Connectivity paper outline

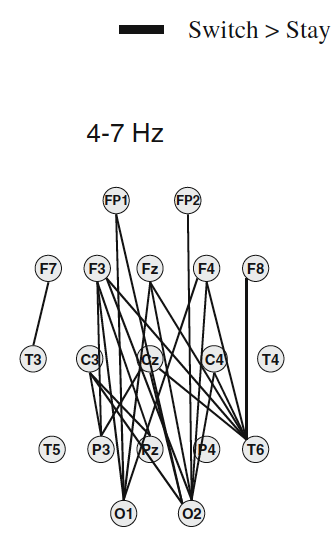
Background

* Cognitive control operates in two modes: proactive (anticipatory) and reactive (target-driven)
* According to dual mechanisms of cognitive control framework (Braver et al., 2007) whether an individual uses proactive or reactive control is dependent on both **task** and **individual** factors
  + Task factors
    - Is there a reliable cue available?
    - Is there sufficient time to prepare?
    - What demands are in place? (speed/accuracy, motivation, arousal etc.)
    - Expectation of interference?
    - Expected working memory load?
  + Consider our usual cued-task switching: we have a cue that reliably predicts task/trial characteristics, with sufficient time to prepare for upcoming conflict at the level of the target. Our tasks bias participants to operate in a proactive control mode. We give them a cue with enough time to prepare for the target and we instruct our participants to use the cue to prepare for the upcoming trial. NB: they also need to use reactive control to resolve interference (or complete task-set reconfiguration) but predominantly the cue is there to encourage proactive control
  + Individual factors
    - Cognitive capacity
    - Strategy choice
  + If an individual has enough cognitive capacity (e.g. high working memory capacity, intelligence, fast processing speed etc.) they should have “reserve” in the system to utilise the more costly proactive control mode. Thus, in high capacity individuals we should see cognitive control operating in a proactive mode.
  + These individual factors Braver talks about are similar to the idea of neural efficiency, i.e. more intelligent individuals activate more focused regions of the cortex during simple tasks and thus use less glucose/energy leading to more efficient information processing
* In order for cognitive control to work we need to be able to integrate information across modalities, with this information processing seeming to be related to lower frequencies in the human EEG (theta, 4-7 Hz; and alpha, 8-13Hz)
  + **Theta is commonly associated with memory performance and central executive component of working memory**
    - theta phase is linked to memory encoding in the rat (place cells)
    - theta-to-gamma phase coupling is related to individual memory capacity in humans
    - theta coherence across the scalp is linked with encoding stages in memory tasks
    - fronto-parietal theta coherence is linked with “central executive” processes during working memory tasks
    - few studies done for actual task switching but those few do suggest that:
      * switch trials are associated with increased parietal/occipital theta power (Sauseng et al., 2006)
      * switch trials are associated with stronger theta coherence across the scalp (Sauseng et al., 2006)
      * faster trials are associated with increased theta power across the scalp (Gladwin et al., 2006)
  + **alpha is broadly associated with inhibition**
    - increased alpha during eyes-closed rest is thought to reflect idling or non-working
      * the increased alpha power is thought to reflect widespread synchronisation across inhibitory neurons –an increase in alpha can be the result of populations of inhibitory cells firing (and thus inhibiting neighbouring neurons) or it can be the result of excitatory/inhibitory cells becoming rhythmically entrained to the alpha frequency of other cells
    - increased alpha is linked with inhibition – e.g. during a multi-modal task switching paradigm, when there was a switch from visual to auditory modality there was increased alpha over occipital scalp electrodes (Gladwin & de Jong, 2005)
      * Mansfield, Karayanidis & Cohen (2012) - increased alpha over parietal sites for repeat vs non-informative trials prior to target onset; which might reflect inhibition of competing task sets
      * Increased alpha for switch-away vs non-informative cues after cue onset, which may reflect differences in inhibition (in toaway paradigm we inhibit one task for switch away trials but for non-informative we don’t know task/trial identity and thus shouldn’t inhibit any task sets)
    - During tasks we see a decrease in alpha power (alpha desynchronisation) thought to be associated with breaking of neural inhibitory trains and thus information processing
    - During rest (and after a stimulus has been processed/responded to) we see an increase in alpha; the “resynchronisation”
      * Controlling for an individual’s alpha frequency, we see that upper alpha re/desynchronisation are linked with semantic processing demands and that lower alpha is a more distributed anticipatory process
      * These re/desynchronisation processes in alpha have been linked to memory capacity, task performance and intelligence (e.g. Doppelmayr et al., 2002; Hummel & Gerloff, 2005; Klimesch et al., 2000; Micheloyannis et al., 2006)

Aims

* Given Mansfield et al’s (2012) power findings, we should be able to replicate and extend upon these by using the same paradigm (traditional toaway) with the all-repeat condition as a baseline

1. Repeat vs all-repeat should have stronger pre-target alpha because there is inhibition of other tasks
2. switch-to vs switch-away should have stronger alpha desyncronisation after the switch d-pos (which would reflect additional task-related information processing that is absent when the identity of the task cannot be determined)
3. fronto-parietal connectivity should be evident in the theta/lower alpha band during cue-to-target interval. This should vary depending on the information provided by the cue (and thus the need to anticipate/utilise proactive control) e.g. switch > repeat, switch-away > switch-to, informative > parital > non-informative



🡨----- similar to this idea!

Because we have a resting state period we can also determine *relative* alpha re/desynchronisation effects and determine an individual’s alpha frequency. This means any differences we see can be attributed to the frequency band in question and not due to individuals with higher/lower alpha frequencies skewing the data.

* Given the DMC framework, we should be able to predict how theta and alpha relate to differences between our distractor toaway paradigm and our typical toaway paradigm:

1. Distractor paradigm requires higher levels of proactive control than traditional toaway
   1. Should see stronger switch related alpha during CTI
   2. Fronto-parietal theta band connectivity effects should be stronger for the distractor paradigm where proactive control is required even more
   3. Informative > non-informative alpha power to reflect inhibition of tasks (possible when you know what upcoming task will be –informative cue; not when you don’t)

* Finally, given the DMC predictions for individual differences in control mode uses, and that differences in connectivity/power may be related to performance, we can expect that:

1. Increased fronto-parietal theta connectivity is associated with better task-switching performance
   1. E.g. reduced mixing + switching costs, faster RT, better accuracy
2. Increased fronto-parietal theta connectivity is associated with an individual’s criterion shifting (better able to utilise proactive control will influence criterion values)
3. Increased alpha desynchronisation during CTI is associated with switching performance and increased alpha resynchronisation pre-target with repeat trial performance

This study will thus be a novel investigation into the role of alpha and theta synchronisation and connectivity as an important influence on proactive cognitive control. It will also be the first study to systematically look at the relationship between individual control (using a range of outcome measures) and neural synchronisation using paradigms that clearly require proactive control. The task switching studies I referred to before (except Mansfield et al) use alternating run designs that makes it difficult to disentangle control processes.

It’s also important to remember I did find a relationship between resting alpha/theta ratios and task switching performance for ACNS. The relationship may have been driven by individuals with lower IAFs, which I did not control for before.

Methodology

Study 1 – distractors toaway (n = 19)

Study 2 – traditional toaway (n = 18)

Individual alpha frequency will be determined by looking for peak alpha power during rest

Upper alpha = IAF + 2Hz

Lower 1 alpha = -4 to -2Hz from IAF

Lower 2 alpha = -2Hz to IAF

Theta = 4-7Hz

1000ms epochs at rest vs 1000ms cue-to-target epochs for each trial type

Connectivity = debiased weighted phase lag index

Currently connectivity is still based on a threshold ( e.g. strongest 5% connections/values need to be higher than x

We could construct a minimum spanning tree for our network so that all individuals/conditions have the same average level of connectedness. This is important because some trial types are predicted to have stronger connectivity strengths than others – if we choose an arbitrary threshold we may lose important information that lies beneath our cut-off. A minimum spanning tree may cut out some connections that exist BUT will allow a fair comparison across conditions and individuals. **Please note, I am only using the MST as a backbone for the network – I won’t be running graph theoretical analysis on these networks.**