Donders Institute
for Brain, Cognition and Behaviour

Cognitive and neural mechanisms of selective stopping

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Project-proposal meeting
September 24, 2015

From simple stopping to selective stopping

Simple stopping
stopping *any* response to *any* intervening stimulus

Action-selective (AS) stopping
stopping certain responses

Stimulus-selective (SS) stopping
stopping responses to certain stimuli

Simple stopping

… is well understood

- Theory: race between GO and STOP processes
  Logan & Cowan (1984) Psych Rev; Boucher et al. (2007) Psych Rev
- Neurophysiology: stopping manifests in motor system
  Hanes et al. (1998) JNP; Paré & Hanes (2003) JNS; Schmidt et al. (2013) Nat Neuro
- Human fMRI/TMS: fronto-striatal areas also involved
  Aron & Poldrack (2006) JNS; Li et al. (2006) JNS; Zandbelt & Vink (2010) PLoS ONE

… but is limited as framework of cognitive control

- Mimics emergency and sports situations
- May only indirectly relate to clinical control deficits

Selective stopping

… has ecological validity and clinical relevance

- Ubiquitous in daily life, e.g. in traffic
- Seems relevant for tic suppression, food intake
  Aron (2011) Biol Psychiatry; Lawrence et al. (2015) Appetite

… but its mechanisms remain poorly understood

- No theory of selective stopping performance
- Selective stopping has been conceptualized as a unitary construct, relationship between various forms is unclear

What are the cognitive and neural mechanisms of selective stopping?

Experiment 1 - Cognitive mechanisms

1. What is the mechanism of selective stopping?

- Lateral inhibition
  Boucher et al. (2007) Psych Rev; Ramakrishnan et al. (2012) JNS
- Blocked input
  Logan et al. (2015) Psych Rev
- Reset
  Salinas & Stanford (2013) JNS

2. Is this mechanism selective or non-selective?

- Selective
  Sharp et al. (2010) PNAS; Cai et al. (2011) JNS
- Non-selective
  MacDonald et al. (2012) JNP; Bissett & Logan (2014) JEP Gen

Experiment 2 - Neural mechanisms

3. How does action-selective and stimulus-selective activation patterns compare?

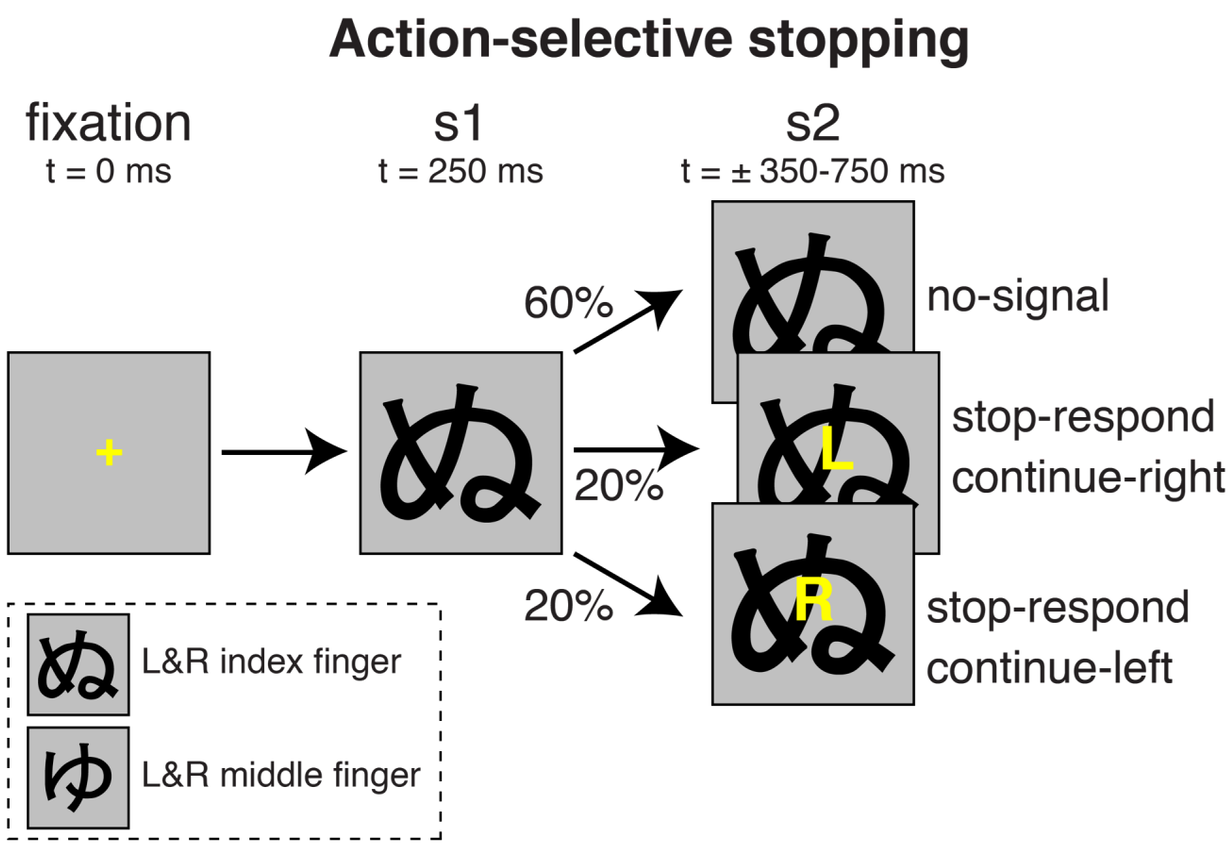
Similarities

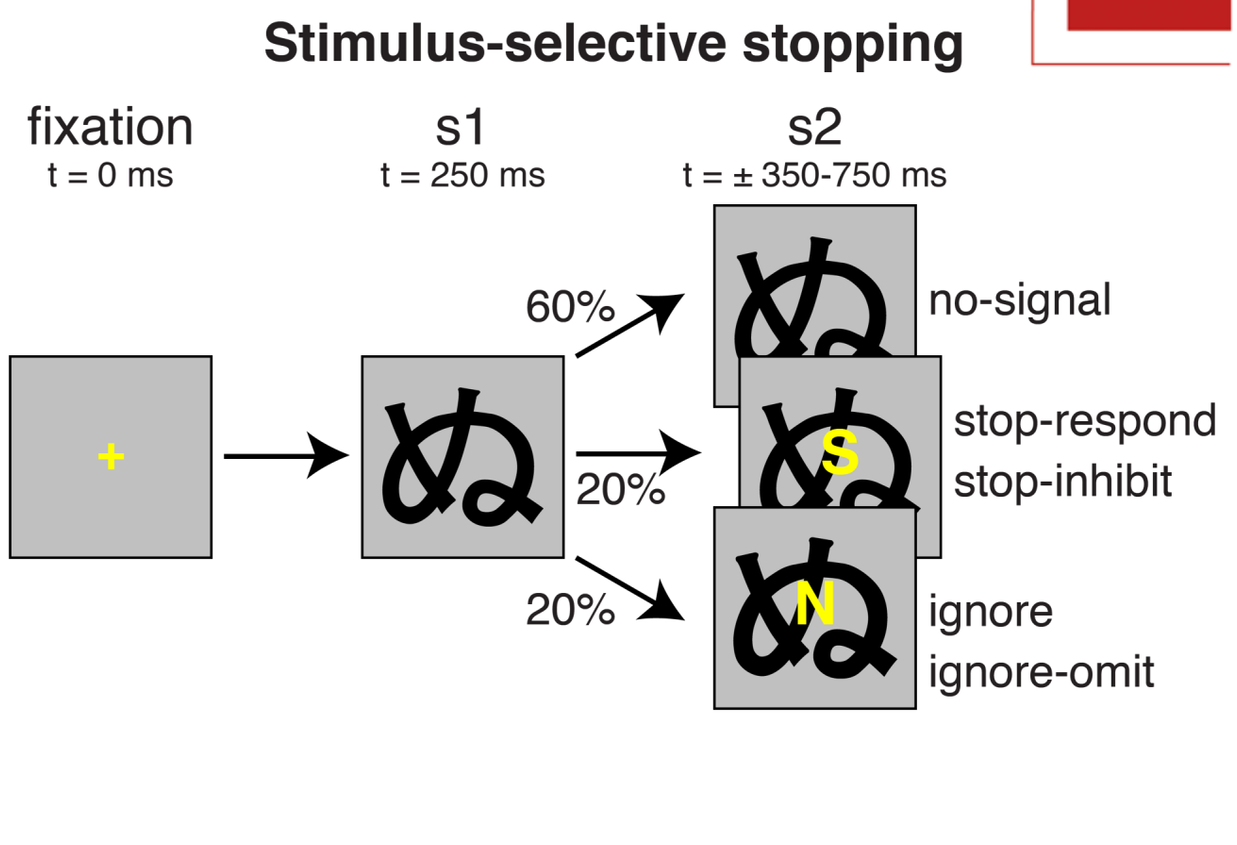
- Both forms of selective stopping have been reported to activate regions implicated in simple stopping

Differences

- AS may rely more on motor-related areas
- SS may rely more in stimulus-driven attention areas

Task design, procedure, and resources





Experiment 1 - modeling

Behavioral lab time

- 5000 trials total (5 SOAs, 100 trials per SOA)
  - AS: 60% NS, 20% L, 20% R
  - SS: 60% NS, 20% S, 20% N
  - Block-design
- 2 s / trial: ~ 167 min. total
- 5 sessions, 10 blocks of 100 trials/session
- 10 Ss, based on similar modeling studies
  Leite & Ratcliff (2010) Att Percept Psychophys; Logan et al. (2014) Psych Rev; Logan et al. (2015) Psych Rev

Experiment 2 - fMRI

Scanner time

- 750 trials total (5 SOAs, 15 trials per SOA)
  - AS: 50% NS, 20% L, 20% R, 10% ‘rest’
  - SS: 50% NS, 20% S, 20% N, 10% ‘rest’
  - Event-related design (AS and SS intermixed)
- 4 s / trial: ~ 50 min. total
- T1-weighted scan: 10 min. total
- 30 Ss, based sample size estimation with PowerMap, using data from previous fMRI study of stopping
  Zandbelt & Vink (2010) PLoS ONE

Disk space

- 3Gb x 1 session x 30 Ss = 90 Gb

Data analysis - Computational modeling (Experiment 1)

Model type: sequential sampling models

Provide mechanistic explanation of stopping

Boucher et al. (2007) Psych Rev; Ramakrishnan et al. (2013) JNS; Logan et al. (2014) Psych Rev

Models to be tested

Mechanism of STOP-GO interaction

- Lateral inhibition
- Blocked input
- Reset

Selectivity of STOP-GO interaction

- Selective
- Non-selective

Outcome measures

Psychometric functions and RT distributions

Boucher et al. (2007) Psych Rev; Ramakrishnan et al. (2013) JNS; Logan et al. (2014) Psych Rev

Optimization and model selection

Algorithm: Simplex with random starting points

Nelder & Mead (1965) Compute J

Cost function: Bayesian information criterion (BIC)

Leite & Ratcliff (2010) Attent Percep Psychophys; Logan et al. (2014) Psych Rev

Model selection: model with lowest BIC is best model

Leite & Ratcliff (2010) Attent Percep Psychophys; Logan et al. (2014) Psych Rev

Functional MRI acquisition

3.0 T, standard multi-echo EPI

Poser et al. (2006) Magn Reson Med

Contrasts of interest

Action-selective:

- (continue - no-signal$_{slow}$) - (ignore$_{fast}$ - no-signal$_{fast}$)

Stimulus-selective:

- (stop-inhibit - no-signal$_{slow}$) - (ignore$_{fast}$ - no-signal$_{fast}$)

Differences b/w action- and stimulus-selective stopping

- Contrast: action-selective vs. stimulus-selective

Similarities b/w action- and stimulus-selective stopping

- Conjunction: action-selective ∩ stimulus-selective

Region-of-interest analysis in predefined areas

rIFC, pre-SMA, striatum, M1

Whole-brain voxel-wise analysis

FWE, cluster-level correction

How data are relevant to the central issue

Computational modeling (Experiment 1):

- Model selection will identify which stopping mechanism and form of selectivity best explains performance.

Functional MRI (Experiment 2):

- Contrast and conjunction analyses will identify brain regions common and unique for action- and stimulus-selective stopping

The studies together yield complementary insight into the mechanisms of selective stopping

Broader impact

Computational modeling (Experiment 1):

- Model may provide the first formal theory of selective stopping performance

Functional MRI (Experiment 2):

- Imaging findings will be informative about how various forms of flexible behavior are implemented
- May guide future neurophysiology and brain stimulation studies on selective stopping