Executive functions and cognitive control

Weighting: 1/17

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# Agenda

* What are executive functions
* The article: Neural correlates of response inhibition in children with attention-deficit/hyperactivity disorder: A controlled version of the stop-signal task
* Motivation and hypothesis
* Method
* Results
* Authors’ conclusion
* Criticism
* Greater perspective

## What are executive functions?

**Executive function:** The cognitive functions that allow flexible and goal-directed control of thought and behavior. [13]

**Attentional capture effect:** the act of noticing (orienting to) and appreciating the significance of a new object (here, stop signal) produces significant brain activity without necessarily involving inhibition-related activity

**Oddball effect**: In the visual oddball task, participants watch a stream of rapidly presented standard stimuli (e.g., squares varying in size and color), looking for infrequent target stimuli (e.g., circles). Compared to the common standards, the oddball targets evoke a positive ERP response known as the P300 that begins around 300 milliseconds.

* P300 has been shown to arise from a distributed set of generators that include parietal cortex, medial prefrontal cortex, and lateral prefrontal cortex, with concurrent activity also observed in subcortical regions including the hippocampus.

**Four types of inhibition (Purves):** Halting behaviours that are well trained or previously or previously valid; preventing irrelevant information from interfering with other processing; restraining actions that are inappropriate in a given social context; removing irrelevant information from working memory

# The article: Neural correlates of response inhibition in children with attention-deficit/hyperactivity disorder: A controlled version of the stop-signal task

* Earlier studies have some methodological concerns, they may have confounders in the form of the attentional capture- and oddball effects.
* Several brain areas included in stop-signal tasks (inhibition) are also active in oddball paradigms (attention capture/surprise) so processes are hard to tease apart.

## Motivation and hypothesis

The aim of this study was to control for confounding factors and improve the specificity of the stop-signal task to investigate inhibition mechanisms in children with ADHD.

* Based on previous studies, we hypothesized that children with ADHD will show less activation in the dmPFC than TD children, and in the case of a specific inhibitory role for the rIFG (inferior frontal gyrus) in children, will show reduced activation in the rIFG as well.
* We expected that children with ADHD will perform worse than TD children, with evidence for inhibition problems (increased SSRT), but also for more general attentional problems (increased MRT, RTV, omission errors)
* Finally, additional analyses were performed to assess error-related brain activation during failed inhibition.

## Method

* N = 21 ADHD, 17 TD
* fMRI
* Stop-signal task. 2 practice runs outside scanner, then 1 inside.
* 8 experimental runs (60 trials each)

### Runs

* White fixation cross on black background 500 ms
* Go stimulus 1500 ms
* Inter-trial interval varies between 1000 and 5000 ms
* About 1/3 of all trials somehow included a stop signal
* Stop-signal: 16.6%
* FI-C: 8.3%
* SI-C: 8.3%
* Stop-signal delay (SSD) adapted trial-by-trial to yield approximately 50 % successful and 50 failed inhibition

### Trial types

* Go: 66.6 %. Determine whether the aeroplane points left or right
* Stop-signal: 16.6 %. Go signal followed by a stop signal after an individually adjusted stop-signal delay
* Successful-inhibition control (SI-C): 8.3 %. Stop signal, go signal (after stop)
  + Designed to have similar stimulus complexity (1), frequency (2), and lack of motor response (3) as successful inhibitions in normal stop-signal trials
  + Controls for differences in visual processing (1), attentional capture (2) and activity specifically related to active response inhibition (3)
  + What does it look like when you successfully inhibit your response?
  + Looks more closely at inhibition brain activity: successful inhibitions on normal stop-signal trials have one more step than SI-C (which do not have active inhibition) therefore, subtracting SI-C activity from normal SI activity should leave you with just the inhibition activity (subtraction method)
* Failed-inhibition control (FI-C): 8.3 %. Go signal, response, stop signal (only appears after response)
  + Similar stimulus complexity (1), frequency (2), and motor response (3) as failed inhibitions on normal stop-signal trials
  + Controls for same issues as SI-C but allows motor response
  + What does it look like when you actually make a mistake?
  + Looks more closely at error brain activity: Failed inhibition on normal stop-signal trials have one more step than FI-C (which do not have the inhibition part, only the error part) therefore, subtracting FI-C activity from normal FI should leave you with just the inhibition activity (subtraction method)

## Results

### Table 1: Group characteristics and task performance (behavioural data)

* Stop-signal RT is difference between mean RT and stop-signal delay (adjusted as subjects go through test) – no difference between groups here
* SSRT: ADHD children needed significantly longer to successfully react to stop-signals than TD
* Omission errors: ADHD children more often missed trials by not responding than TD
* Neither ADHD nor TD had significantly more successful inhibitions

### Table 2 + Fig 2: fMRI activation differences between normal and control trials

* Successful inhibition contrast (isolated inhibition-related activity)
  + It can be seen that TD children have more significant activity in all areas but one, compared to ADHD.
  + Areas that are involved in successful inhibition for ADHD are not significantly different in activity from TD
* Failed inhibition contrast (isolated error-related activity)
  + ADHD have a larger degree of activity in precentral gyrus, postcentral gyrus, posterior insula
  + But not significantly different activity in Precentral gyrus, posterior insula and Precentral gyrus, postcentral gyrus

Between group differences:

* Areas related to successful inhibition (based on TD ROIs): greater activity for TD than for ADHD children
* Areas related to errors (based on ADHD ROIs): greater activity for ADHD than for TD children

## Authors’ conclusion

* Confirmed hypoactivity (less activity) in key inhibition areas for ADHD
* Controlled for confounders of attentional capture, visual representation differences and motor responses
* Findings are supplemented by behavioural evidence for slower inhibition (higher SSRT) and more omission errors in ADHD
* ADHD is as much about lacking inhibition as lacking attention

## Criticism

* Correlations
* Other studies have found no difference in SSRT between ADHD and TD
* Small sample considering their findings contradict earlier studies
* Own criticism:
  + Most children were on stimulant medication. Though discontinued during the experiment, MPH treatment have been reported to have long term effects on brain functioning
    - Others have reported that MPH is insufficient to normalize neurofunctional deficits
    - Furthermore: Acute withdrawal symptoms might have affected the results
  + SI-C trials may trigger attention capture activation because they are relatively rare and start with a different stimulus than all other trials
  + Insula has been proposed as an important area for uncertainty. Activity here may be due to differences in certainty between SI and SI-C
* **Can we assume no inhibition in SI-C trials? If response is trained, participants may still inhibit it**
* **Is SI contrast really only inhibition? Are we isolating inhibition or response initiation?**

## Grand Perspective™

* **Disinhibition syndrome:** Also called frontal disinhibition syndrome. A collection of behavioral signs and symptoms, typically caused by damage to the ventral prefrontal cortex; mani-fested by a loss of control, inappropriate outbursts, and a lack of inhibition in social settings. Compare dysexecutive syndrome.
* **Dysexecutive syndrome:** Also called frontal dysexecutive syndrome. A collection of behavioral signs and symptoms, typically caused by damage to the dorsolateral prefrontal cortex; manifested by an inability to change behavior willfully and flexibly according to context. Compare disinhibition syndrome
* **Monitoring:** The process that evaluates the appropriateness of a given behaviour for the current context; examples include evaluating the accuracy of answers generated during a memory test or the adequacy of a response rule in an executive function paradigm
* **Schizophrenia:** Some brain disorders are associated with deficits in this form of inhibitory control. In particular, patients with schizophrenia perform normally on go trials but are greatly impaired on no-go trials. These behavioural impairments are accompanied by abnormal ERP and fMRI responses, suggesting a frontal lobe deficit in schizophrenia. (Purves)
* Stroop
* Vigilance/oddball tasks
* Cocktail party effect (attentional capture)
* RTPD