attention-and-Effort-Kahneman/a07ffad799cffee3ef6a2b33f4a56bffcc5b747d

[4] D. Possti, F. Fahoum, R. Sosnik, N. Giladi, J. Hausdorff, A. Mirelman, I. Maidan "Changes in the EEG spectral power during dual-task walking with aging and Parkinson's disease: initial findings using Event-Related Spectral Perturbation analysis," *Journal of Neurology*, vol. 268, no. 1, pp. 161–168, Aug. 2020, doi: https://doi.org/10.1007/s00415-020-10104-1.
[5] E. Bisson, B. Contant, H. Sveistrup, and Y. Lajoie., "Functional Balance and Dual-Task Reaction Times in Older Adults Are Improved by Virtual Reality and Biofeedback Training," *CyberPsychology & Behavior*, vol. 10, no. 1, pp. 16–23, Feb. 2007, doi: https://doi.org/10.1089/cpb.2006.9997.
[6] T. E. Howe, B. Lövgreen, Frederick W.J. Cody, V. J. Ashton, and J. Oldham, "Auditory cues can modify the gait of persons with early-stage Parkinson's disease: a method for enhancing parkinsonian walking performance?," *Clinical Rehabilitation*, vol. 17, no. 4, pp. 363–367, Jul. 2003, doi: https://doi.org/10.1191/0269215503cr621oa.
[7] J. Cortney Bradford, J. R. Lukos, A. Passaro, A. Ries, and D. P. Ferris, "Effect of locomotor demands on cognitive processing," *Scientific Reports*, vol. 9, no. 1, Jun. 2019, doi: https://doi.org/10.1038/s41598-019-45396-5.