Introduction. EEG (electroencephalography) is a low-cost, accessible method of investigating electrical brain activity that is sensitive to rapid changes. Transcutaneous Electrical Acupoint Stimulation (TEAS), like electroacupuncture (EA), is an acupuncture-related method of stimulation.

Objective. To determine whether there is a central ‘frequency following response’ (FFR) to peripheral stimulation (i.e. if TEAS is applied at 2.5Hz, that frequency more likely to appear in the EEG).

Methods. In each 2-hour session, TEAS was applied at ‘strong but comfortable’ intensity for 5 minutes at 6 different combinations of LI4 and ST36 (in balanced order). Five participants attended for 2 sessions (2.5Hz or 10Hz TEAS), two for one session each. EEG was monitored for 5 minutes before and after each 5-minute stimulation, recorded from scalp electrodes as electrical power or amplitude, and then analysed into frequency bands (0-45Hz), including Delta-related (c. 2.5Hz) and Alpha-related (c. 10Hz).

Changes in the following EEG measures in these bands might support the FFR hypothesis for TEAS:

- Absolute spectral power, ASP, the amount of electrical power, at a scalp measurement electrode in a particular EEG band (measured in μV²)
- Relative spectral power, RSP, the ASP in a band divided by the total ASP for all ranges
- Amplitude, A (measured in μV)
- Derivations of spectral power, such as Ratios of spectral power in different bands, or left/right Asymmetry
- Average frequency within bands, AvHz, and its standard deviation (AvHz SD)
- Frequency with maximum power within bands, PkHz
- Coherence, Coh, a measure of phase synchronisation or coupling between signals at different electrodes
- Cross-correlation, XC, used to assess time delays between signals at different scalp electrodes
- Phase delay, PD, a measure of the temporal ‘lead’ or ‘lag’ of spectra between electrodes
- Autocorrelation, AC, a measure of the self-similarity of the EEG signal over time, or how often it repeats at a single electrode.

One method used to assess change in a measure was to subtract its value at 10Hz from that at 2.5Hz, then analyse into frequency bands (0-45Hz), including Delta-related (c. 2.5Hz) and Alpha-related (c. 10Hz).

Results. Numbers of EEG measures findings: (a) similar for 2.5 & 10 Hz; (b) different; (c) supportive, or (d) contradictory, of the FFR hypothesis; (e) neither supportive nor contradictory of the hypothesis.

Example findings

- Fig 4 ASP Pmmfs for all stimulation locations.
- Fig 5. Mean Pmmfs for ASP and RSP. Both are greater in the EEG band centred on 2.5Hz (ctr2.5) than in ctr10, supportive of the FFR hypothesis.

However (Fig 6), summed (rather than averaged) PD counts show maxima and minima that do not support a FFR, although mean summed Pmm is still lower in ctr2.5 than ctr10, supporting the hypothesis.

Possible confounding factors

- Stimulation amplitude (positive) – greater at 10Hz than 2.5Hz (p<0.001) (Fig 1)
- Visit order (unlikely) – e.g. comparing by visit rather than stimulation frequency results in a shift in RSP minimum from Alpha (ctr10) to Theta (ctr7.5) (Fig 2)
- Pre-existing baseline differences (very possible) (Fig 3)
- Individuality of response will obscure changes due to frequency (definite)

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Fig 1. Amplitude & stimulation frequency

Fig 2. Differences in mean RSP for visit1–visit2 & 2.5Hz–10Hz

Fig 3. RSP Pmmfs, showing differential ctr2.5/ctr10 effect already at baseline, before stimulation.

However, RSP counts show that while proportion of positive to negative differences (2.5Hz–10Hz) was significant for all Locations (more positive differences for the Locations taken together), at baseline (Pre-EC), there were more negative differences. This may indicate lack of a carry-over effect from baseline.

Conclusions

- At this stage, only ASP and RSP provide markedly more support than non-support for the FFR hypothesis.
- A central frequency following response to rhythmic electrical stimulation remains possible.
- However, individual response is very variable and may mask a FFR.
- Further research is justified, to clarify the possible role of confounding factors, and also explore issues such as whether a FFR occurs in response to some frequencies and not others, or in some individuals and not others.
- If evidence for a FFR is found, this would throw new light on the effects of different EA/TEAS stimulation frequencies on the brain and indeed different mental states, with potential for immediate clinical application.